



Mid-term Evaluation of the Performance of the Implementation of the EU Space Programme and of EUSPA

November – 2023





© European Union, 2024

The Commission's reuse policy is implemented by Commission Decision 2011/833/EU of 12 December 2011 on the reuse of Commission documents (OJ L 330, 14.12.2011, p. 39, ELI: <http://data.europa.eu/eli/dec/2011/833/oj>).

Unless otherwise noted, the reuse of this document is authorised under the Creative Commons Attribution 4.0 International (CC BY 4.0) licence (<https://creativecommons.org/licenses/by/4.0/>). This means that reuse is allowed, provided appropriate credit is given and any changes are indicated.

This document should not be considered as representative of the European Commission's official position.

PDF ISBN 978-92-68-12491-8 doi:10.2889/520780 HV-02-24-153-EN-N

EUROPEAN COMMISSION

Directorate-General for Defence Industry and Space
Contact: DEFIS-C1@ec.europa.eu

*European Commission
B-1049 Brussels*

Contents

1.	INTRODUCTION TO STUDY CONTEXT AND OBJECTIVES	6
1.1.	Introduction to the study context.....	6
1.2.	Objectives and Scope of the study	8
2.	STUDY METHODOLOGY	8
2.1.	Study Logic.....	8
2.2.	Methodology	9
2.2.1.	Methodology for Phase 1	9
2.2.2.	Methodology for Phase 2	10
2.2.3.	Methodology for Phase 3	23
3.	EVALUATION OF THE PERFORMANCE OF THE IMPLEMENTATION OF THE EU SPACE PROGRAMME	23
3.1.	Copernicus Component.....	23
3.1.1.	Introduction to the Copernicus Component	23
3.1.2.	The Copernicus Component entrusted tasks and entrusted entities ..	26
3.1.3.	Effectiveness of the Implementation of Copernicus	29
3.1.4.	Benefits assessment of the Copernicus Component.....	45
3.1.5.	Efficiency and Cost Benefit Assessment of Copernicus	113
3.1.6.	Relevance Assessment of Copernicus.....	116
3.1.7.	EU Added Value	143
3.1.8.	Policy Coherence.....	144
3.1.9.	Additional insights to the Copernicus component	149
3.2.	Galileo/EGNOS Components.....	154
3.2.1.	Introduction to the Galileo / EGNOS Component	154
3.2.2.	The Galileo / EGNOS component entrusted tasks and entrusted entities	156
3.2.3.	Effectiveness of the Implementation of Galileo / EGNOS	161
3.2.4.	Benefits assessment of the Galileo / EGNOS Components	189
3.2.5.	Efficiency and Cost Benefit Analysis of Galileo / EGNOS	205
3.2.6.	Relevance Assessment of Galileo / EGNOS.....	207
3.2.7.	EU Added Value	285
3.2.8.	Policy Coherence.....	286
3.2.9.	Additional insights to the EGNSS Component	297
3.3.	SSA Components	299
3.3.1.	Introduction to the SSA Component	299
3.3.2.	The SSA component entrusted tasks and entrusted entities	302
3.3.3.	Effectiveness of the Implementation of SSA	304
3.3.4.	Benefits assessment of the SSA component.....	313
3.3.5.	Efficiency and Cost Benefit Assessment of SSA.....	366
3.3.6.	Relevance assessment of SSA.....	368
3.3.7.	EU Added Value	371
3.3.8.	Policy Coherence.....	373
3.3.9.	Additional insights to the SSA component	376

3.4.	GOVSATCOM Component.....	377
3.4.1.	Introduction to the GOVSATCOM Component	377
3.4.2.	The GOVSATCOM component entrusted tasks and entrusted entities	378
3.4.3.	Effectiveness of the Implementation of GOVSATCOM	381
3.4.4.	Benefits assessment of GOVSATCOM	389
3.4.5.	Efficiency and Cost Benefit Assessment of GOVSATCOM.....	397
3.4.6.	Relevance Assessment of GOVSATCOM.....	399
3.4.7.	EU Added Value	399
3.4.8.	Policy coherence.....	400
3.4.9.	Additional insights to the GOVSATCOM component	402
3.5.	Horizontal Actions supporting EU Space Programme.....	404
3.5.1.	IOD/IOV entrusted activities.....	404
3.5.2.	CASSINI initiative and entrusted tasks under scope of assessment	413
3.6.	Growth Indicators	421
4.	EVALUATION OF THE PERFORMANCE OF THE EUSPA TASKS	429
4.1.	EUSPA Core Tasks	429
4.1.1.	Introduction to the core tasks	429
4.1.2.	Evaluation of the effectiveness of EUSPA core tasks.....	434
4.2.	EUSPA Entrusted Tasks	449
4.2.1.	Fundamental Elements	450
4.3.	EUSPA's Conflict of Interest Policy.....	456
	APPENDIX	458

1. INTRODUCTION TO STUDY CONTEXT AND OBJECTIVES

1.1. Introduction to the study context

Since the mid-20th Century, European institutions understood the growing strategic relevance of space. The traditional approach to space activities, science and technology-push driven, had to evolve into something different to exploit the potential of the space sector in the broader industrial scene and in the wider economy.

By the 1990s, the paradigm shift began: **demand-pull** in the field of space applications was recognised as a major driver for the space policy, alongside the traditional technology-push. This shift was entrenched with the launch of the two-flagship space programmes of the European Union: European Global Navigation Satellite System (EGNSS) in 1994, and the GMES (then to be renamed Copernicus) in 1998.

EGNSS was conceived as two steps. First was the development of EGNOS, the European Geostationary Navigation Overlay Service, satellite based augmentation system designed to improve the precision of GPS over Europe for primarily aviation end use. The second step was the development of full independent GNSS capability, the Galileo system.

GMES was an ambitious programme to provide free and open satellite imagery to end users, with the aim of fostering a vibrant and innovative downstream sector in Europe. In 2014, GMES was renamed Copernicus through a dedicated regulation, which then extended EU support to the programme.

This action resulted in the adoption of the European Space Policy (ESP). In addition to introducing elements of **industrial and international policy** and acknowledging, for the first time, **security of space infrastructure** as a growing concern, the ESP set forth a **new approach to the governance of space in Europe**. The policy defines a distinction of roles between the European Space Agency and the European Union. Development of space technologies and systems, and space exploration activities constitutes the scope of action of the European Space Agency. While the role of the European Union focuses on the aggregation of political will in support to the achievement of the space policy, on ensuring the availability and continuity of operational services, and on fostering the development of downstream sector.

The Treaty on the Functioning of the European Union (TFEU, also known as the Lisbon Treaty) in 2012, gave additional impulse to the further development the overall space strategy for Europe. As stated in the TFEU, space is recognised as a strategic element of the overall EU policy to promote scientific and technical progress, industrial competitiveness and implementation of its other policies.

Based on this, the European Commission developed and adopted the EU space industrial policy *Releasing the Potential for Growth in the Space Sector* in 2013.

The policy recognises space industry potential to generate growth, create jobs and contribute to the attainment of the objectives of the Europe 2020 Strategy. It calls for a greater coordination between the space activities of the EU, the ESA and the Member States to avoid duplication of structures and to achieve synergies. Moreover, it establishes the need for a genuine internal market for the space industry, with a legal framework coherent with MS legislation. In addition, it identifies navigation, earth observation and satellite communication as the sectors with the highest potential for growth and innovation.

In 2016, the Commission adopted the EU Space Strategy, stating the EU's ambitions in space and confirming space as an increasing priority for the Union. The strategy had set different strategic goals that can be summarised as:

- Maximising the benefits of space for society and the EU economy

- Fostering a globally competitive and innovative European space sector
- Reinforcing the EU autonomy in accessing and using space
- Strengthening EU's role as a global actor.

In April 2021, the Council and Parliament adopted Regulation (EU) 2021/696 which set forth the new EU Space Programme for the years 2021-2027. Notably the regulation defines the scope of the new programme, bringing together Copernicus, Galileo/EGNOS, SSA and GOVSATCOM initiatives.

The EU Space Programme Regulation

The 2021 EU Space Programme Regulation is the main subject of this study. The regulation established the European Union Space Programme for the MFF 2021-2027, its objectives, its EUR 14.88 B budget, and its rules & implementation. The regulation also establishes EUSPA as an evolution of the European GNSS Agency, with a substantially extended mandate pertaining to all five components of the Union Space Programme.

As of 2021, EUSPA is mandated with the operation of the Galileo Security Monitoring Centre, PRS tasks, communication, market development and promotion activities for services of Galileo, EGNOS & Copernicus, Security Accreditation of all the EU Space Programme components, operational security for Galileo and EGNOS, provide expertise for the Commission.

EUSPA has been entrusted by the Commission, with tasks pertaining to EGNOS, Galileo, SSA, GOVSATCOM and the downstream uptake of Copernicus.

In addition to EUSPA, several “entrusted entities” are tasked with implementing the regulation in specific areas of expertise. The following are the entrusted entities:

- European Space Agency (ESA),
- European operational satellite agency for monitoring weather (EUMETSAT),
- European Centre for Medium-Range Weather Forecasts (ECMWF),
- European Environment Agency (EEA),
- Mercator Ocean International (MOI),
- The European Border and Coast Guard Agency (FRONTEX),
- European Maritime Safety Agency (EMSA),
- European Union Satellite Centre (SatCen).

Objectives of the EU Space Programme

Article 4 of the EU Space Programme Regulation establishes the general objectives of the Union space Programme, building on those of the 2016 regulation. The new objectives are summarized as below:

- To provide high quality, up to date, secure (where appropriate) space data, information and services at a global level (where possible) without interruption that meets the existing and future needs to European Union
- To maximize the socioeconomic benefits in the EU while promoting the widest uptake of the data, both within and beyond the EU.
- To enhance the safety and security of the EU and reinforce its autonomy especially in terms of technological independence.
- To promote the role of the EU as a global actor in the space sector
- To enhance the safety, security and sustainability of all outer space activity.

In addition, article 4 also establishes several specific objectives for each of the components of the European Space Programme, summarized as follows:

- **Galileo & EGNOS:** provide long term, state of the art, secure PNT while ensuring continuity and robustness
- **Copernicus:** deliver accurate and reliable EO data, information and services on a long term and sustainable basis in support of the Union and member state policies.
- **SSA:** enhance capabilities to monitor, track and identify space objects and debris to increase the performance and autonomy of capabilities under the SST sub component, to provide SWE services and to map and network Member States capacities under the NEO sub component
- **GOVSATCOM:** to ensure the long term availability of reliable, secure and cost effective satellite communication services for GOVSATCOM users.
- To support an autonomous, secure and cost-effective capability to access space
- To foster the development of a strong Union space economy.

Article 6 of the regulation also specifically mandates that the programme promote capacity building across the EU by supporting innovation activities that make use of space technology, activities that aim to foster public demand and public sector innovation, entrepreneurship, business friendliness, education and training, access to processing and testing facilities, certification and standardisation, and the reinforcement of the European supply chain.

1.2. Objectives and Scope of the study

The EU Space Programme Regulation is the founding text for the Union Space Programme. Considering the importance of the programme to European society, the contributions it aims to provide in support of sustainability and social benefits, the economic importance of the programme in terms of jobs supported, and the large budget committed to the programme, and it is important to monitor and evaluate the implementation of the regulation.

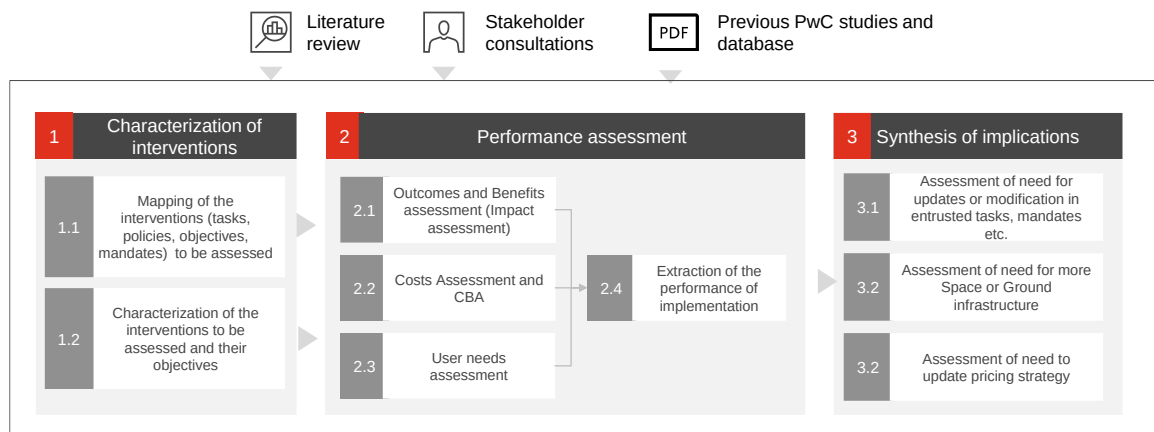
Indeed, such an evaluation is strongly aligned with the principles of evidence-informed policymaking (formerly known as “evidence-based policymaking”): the idea proposes that political decision-making should be informed by objective evidence. This ensures that public spending is committed in a manner aligned with the best interest of the public and ensures that a regulation is functioning as intended.

2. STUDY METHODOLOGY

2.1. Study Logic

The study logic comprises three phases, further broken down into nine main tasks, as illustrated in the figure below.

Figure 2: Proposed study logic



The first phase involves a characterization of the interventions. Under this phase the team identifies the different tasks, mandates and policies under the EU Space Programme that are expected to be assessed in this study and characterizes them extensively based on stakeholder consultations and review of relevant literature.

The second phase of the study is the actual performance assessment of the implementation of the EU Space Programme, where the team conducts four tasks. The first is the Impact assessment, which on one hand will aim to assess the outcomes and achievements of the interventions, including the programme and services performance and on the other hand will aim to assess the socio-economic benefits resulting from the EU Space Programme, particularly from the interventions under scrutiny. The second task is a costs analysis of the interventions to enable a cost-benefits assessment. The third task is an end-users needs assessment to look at the current and evolving intermediate- and end-user needs under the different programmes. Then the outputs of these three tasks is used to evaluate a set of criteria and indicators that will allow the performance assessment.

Phase two heavily relies on stakeholder inputs from the European entities, consortia that were awarded contracts under the different programs and end-users of the programs.

The last phase of this study is the synthesis of implications, and conclusions. This phase uses the outputs and findings of the assessments performed in phase 2 to evaluate whether any modifications or updates in the European Commission's interventions are needed. It will particularly evaluate the need for modifications in the tasks or mandates of European entities, the need for additional space or ground infrastructure, or the need for adaptation in the pricing strategy of GOVSATCOM, Copernicus and SSA.

The data inputs for this study are of three types, the first is desk research and literature review which will heavily focus on all the documentation related to the EU Space Programme and Regulation, the entrusted entities and their tasks, in addition to the Space Programmes being evaluated. This study will also leverage on the many previous studies and assessments it has performed related to the EU Space Programmes. Additionally, stakeholder inputs are expected to be a critical factor for this study to gather the right evidence for the assessments.

2.2. Methodology

2.2.1. Methodology for Phase 1

This phase defines the scope of analysis for the remaining of the study. The team first mapped the different tasks, mandates, objectives and policies that will be reviewed, under each of the EU Space Programmes or thematic under scope that include Galileo, EGNOS, Copernicus, SSA, Cassini, GOVSATCOM and EUSPA tasks. For the selected tasks, mandates or policies, the team defined the activities they entail and the timeline for their evaluation (taking as starting point June 2021).

The activities under scope of this assessment include the entrusted tasks to the entrusted entities under the different Space Programmes, however for EUSPA they also include its own core tasks.

Once these activities were defined, the team proceeded to characterizing them following the framework below:

Figure 3: Framework to characterize the tasks to be assessed



For each Space Program and the entrusted entity involved in the programme, the team characterized the intervention groups or the high-level themes of interventions and tasks that this entity was responsible for carrying out. Each group was then defined to identify the different tasks and detailed activities that it entails. The team also identified and characterized the initial objectives or targets that were expected of the tasks. These objectives serve as a baseline to compare and evaluate the performance of the implementation of the tasks. The team further characterized the tasks by identifying the budgets allocated for them, the different stakeholders and decision makers involved in their implementation, and also the targeted end users.

In principle, each of the characterized lines demonstrated in the figure above is be assessed separately in the next phase of the study, it was possible however, when relevant and for simplification purposes to combine several tasks (under the same entity and programme) to be assessed as one (i.e. assess at the level of the intervention group), when the objectives are aligned etc. and this is done in alignment with the client.

This characterization approach permits at the end of the study to synthesize the results in different ways, i.e. the performance assessment can be synthesized or grouped per Space Programme, per Entrusted Entity or per intervention group.

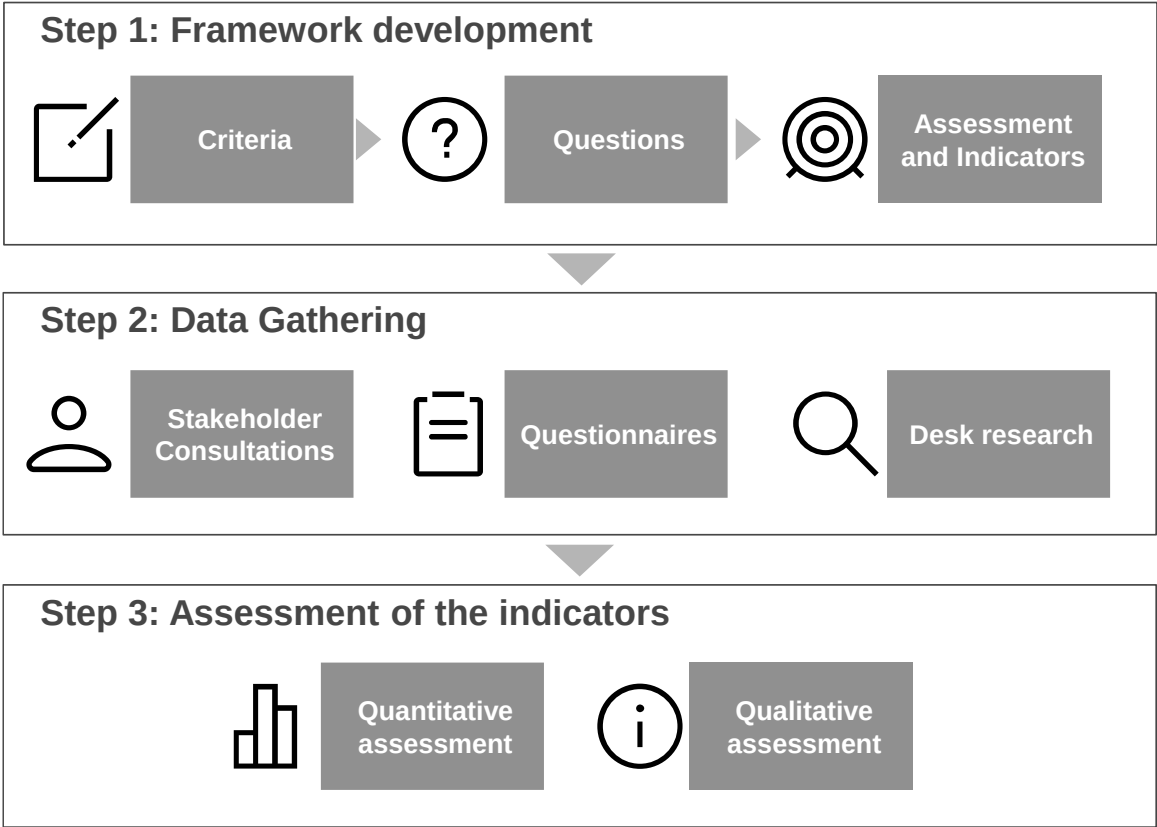
This phase of the study was heavily based on desk research and literature review related to the EU Space Programmes, entrusted activities, mandates, and objectives in addition to discussions with the client to ensure that the correct and relevant scope for the assessment is adopted. The types of documentation that were reviewed include the Space Regulation, Contribution agreements, Work Programs and Annual Implementation reports. This task also heavily relied on targeted consultations with the EC and entrusted entities to support the characterization of their tasks, activities and outcomes etc.

2.2.2. Methodology for Phase 2

The aim of this assessment is to compare the performance of the EU interventions with the initial objectives and expectations they were developed for and to assess whether these results have been achieved in the best way and at minimum cost.

There are three steps for the approach for this assessment as demonstrated in the figure below:

Figure 4: Approach for performance assessment



The first step is the consolidation of the framework that will be adopted for the assessment. The study proposal already provided a high-level framework that was further developed in alignment with the client at the beginning of the study.

In accordance with the Better Regulation toolbox, the assessment of the performance of the implementation of Entrusted entities’ tasks, objectives, mandates and policies will be done based on the evaluation of 5 main axes: Effectiveness, Efficiency, Relevance, Coherence and Added Value (described later).

These 5 axes are assessed for the interventions mapped and characterised in the previous phase. The assessment of each axis is based on answering a set of key and critical questions, which in turn is done via the evaluation of key indicators. These indicators are pre-defined by the team in an iterative process with the client, and the final list of indicators would then be approved by the client before proceeding with the assessment. To evaluate the indicators per axis, different types of assessments are required and will serve as inputs including an Impact assessment (a results and benefits assessment), a cost-benefit assessment and a user needs assessment.

The reason that the assessments to evaluate the 5 axes are consolidated into a set of indicators is to facilitate the comparison of this study results with future or previous studies, and to allow for a simplistic synthesis of the study with clear, short and direct conclusions. Additionally, indicators would allow the client to keep track of the performance progress of the different programs implementation and would provide the client with a clear view on the status.

The second step will be the data gathering via different channels in order to gather as much evidence as possible to perform the assessments of the framework and to evaluate the defined indicators and find the most accurate answers to the questions.

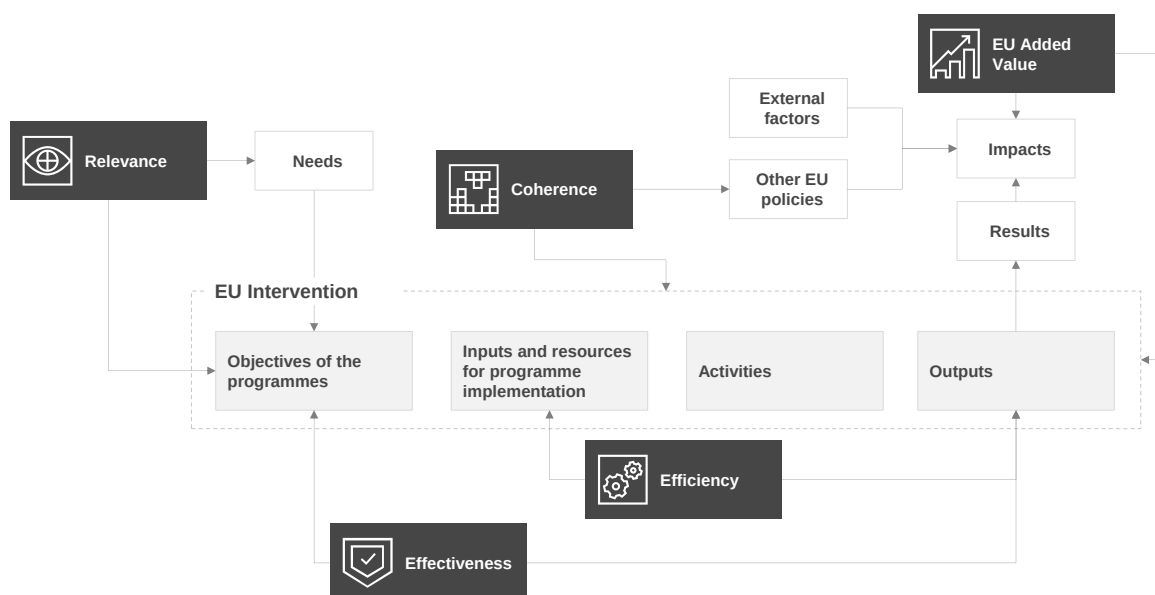
The third and final step would be to analyse the data gathered in order to evaluate the indicators either quantitatively or qualitatively (depending on the type of indicator and availability of data) and to provide conclusions on the criteria evaluation. This thereby will

enable drawing conclusions on the performance of the implementation of the interventions to indicate whether there is a need to update or modify the tasks, mandates and policies under assessment.

The Performance Assessment Framework

The following diagram represents a simplified view of the European Commission's intervention logic which is used to assess the activities mapped above. The European Commission's interventions start from a set of needs that are identified. From these needs, the Commission defines a set of objectives for its programmes meant to address and close the gaps. To meet these objectives a set of activities are developed to be carried out, with an allocation of resources and necessary inputs. At the end the results and impacts of these activities are evaluated to assess whether the needs are being addressed or whether modifications are needed. The Commission aims to ensure that the new interventions are in line with other external factors and EU policies to avoid duplication and contradiction and ensure a smooth and coherent European approach. It is also a priority to ensure an EU Added Value to these activities and their impacts, to ensure that the resources are well spent.

Figure 5: Simplified EU intervention Logic and assessment axes



From this logic, there are 5 axes that are important to assess the performance of the interventions. This report covers the first axis, which is effectiveness and below is the methodology used for this axis.

2.2.2.1. Axis 1: Effectiveness

It is a comparison between the intervention objectives and outputs. Effectiveness assesses how successful actions have been in achieving or progressing towards the objectives of the programme under evaluation, or how short they have fallen from these objectives and the reasons behind that. It should also include considerations on whether the objectives can be achieved in time or with delay. The main questions that the effectiveness criterion evaluation should answer are the following:

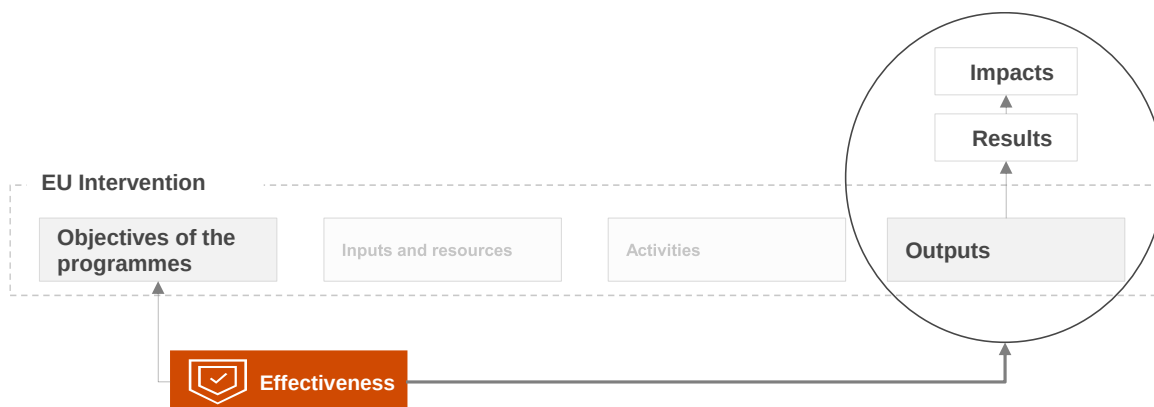
- To what extent have the objectives of the intervention (tasks, measures, policies etc.) been achieved?
- What have been the (quantitative and qualitative) effects of the intervention?
- To what extent do the observed effects correspond to the objectives?
- To what extent can these changes/effects be credited to the intervention?

- What factors influenced the achievements observed?
- To what extent did different factors influence the achievements observed?

To evaluate the effectiveness of the interventions and to answer the questions above, the team will proceed to assess the impacts and the outcomes (i.e. the changes) that have materialized from the intervention and will compare those to the objectives of the intervention as demonstrated in the figure below:

It is important to highlight that this axis takes two dimensions into consideration, the first dimension covers the effectiveness of the performance of the entrusted tasks to entrusted entities and the 2nd dimension covers the performance of the Space Programme itself.

Figure 6: Intervention effectiveness assessment approach



The objectives of the programme are mainly extracted from phase 1 that included the characterization of the interventions, and it uses as main data inputs the Annual Activity Reports (AIRs) and consultations with the Commission representatives and the entrusted entities representatives. A results assessment and an impact assessment are done and used to assess effectiveness. To be able to perform an accurate comparison and assessment of the outcomes versus the expectations, the study will define a set of indicators that will be used for the effectiveness assessment. For each indicator, a value for the objective or the expectations is defined and serves as a baseline, and a value for what has actually been achieved (results or impacts) will be computed from the results and impact assessment.

Results (achievements) assessment

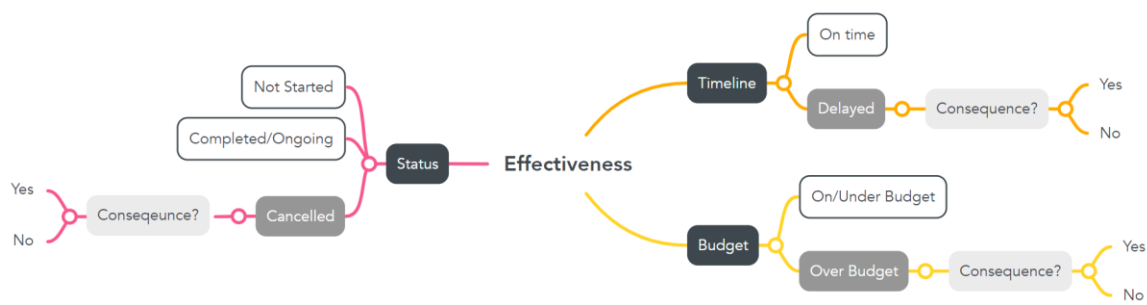
Before digging into the detailed impact assessment and the wider benefits of the interventions under assessment, the team mapped the results and achievements that have been established throughout the program. These achievements stem from the different entrusted tasks and the actions and activities that have been taken under the umbrella of the intervention, at the different phases of the value chain (which is characterized under phase 1 of the study). With these mandates and activities acting as a starting point, the team translated each one of them into a list of measurable Key Performance Indicators (KPIs) that can be assessed (based on the KPIs that these entrusted entities are required to report on) and whose analysis would provide a clear indication of the program or the service performance status. Stakeholder consultations were conducted to support the development and validation of the exhaustive list of KPIs that is most relevant to evaluate the intervention results.

The assessment was split into two sections:

Assessment of the implementation of the entrusted tasks by entrusted entities

This portion of the assessment focused on three factors that impact the effectiveness assessment. The figure below outlines the various factors, and drivers related to the implementation of the entrusted tasks.

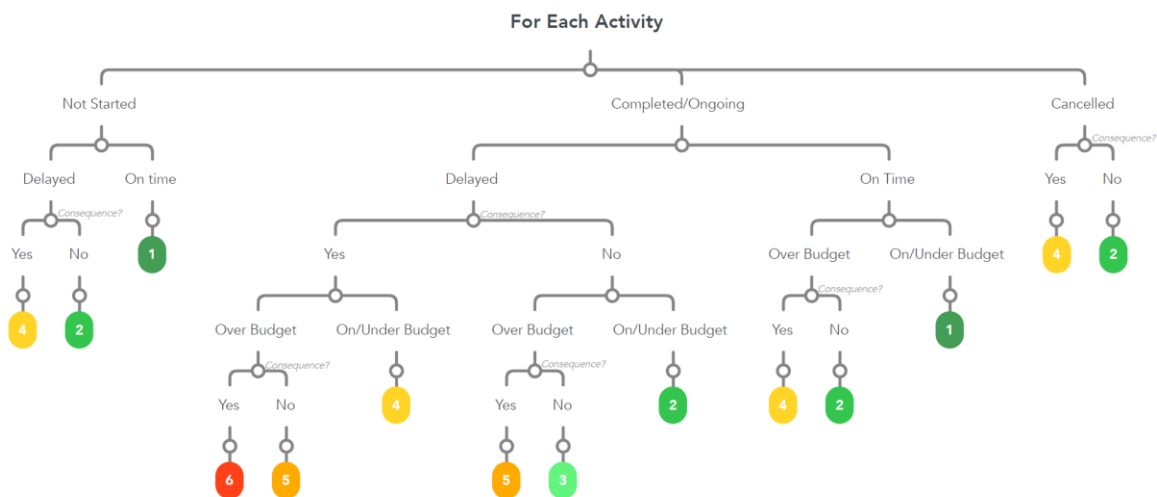
Figure 7: Methodology to assess implementation of entrusted tasks



Each **factor** can have a **deviation** with or without a **consequence** that could affect the **Effectiveness** of the implementation of the Contribution Agreement

Based on the previous illustration, the team created a mapping of every possible outcome for an activity that corresponds to a number between a scale of 1-6.

Figure 8: Mapping of activity to determine outcome of implementation of entrusted tasks



It is important to note that the number assigned is not a score and the 1-6 scale is not linear, however it aims to provide the specific outcome for each activity. The figure below describes the meaning of each outcome within this scale.

Figure 9: Definition of scale to assess implementation of entrusted tasks

1	Implemented as per Contribution Agreement	2	One deviation from Contribution Agreement with no consequences	3	Two deviations from Contribution Agreement with no consequences
4	One deviation from Contribution Agreement with one consequence	5	Two deviations from Contribution Agreement with one consequence	6	Two deviations from Contribution Agreement with two consequences

NA Non Applicable / Out of scope of assessment

For each activity, a number between 1-6 will be assigned based on the mapping to demonstrate the level of effectiveness of each activity, with 1 being the most effective and 6

being the least effective implementation. Additionally, the cause, mitigation, and specificity of the consequence will be described qualitatively. This information was then consolidated at the intervention level for each entrusted entity across the several programmes.

Assessment of the performance of the Space Programme

This portion of the assessment is focused on the performance of each Space Programme based on a set of corresponding KPIs as outlined in the contribution agreement. The table below provides a non-exhaustive list of indicators assessed.

Table 1: Overview of KPIs for EU space components

Programme	KPIs
Copernicus	- Number of users - Number of activations requested or served - User satisfaction - % Reliability, availability, and continuity - Number of new information products delivered - Amount of data generated
Galileo	- Total # of satellites - Navigation service performance - Timely achievement of service milestones - Timely delivery of reports - GSC¹ portal statistics - Share of market
EGNOS	- # of airports with EGNOS APV-I & LPV-200 procedures (for an explanation of acronyms see link below)² - APV-I & LPV-200 availability - APV-I * LPV-200 & NPA EGNOS SOL coverage area over EU-MS+NO+CH (+IS*) land masses
SSA	- Number of users - Availability of services
GOVSATCOM	- Number of users - Availability of services - Contracts signed schedule - Contracts commitment ceiling - Research & Development contracts cost accrued - Milestone achievement chart
IOD IOV	Trend chart showing the % of the cumulative number of Invitations to Tender³ (ITTs) issued vs. the cumulative number of ITTs planned for the same period Trend chart showing the % of the cumulative number of contracts signed vs. the cumulative number of contracts planned for the same period

¹ GSC is the Service Centre which provides a single interface for the Galileo Open Service (OS) and Commercial Service (CS) user communities and offers specific added-value services.

² https://www.euspa.europa.eu/sites/default/files/content/press_releases/PR-GSA-15-05%202015%20EGNOS%20LPV-200%20final.pdf

³ In negotiated procedures the ITT is replaced by a Request for Quotation

Trend chart showing the % of the cumulative actual commitment ceiling vs. the cumulative planned commitment ceiling for the same period

Trend chart showing the % of the cumulative actual cost accrued vs. the cumulative planned cost for the same period

Trend chart showing the number of milestones achieved vs the number of milestones planned

Table showing the actual price of each contract

Histogram showing the actual cumulative share of each country in the value of the contracts

**No particular KPIs are listed for Cassini, except for “the performance of the services provided” therefore KPIs are developed for each of the services under scope of assessment for CASSINI based on consultations with the entrusted entities.*

Impact Assessment

Impact assessments require the utilization of a solid methodological approach representing a common framework that can be tailored to the needs of the different space programs and activities which also allows for the comparison of results between different impact assessments or with a certain baseline scenario. It is also important to build and assess a framework of indicators for monitoring the progress in the implementation of a given policy, strategy or intervention and so, for evaluating its intended impacts and comparing them with a baseline scenario to deduce whether the objectives or expectations of the intervention have been met or whether they have fallen short and by how much.

Over the past few years, several impact assessments have been performed covering the multiple EU Space Programmes that are under the scope of this study. Due to the large scope of this study, and the large number of tasks and programs under assessment, the team proposed to not perform the impact assessment from scratch but to rather leverage on the previous studies, efforts and resources that have been exerted on the impact assessments and to extrapolate those for this study. Therefore, the steps for the impact assessment look as follows:

Figure 10: Impact assessment approach



The first step was to define the benefits and the criteria or indicators used to assess these benefits.

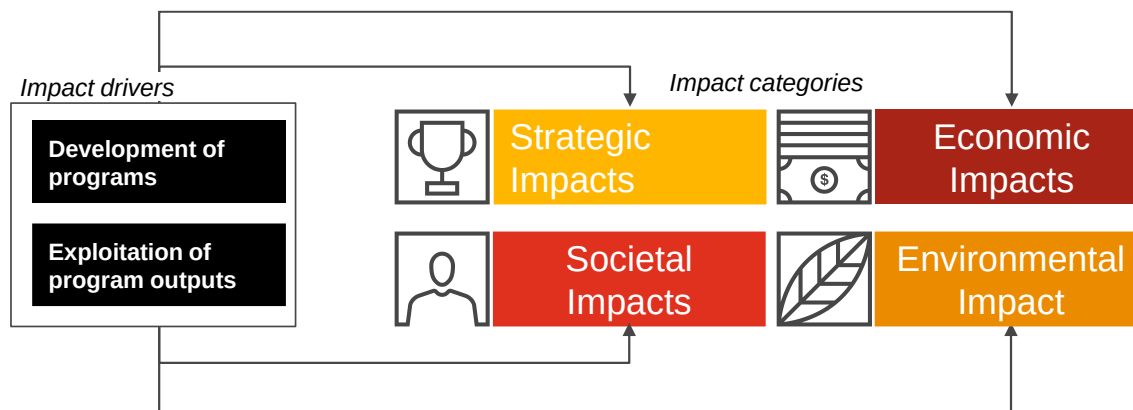
Generally, we can differentiate between two levels of impacts coming from 2 types of impacts drivers:

- The first level of impacts includes those driven by the “development” of a project, infrastructure or capacities, and they are direct consequences of the investment. These are the benefits that are linked to the development of the knowledge and resources associated with the activity. These are generally realized at the level of the companies or entities that directly participated to the project or programme
- The second level of impacts includes those driven by the “exploitation” of what has been developed initially. Generally, these impacts are realized at the levels of intermediate and end users, benefitting of the services or products that have been

developed under the programme and applying them in specific use cases. I.e., these benefits are linked to the market segments where the technologies, products and services developed are expected to be utilized. Impacts generated from this impact driver would only be assessed if deemed sizeable (i.e., if there is a large-scale exploitation of products developed under the programme or projects)

Even though different benefits and impacts can be generated from each impact driver, they are not mutually exclusive and can always be categorized according to the following classification:

Figure 11: Classification of impacts



This classification is generic and broadly applicable to all types of research activities, space programmes and policies. The definition of the impacts and their association with each of the four categories is strongly dependent on the kind of initiatives/interventions conducted, their status (e.g., whether a project or a program is still at feasibility study level, design level, development or operations), and on the involved stakeholders. For the purposes of this study, PwC has identified a set of preliminary impacts under each of the impact categories that would be relevant to evaluate under the scope of the study, and it is as follows:

**CAVEAT: the way the impacts are distributed under “development” or “exploitation” is not a standardized distribution, however it is specific to the nature of the activities whose impacts are being assessed. Therefore, this distribution in the figure below is merely a demonstration of the benefits expected to materialize at the level of project development and exploitation*

Table 3: list of impacts considered for the study

Impact Category	Impact	Development impacts	Exploitation impacts
Economic Impacts	GDP impact	X	
	Employment impacts	X	
	Industry stimulation	X	
	Enabled revenues	X	X
Strategic Impacts	EU industry competitiveness and leadership	X	
	EU non dependence	X	
Societal Benefits	Human capital	X	
	Inspiration	X	
	Improved Quality of life		X
	Improved Public Health		X

Environmental Benefits	Citizen Safety & Security	X
	Reduced emissions	X
	More efficient use of resources	X
	Reduced waste	X

These impacts are further broken down into sets of KPIs whose evaluation would permit a thorough understanding of the Programmes outcomes and benefits. The list of KPIs proposed by PwC corresponds to the extent possible to standardized KPIs to allow for comparisons with other studies, ensure transparency, and enable the monitoring of the development of the performances of these projects.

As mentioned above, to assess these KPIs the team relied on previous studies. When it was deemed that the data extracted from previous studies required updating, certain parameters were updated from new impact values. Impact assessments previously performed by PwC include:

- Study to examine the socioeconomic impact of Copernicus in the EU (2016)⁴
- Study in support of the Impact Assessment of an EU GOVSATCOM initiative (2017)⁵
- Copernicus ex-ante societal impact assessment (2018)⁶
- Copernicus market report (2019)⁷
- Impact Assessment of EGNSS FE R&D in synergy with H2020 and analysis of business and technology gap (2021)⁸
- Socio-economic impact assessment and accompanying foresight study of selected European Space Agency (ESA) Earth observation activities & Socio-economic impact assessment of ESA's ground systems engineering and operations activities and the Space Safety programme for ESA (the two studies issued in 2019 are public⁹, an update was performed in 2022 and was available for consultation by the Commission)
- An assessment of the possible EU space situational awareness initiative¹⁰

Other sources of information were used for statistics of the EU space economy:

- Structure of the European Space Manufacturing Sector by ASD EUROSPACE (2021)¹¹

This is expected to facilitate the process of updating, extrapolating and complementing the assessment.

In the next steps of the study, the rest of the axes would be assessed, and the framework adopted would be described.

⁴ <https://op.europa.eu/en/publication-detail/-/publication/97a5cf70-aa5f-11e6-aab7-01aa75ed71a1>

⁵ <https://op.europa.eu/en/publication-detail/-/publication/f9004854-0d50-11e8-966a-01aa75ed71a1/language-en>

⁶ https://www.copernicus.eu/sites/default/files/2018-10/Copernicus-Ex-Ante-Final-Report_0_0.pdf

⁷ https://www.copernicus.eu/sites/default/files/PwC_Copernicus_Market_Report_2019.pdf

⁸ Not public, was available to the Commission

⁹ https://www.esa.int/About_Us/Business_with_ESA/Global_Space_Economic_Forum/ESA_Studies

¹⁰ <https://op.europa.eu/s/y6mw>

¹¹ Not public, but was available for consultation by the Commission

2.2.2.2.Axis 2: Efficiency

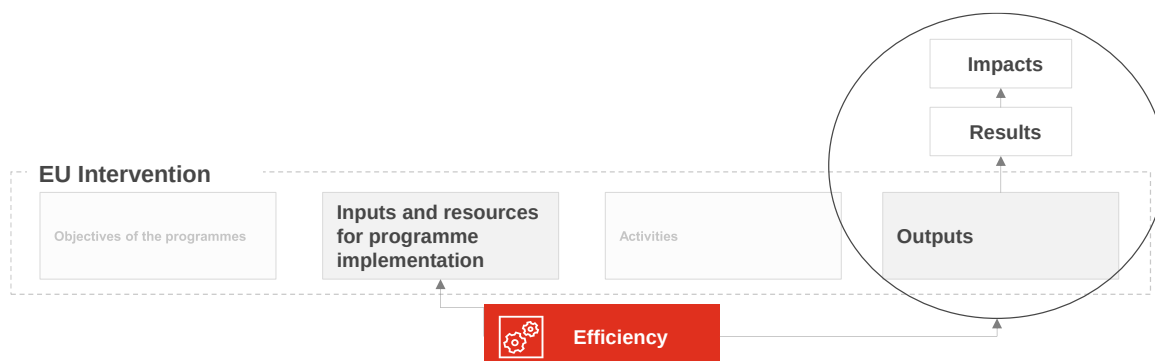
Efficiency assessment typically compares the resources spent on an intervention to the actual outcome or change that was caused by that intervention. It includes the analysis of administrative and regulatory burdens and examines aspects of potential simplifications. This task also examines the cost efficiency of a programme and therefore looks into the costs and benefits resulting from that programme. The findings should pinpoint areas where there is a potential to reduce inefficiencies in the elements listed above.

The main questions that the efficiency criterion evaluation should answer are the following:

- To what extent are the costs involved justified, given the changes/effects which have been achieved?
- To what extent are the costs proportionate to the benefits achieved? What factors are influencing any discrepancies?
- What factors influenced the efficiency with which the achievements observed were attained?
- How affordable were the costs borne by different stakeholder groups, given the benefits they received?
- To what extent has the intervention been cost effective?

To evaluate the efficiency of the program and answer the questions above, the team will perform a costs assessment (assessment of resource and inputs) of the interventions and will compare those to the benefits previously evaluated (under effectiveness) in a cost-benefits assessment format as demonstrated in the figure below:

Figure 12: Approach for efficiency assessment



Cost Benefit Assessment - CBC

Two elements are significant for the CBA, they are a cost assessment and a benefits assessment. The benefit assessment is expected to be developed under the effectiveness axis. Therefore, the missing element for the Efficiency analysis is a costs assessment. The objective of a costs assessment is to assess the expected and accrued costs of the different interventions that are under analysis. This is expected to be a simple task to be performed based on consultations with the main stakeholders involved (EU entities and the consortia awarded contracts relevant to the interventions).

The most important factor in the CBA is to ensure that the Costs and Benefits comparisons are coherent. I.e., the same units shall be used for comparison (ideally a monetary unit: Euro) and that for each intervention under assessment, the correct scope for the costs and benefits is assessed, i.e., the benefits shall be those generated by the “cost” spending.

For each programme or intervention under assessment, the team would compare the costs to the benefits that they have resulted in, to understand whether the benefits have outweighed the costs or not.

The assessment of the efficiency will take conclusions from the cost benefit analysis to evaluate whether the resources consumption has been efficient vis-a-vis the size of benefits generated.

2.2.2.3.Axis 3: Relevance

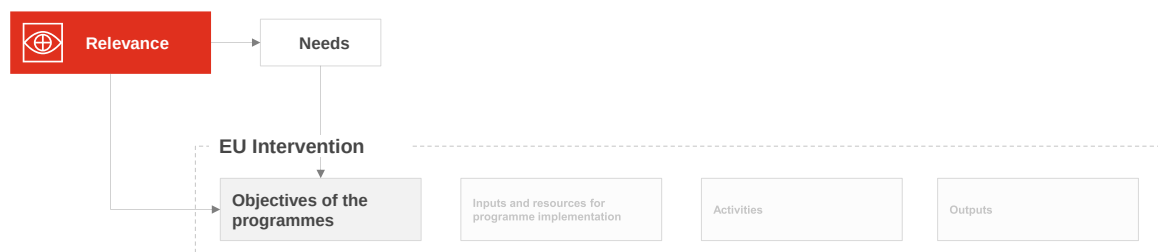
It evaluates the relationship between the society's needs and gaps and the intervention's objective and purpose. It determines whether the right problem drivers have been identified during the creation of the programme. Incorrect assumptions might have been made when identifying the cause-and-effect relationships, or circumstances might have changed, and the needs and issues have evolved since the initial definition of the programme's objectives.

The main questions that the relevance criterion evaluation should answer are the following:

- To what extent is the intervention still relevant?
- To what extent have the (original) objectives proven to have been appropriate for the intervention in question?
- How well do the (original) objectives (still) correspond to the needs within the EU?
- How well adapted is the intervention to subsequent technological or scientific advances? (N.B. Could include issues related to the specify policy here e.g., social, environmental)
- How relevant is the EU intervention to EU citizens?

To evaluate the relevance of the program and answer the questions above, the team will perform a user needs assessment of the different programmes and interventions and will compare those to the programme objectives as demonstrated in the figure below:

Figure 13: Approach for the relevance assessment



User needs and their evolution assessment

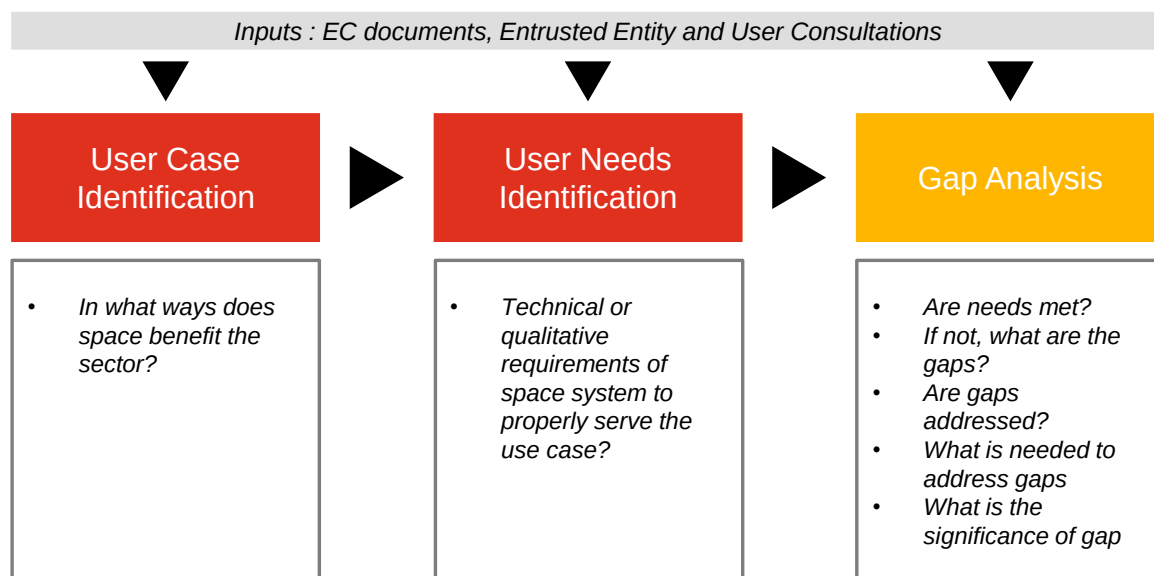
The user needs evaluation aims to identify the extent to which the Space Programme currently addresses the needs of the user communities across the various user domains. The approach takes three main inputs where possible:

- Inputs from documents provided by EC and entrusted entities including the Expression of User Needs for the Copernicus Programme, Customer Requirements Document for SWE, and the EUSPA User Consultation Platform for Galileo/EGNOS.
- Consultations with Entrusted Entities: Entrusted Entity representatives and policy officers have a wealth of knowledge on the emerging trends and demands of each user group.
- Consultations with end user community representatives: end user communities can help fill in gaps in knowledge, or provide another perspective on their needs.

Using these inputs PwC will perform an assessment of the user needs taking the following approach as detailed in the figure below. This assessment would be performed for each

relevant component of the Union Space Programme, and further for each relevant vertical addressed by said component.

Figure 14: User Needs Assessment Approach



The first step is a highlight of the status quo. It will leverage desk research, market reports and other data to give a high-level indication of the current state of the market. This would comprise of mostly looking at the existing trends in the market and key pain points of the user community. The study will also, where relevant, look into the space technology trends specific to that vertical. Finally, the study will also map some of the key use communities that leverage space data in the sector.

The second step deals with identifying use cases. The use cases are concrete examples of where the Union Space Programme currently is or could be used to improve the user experience in the sector.

The third step is done concurrently. Where possible – based on data availability – the study would identify the requirements of the use case. This could be technical requirements such as resolution, latency, precision, reliability, etc., or could be qualitative needs for users such as dedicated platforms.

Finally, the gap analysis. This part of the assessment will heavily rely on stakeholder consultation and look into the extent to which the current Union Space Programme meets the needs of the user communities. Details will only be given where the needs are not fully met as highlighted in the consultations.

Finally, the significance of the gaps will be highlighted, as all gaps are not made equal. Indeed, in many cases, the Union Space Programme cannot fulfil some of the gaps due to the mandate to not compete with industry.

2.2.2.4.Axis 4: Coherence

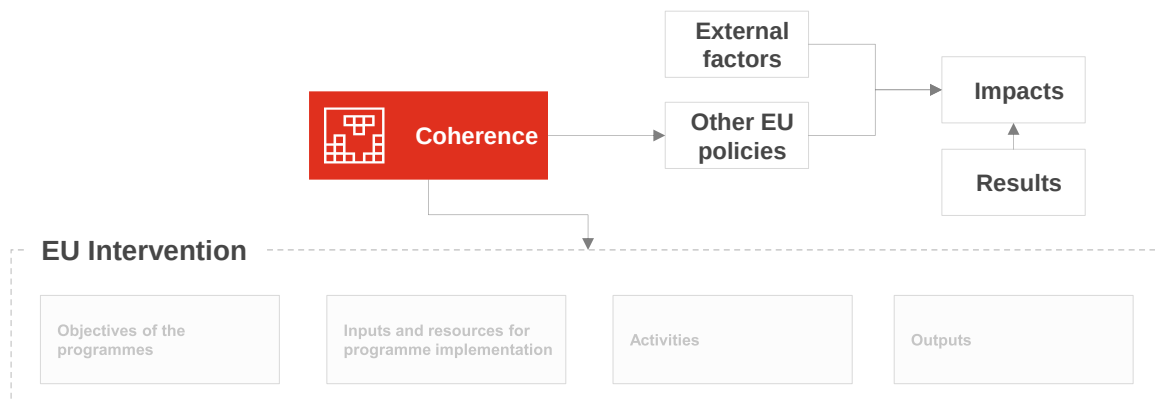
It examines the internal components of the programme to determine how well they operate together and identifies potential overlaps and duplications of efforts. This assessment also examines components from other policies to identify unnecessary overlaps and potential contradictions. This criterion looks for evidence of synergies or inconsistencies between the multiple actions, tasks, policies or objectives that will be assessed.

The main questions that the coherence criterion evaluation should answer are the following:

- To what extent is this intervention coherent with other interventions which have similar objectives?
- To what extent is the intervention coherent internally?
- To what extent is the intervention coherent with wider EU policy?
- To what extent is the intervention coherent with international obligations?

The coherence assessment will be done based on a comparison of the EU intervention being assessed with different policies and actions as demonstrated in the figure below

Figure 15: demonstration of the coherence assessment



The team would identify all the relevant EU policies and external factors for this assessment (such as environmental and climate change policies, transportation policies etc.). The objective is to assess the coherence between the intervention under study with Member States' policies, EU policy (space or non-space), and to evaluate the internal coherence of the Space Programme.

2.2.2.5.Axis 5: EU Added Value

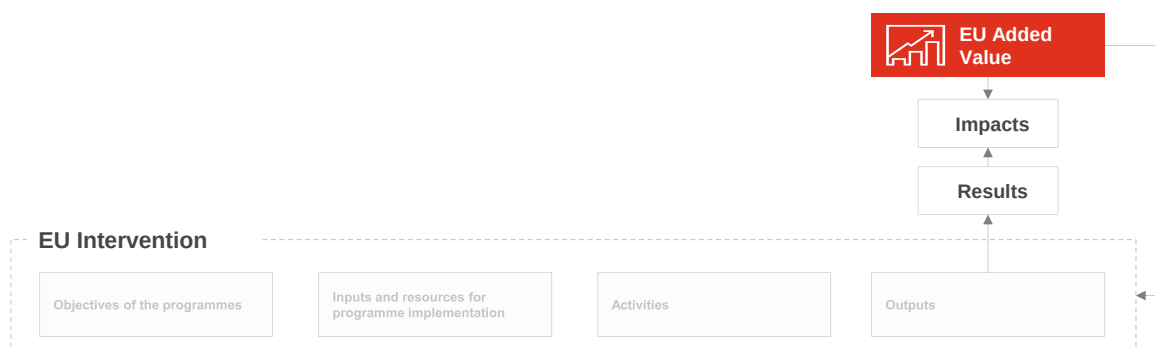
It examines the correlation between the benefits witnessed and the EU intervention. i.e., it aims to assess the causalities that were triggered by EU intervention. This criterion questions whether EU action is the only way to reach the objectives; whether the programme allows better value for money; and whether EU action allow to create synergies and reduce disparities.

The main questions that the EU added Value criterion evaluation should answer are the following

- What is the additional value resulting from the EU intervention(s), compared to what could be achieved by Member States at national and/or regional levels?
- To what extent do the issues addressed by the intervention continue to require action at EU level?
- What would be the most likely consequences of stopping or withdrawing the existing EU intervention?

The EU added value assessment will take as inputs the analysis done under the other axes particularly effectiveness and efficiency. It is demonstrated in the figure below

Figure 16: illustration of the EU added value assessment



This team evaluated this axis on a high level based on inputs from stakeholder consultations. The aim was to determine the added value achieved by the component as a whole, beyond what would have been achieved by Member States acting alone, in a qualitative way. This includes an overview of the performance of the component compared to what could be achieved on a national scale from the perspective of users, Member States, and the overall perception on an international scale.

2.2.3. Methodology for Phase 3

The third phase of the study represents a compilation of all the analysis and results that were obtained under the performance assessment. It is an assessment of the takeaways from the performance assessment across the 5 different axes. These results and their rationales will be used to determine whether any change or modification is necessary for the interventions under study.

The synthesis and recommendations should particularly focus on three main points of the study scope

- The need for additional space or ground infrastructure
- The need to update the pricing policy for Copernicus, SSA and GOVSATCOM
- The need to update the mandate of EUSPA or the entrusted tasks for other entrusted entities

3. EVALUATION OF THE PERFORMANCE OF THE IMPLEMENTATION OF THE EU SPACE PROGRAMME

This study provides a chapter for each space component that covers the assessment of its different elements and then a chapter for the EUSPA tasks assessment.

3.1. Copernicus Component

3.1.1. Introduction to the Copernicus Component

Copernicus is the EU flagship Earth observation programme providing free and open Earth observation data from satellites and other sensors. The system also provides a complete set of services that respond to societal and environmental challenges. Copernicus is a public service designed to address the needs of public policies and administrations and foster economic growth in the EU by supporting public users at local, national, and European level, helping the EU to maintain a prominent role in the international context, strengthening intermediate users, downstream companies, and value-added service providers.

The Copernicus component is subdivided into three sub-components: infrastructure, in-situ, and services.

ESA is mandated with the coordination of the space component, its implementation and evolution, together with the design, development, and construction of the Copernicus space infrastructure. In particular, the Sentinel missions have the following objectives:

Sentinel-1 provides all-weather, day and night radar imaging for land and ocean services. Sentinel-1A satellite was successfully launched on 3 April 2014, Sentinel-1B satellite was launched on 25 April 2016 but the mission was declared inactive on 3 August 2022 after loss of operations. Sentinel-1C is expected to be launched soon and to enhance Sentinel-1 mission performances, while also covering the loss of Sentinel-1B.

Sentinel-2 provides high-resolution optical imaging for land services (e.g., imagery of vegetation, soil and water cover, inland waterways and coastal areas), together with information for emergency services. The two satellites were launched successfully in 2015 and 2017.

Sentinel-3 measures sea surface topography, sea and land surface temperature, and ocean and land surface colour with high accuracy and reliability to support ocean forecasting systems, environmental monitoring and climate monitoring. The payloads onboard are many: Ocean and Land Colour Instrument (OLCI), a conical imaging radiometer, an altimeter, a microwave radiometer and a precise orbit determination package with a GNSS instrument.

Sentinel-4 will have the objective of s to monitor key air quality trace gases and aerosols over Europe in support of the Copernicus Atmosphere Monitoring Service (CAMS) at high spatial resolution and with a fast revisit time. It is expected to be launched in 2024.

Sentinel-5P (Precursor) was launched on 13 October 2017. The primary purpose of this mission is to reduce the data gap between the loss of Envisat in 2012, and the launch of Sentinel-5. Sentinel-5P now provides data for atmospheric composition monitoring.

Sentinel-5 mission consists of high-resolution spectrometer system operating in the ultraviolet to shortwave infrared range with 7 different spectral bands. It is planned to be launched.

Sentinel-6 Michael Freilich provides continuity for high precision altimetry sea level measurements following the Jason-3 satellite. Sentinel-6A was launched in November 2020, and Sentinel-6B is expected for launch in 2025.

On the other hand, the in-situ component is complementary to satellite data. It includes environmental measurements from ground-based to sea-borne or air borne monitoring systems. Moreover, in-situ data also includes geospatial reference data: topographic information such as digital elevation models or transportation network maps.

Finally, there is the service component. It delivers data and products freely available for a wide variety of users. These services integrate together data from the Space and In-situ components in order to offer Copernicus products tailored to the needs of very specific end-users. To better reach end-users, six thematic core services were developed in different areas.

The six services are the Land Service, Marine Service, Climate Change Service, Emergency Service, Security Service and Atmosphere Service. All the services are today operational. Different services enable the creation of several applications, and some prominent (but non-exhaustive) examples are listed in the table below.

Table 4: Copernicus Services main applications

Service	Main Applications
CLMS (Copernicus Land Monitoring Service)	Systematic monitoring of biophysical parameters; Land cover and land use mapping; Thematic hot-spot mapping; Imagery and reference data; Ground motion.
CAMS (Copernicus Atmosphere Monitoring Service)	Air quality and atmospheric composition; Ozone layer and ultra-violet radiation; Emissions and surface fluxes; Solar radiation; Climate forcing.
CMEMS (Copernicus Marine Environment)	Combating pollution, marine protection, maritime safety and routing, sustainable use of ocean resources, developing renewable marine energy resources, supporting blue growth, climate

Monitoring Service)	monitoring, forecasting, and more.
C3S (Copernicus Climate Change Service)	The C3S mission is to support adaptation and mitigation policies of the European Union by providing consistent and authoritative information about climate change. They offer free and open access to climate data and tools based on the best available science.
CEMS (Copernicus Emergency Management Service)	The mapping component of the service (Copernicus EMS - Mapping) has a worldwide coverage and provides Civil Protection Authorities and Humanitarian Aid Agencies with maps based on satellite imagery; the early warning component consists of the European Flood Awareness system, the European forest fire information system, the European drought observatory. The Copernicus exposure mapping component gives periodic production of global geospatial information on human settlements in the form of built-up area grid.
CSS (Copernicus Security Service)	Border surveillance; Maritime surveillance (CMS) ; Support to EU External Action (SESA)

For the future, six high-priority candidate missions (Copernicus Expansion Missions) are being studied, to address EU policy and gaps in Copernicus user needs, and to expand the current capabilities of the Copernicus space component. The key missions are the following:

- **CHIME:** Copernicus Hyperspectral Imaging Mission. Complementing Copernicus Sentinel-2 for applications such as land-cover mapping, it will carry a unique visible to shortwave infrared spectrometer, providing routine hyperspectral observations to support new and enhanced services for sustainable agricultural and biodiversity management, as well as soil property characterisation.
- **CIMR:** Copernicus Imaging Microwave Radiometer. Responding to high-priority requirements from key Arctic user communities, the mission will carry a wide-swath conically scanning multi-frequency microwave radiometer, to provide observations of sea-surface temperature, sea-ice concentration and sea-surface salinity, while uniquely also observing a wide range of other sea-ice parameters.
- **CO2M:** Copernicus Anthropogenic Carbon Dioxide Monitoring. Due to overall space budget shortfalls, the mission has been prioritized amongst the expansion missions. This mission will carry a near-infrared and shortwave-infrared spectrometer to measure atmospheric carbon dioxide produced by human activity, providing the EU with a unique and independent source of information, to assess the effectiveness of policy measures, and to track their impact towards decarbonising Europe and meeting national emission reduction targets. The measurements from the mission would reduce current uncertainties in estimates of emissions of carbon dioxide from the combustion of fossil fuel at national and regional scales.
- **CRISTAL:** Copernicus Polar Ice and Snow Topography Altimeter. The mission will contribute to a better understanding of climate processes, with its dual-frequency radar altimeter and microwave radiometer to measure and monitor sea-ice thickness and overlying snow depth. It would also measure and monitor changes in the height of ice sheets and glaciers worldwide, while measurements of sea-ice thickness would support maritime operations in polar oceans and, in the longer term, would help in the planning of activities in the polar regions.
- **LSTM:** Copernicus Land Surface Temperature Monitoring. The mission will respond to priority requirements of the agricultural user community, for improving sustainable agricultural productivity at field-scale in a world of increasing water scarcity and variability. It would carry a high spatial-temporal resolution thermal infrared sensor to provide observations of land-surface temperature. Such measurements and derived evapotranspiration are key variables to understand and respond to climate variability, manage water resources for agricultural production, predict droughts and also to address

land degradation, natural hazards such as fires and volcanoes, coastal and inland water management as well as urban heat island issues.

- **ROSE-L:** L-band Synthetic Aperture Radar. The mission will provide additional information that cannot be gathered by the Copernicus Sentinel-1 C-band radar mission, since it would carry an L-band SAR, whose longer L-band signal can penetrate through many natural materials such as vegetation, dry snow and ice. It would be used in support of forest management, to monitor subsidence and soil moisture and to discriminate crop types for precision farming and food security.

3.1.2. The Copernicus Component entrusted tasks and entrusted entities

3.1.2.1. Entrusted tasks

In line with the Contribution Agreements and multi-annual work programme 2021-2027 for Copernicus, tasks have been entrusted to the following eight entities:

- ESA
- EUMETSAT
- EEA
- MOI
- ECMWF
- EMSA
- FRONTEX
- EUSPA

Note:

- *SatCen has been excluded from the effectiveness assessment as the Contribution Agreement was not yet signed at the time of the assessment.*

The tasks entrusted to the above entities fall within the four main objectives of the Copernicus component:

- **Objective 1: Data acquisition**
Continued acquisition of data through:
 - (a) the development and operations of the Copernicus Sentinels
 - (b) the access to third party space-borne Earth observation data
 - (c) the access to in situ and other ancillary data
- **Objective 2: Services Provision**
Continued processing of data and information through the Copernicus Services, which includes activities for the generation of value-added information to support environmental monitoring, reporting and compliance assurance, civil protection, and security services
- **Objective 3: Data access and distribution**
Continued data access and distribution, which includes infrastructure and services (including the DIAS) to ensure the discovery, viewing, access to, distribution and exploitation, and long-term preservation of Copernicus data and Copernicus information, in a user-friendly manner
- **Objective 4: User uptake, market development and capacity building**

User uptake, market development and capacity building, which includes relevant activities, resources, and services to promote Copernicus, its data, and services, as well as related downstream applications and their development at all levels to maximise socio-economic benefits as well as the collection and analysis of user needs

For the effectiveness assessment, each Copernicus objective is considered as an intervention group. Under each intervention group, there are several interventions that are entrusted to specific entities. The effectiveness assessment is carried out at the intervention level. The table below shows the 21 interventions that will be assessed in the following section.

Table 5: List of interventions across all entrusted entities

Intervention Group	Entity	No.	Intervention
Objective 1: Data acquisition	ESA	1	Data acquisition entrusted to ESA
Objective 3: Data access and distribution	ESA	2	Data access and distribution entrusted to ESA
Objective 4: User uptake, market development and capacity building	ESA	3	User uptake entrusted to ESA
Objective 1: Data acquisition	EUMETSAT	4	Data acquisition entrusted to EUMETSAT
Objective 3: Data access and distribution	EUMETSAT	5	Data access and distribution entrusted to EUMETSAT
Objective 4: User uptake, market development and capacity building	EUMETSAT	6	User uptake entrusted to EUMETSAT
Objective 1: Data acquisition	EEA	7	Data acquisition entrusted to EEA
Objective 2: Services Provision	EEA	8	Land Monitoring Service Provision entrusted to EEA
Objective 3: Data access and distribution	EEA	9	Data access and distribution entrusted to EEA
Objective 4: User uptake, market development and capacity building	EEA	10	User uptake entrusted to EEA
Objective 2: Services Provision	MOI	11	Marine Environment Monitoring Service Provision entrusted to MOI
Objective 3: Data access and distribution	MOI	12	Data access and distribution entrusted to MOI
Objective 4: User uptake, market development and capacity building	MOI	13	User uptake entrusted to MOI
Objective 2: Services Provision	ECMWF	14	Atmosphere Monitoring Service Provision entrusted to ECMWF
Objective 2: Services Provision	ECMWF	15	Climate Change Service Provision entrusted to ECMWF
Objective 3: Data access and distribution	ECMWF	16	Data access and distribution entrusted to ECMWF
Objective 4: User uptake, market development and capacity building	ECMWF	17	User uptake entrusted to ECMWF
Objective 2: Services Provision	EMSA	18	Security Service (Maritime Surveillance) Provision entrusted to EMSA
Objective 4: User uptake, market development and capacity building	EMSA	19	User uptake entrusted to EMSA
Objective 2: Services Provision	FRONTEX	20	Security Service (Border Surveillance) Provision entrusted to FRONTEX
Objective 4: User uptake, market development and capacity building	EUSPA	21	User uptake entrusted to EUSPA

3.1.2.2.Copernicus budget

The Copernicus budget from the previous MFF between 2014-2020 was a total of 4,15 B EUR. Under the new MFF, the multiannual delegated budget for 2021-2027 is a total of 5,79 B EUR. The table below shows the split at the entrusted entity level for activities under indirect management for the current MFF.

Table 6: 2021-2027 MFF Budget for Copernicus

Entrusted Entity	2021-2027
ESA	€ 4,115,000,000.00
EUMETSAT	€ 735,000,000.00
EEA	€ 135,000,000.00
MOI	€ 228,000,000.00
ECMWF	€ 411,000,000.00
FRONTEX	€ 67,000,000.00
EMSA	€ 73,000,000.00
EUSPA	€ 30,000,000.00
Total	€ 5,794,000,000.00

Note: For the new MFF, the budget allocated to SatCen is not included as the Contribution Agreement. Additionally, while the FRONTEX budget has been included in the 2021-2027 budget, it has not been included below in the annual budget overview since, even though the Contribution Agreement has been signed, the budget for the new MFF is still under negotiation with FRONTEX. Additionally, the budget allocated to Cassini is also not included as there is a separate section below dedicated to Cassini.

At the yearly level, the table below shows the budget at the intervention level for each entity for 2021-2023, amounting to a total of 2.2 B EUR.

Table 7: Annual budget from 2021-2023 for Copernicus

No.	Intervention	2021	2022	2023
1	Data acquisition entrusted to ESA	€ 510,112,129.00	€ 404,290,000.00	€ 485,950,000.00
2	Data access and distribution entrusted to ESA	€ 7,500,000.00	€ 30,000,000.00	€ 3,000,000.00
3	User uptake entrusted to ESA	-	-	€ 650,000.00
4	Data acquisition entrusted to EUMETSAT	€ 62,582,590.00	€ 92,868,000.00	€ 95,050,000.00
5	Data access and distribution entrusted to EUMETSAT	€ 4,250,000.00	€ 15,000,000.00	€ 12,800,000.00
6	User uptake entrusted to EUMETSAT	€ 700,000.00	€ 3,132,000.00	€ 3,150,000.00
7	Data acquisition entrusted to EEA	€ 2,000,000.00	€ 2,500,000.00	€ 1,550,000.00

8	Land Monitoring Service Provision entrusted to EEA	€ 27,150,000.00	€ 12,650,000.00	€ 15,550,000.00
9	Data access and distribution entrusted to EEA	€ 400,000.00	€ 400,000.00	€ 2,200,000.00
10	User uptake entrusted to EEA	€ 1,450,000.00	€ 1,450,000.00	€ 1,700,000.00
11	Marine Environment Monitoring Service Provision entrusted to MOI	€ 49,100,000.00	€ 27,800,000.00	€ 27,000,000.00
12	Data access and distribution entrusted to MOI	€ 1,500,000.00	€ 1,020,000.00	€ 1,000,000.00
13	User uptake entrusted to MOI	€ 900,000.00	€ 1,200,000.00	€ 1,100,000.00
14	Atmosphere Monitoring Service Provision entrusted to ECMWF	€ 30,960,000.00	€ 20,600,000.00	€ 16,100,000.00
15	Climate Change Service Provision entrusted to ECMWF	€ 53,460,000.00	€ 32,600,000.00	€ 25,200,000.00
16	Data access and distribution entrusted to ECMWF	€ 1,200,000.00	€ 1,200,000.00	€ 4,500,000.00
17	User uptake entrusted to ECMWF	€ 80,000.00	€ 2,800,000.00	€ 5,300,000.00
18	Security Service (Border Surveillance) Provision entrusted to FRONTEX*	-	-	-
19	Security Service (Maritime Surveillance) Provision entrusted to EMSA	€ 17,795,000.00	€ 9,719,200.00	€ 9,700,000.00
20	User uptake entrusted to EMSA	€ 205,000.00	€ 280,800.00	€ 300,000.00
21	User uptake entrusted to EUSPA	€ 4,000,000.00	€ 5,000,000.00	€ 5,000,000.00
Total		€ 799,344,719.00	€ 674,110,000.00	€ 726,400,000.00

* FRONTEX budget not included as mentioned in the note above

3.1.3. Effectiveness of the Implementation of Copernicus

The assessment of the effectiveness of implementation is divided into two interrelated sections:

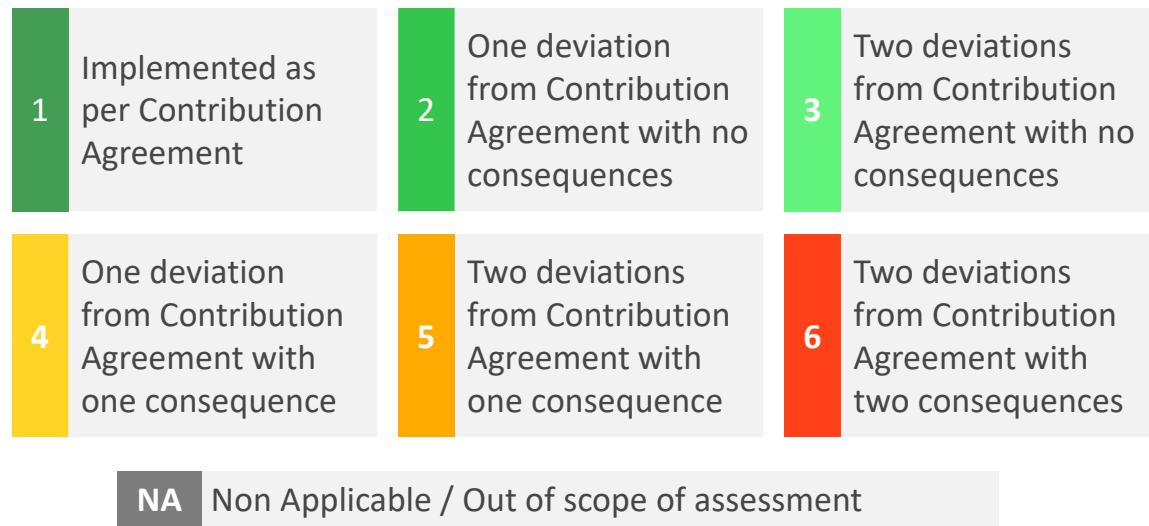
- First, the extent to which the interventions outlined above were completed within the allocated time and budget, and the outcomes or severity of any delay or budget overrun that may have occurred.
- The second, the performance of the Copernicus Component based on six main indicators.

3.1.3.1. Assessment of the implementation of the entrusted tasks by entrusted entities

The effectiveness of the implementation of the entrusted tasks, or activities, is determined through the results assessment. The assessment was carried out based on questionnaires and interviews with the entrusted entities and information from the Annual Implementation Reports.

Each of the 21 interventions outlined in the previous section comprises several activities. These activities were extracted directly from the annual work programmes in the Annex to the Commission Implementing Decision, with a few changes as discussed with the entities based on their Annual Implementation Plans. As described in the results assessment methodology section, the specific outcome of each activity was determined based on its status, timeline, and budget, that mapped to a numerical outcome on a scale of 1-6. As shown in the figure below, each number defines a different outcome within this scale and does not provide a score for the outcome.

Figure 18: Definition of scale to assess implementation of entrusted tasks



Any deviations or consequences in the implementation of the activities have been qualitatively explained in the results below. It is important to note that while the assessment was carried out at the activity level, the results shown below have been consolidated at the intervention level. A detailed view of the assessment at the activity level can be found in the Appendix.

ESA

The following three interventions were assessed under the scope of the agreement with ESA. This section reflects activities carried out in 2021, 2022 and up to June 2023.

Note: There are a total of 11 activities under the 3 interventions. The detailed list of activities can be found in the Appendix.

Intervention 1: Data acquisition entrusted to ESA

Description of Activities

Includes activities related to the space segment development, launch services procurement, overall operations of the Copernicus Space Component, maintaining the quality of Sentinel data, and management of access of Sentinel and 3rd party data. It also includes the development of Sentinel evolution missions and activities related to CCMs.

Overview of Results

Most activities under this intervention are ongoing or were completed on time as per the contribution agreement.

The launch procurement of the Sentinels covered by the Contribution Agreement and its Technical Annex is covered by the spacecraft specific contracts under the Framework Contract for Copernicus Launch Services, as signed between the European Commission and Arianespace. Due to the unavailability of Sentinel-1B and the urgency to launch Sentinel-1C as replacement, it was agreed to sign the Sentinel-1C launch contract in 2022, independently

from the Framework Contract which was still not finalized at the time. Then, the delay in launching Sentinel-1C due to the unavailability of the Vega-C launch vehicle has led to an impact on products and services delivered by four of the six Copernicus Services. This has not led to any critical consequences or a complete absence of products since Sentinel-1A is still operational. However, even with a mitigation plan of optimizing Sentinel-1A and acquiring CCM data, the data that is unavailable due to the loss of Sentinel-1B cannot be fully covered. The unavailability of the Vega C launcher, an external factor on the ESA Copernicus activities, has delayed the launch of Sentinel-1C.

Additionally, ESA had to prolong the already existing CCM contracts into 2024, until a new innovative subscription scheme for data buy as part of the Dynamic Purchasing System (DPS) was introduced for CCMs.

Intervention 1 Qualification	8 out of the 9 activities (89%) were Implemented as per the Contribution Agreement
	1 out of the 9 activities (11%) had one deviation from the Contribution Agreement with no consequences

Intervention 2: Data access and distribution entrusted to ESA

Description of Activities

Includes delivery of full, open, and free operational data services for Sentinel-1/2/3/5P across the user communities including support for user level data and data access services, maintenance, and evolution of data access interfaces to ensure data access continuity and availability, and providing operational Sentinel data access services as part of an open cloud-based ecosystem.

Overview of Results

The activities entrusted to ESA under this intervention were completed on time and on budget.

Intervention 2 Qualification	All activities implemented as per Contribution Agreement

Intervention 3: User uptake entrusted to ESA

Description of Activities

Includes activities related to communications, user uptake, market development and capacity building activities, addressing new partnerships in line with commercialisation and internationalisation efforts of the Copernicus Component.

Overview of Results

The activities entrusted to ESA under this intervention are ongoing and started on time in Q3 of 2023.

Intervention 3 Qualification	All activities implemented as per Contribution Agreement

Summary of results assessment for ESA

ESA was responsible for the development and operations of the space component, launch procurement, management of Sentinels and CCM data, and had successfully ensured data access continuity and availability for all Sentinel data. **ESA has implemented most of the entrusted activities with no delays, budget overruns nor consequences.** Two out of three

interventions were implemented as per the contribution agreement. Within Intervention 1, only one activity was delayed as impacted by factors outside the Copernicus Component, and had an effect on the Copernicus services. However, this was not a consequence of ESA’s ability in implementing the tasks, but rather external factors, including the unavailability of VEGA-C to launch Sentinel-1C in order to replace Sentinel-1B. For upcoming activities, ESA is also responsible for the development of six new Sentinel Expansion missions, which are under development with all milestones being met.

EUMETSAT

The following three interventions were assessed under the scope of the agreement with EUMETSAT. It is important to note than the activities entrusted in 2021 are not considered within the scope of this assessment as these activities had all been financially covered under the previous MFF, as agreed with the Commission. This section therefore reflects activities carried out in 2022 and up to June 2023 as most of the activities entrusted to EUMETSAT are continuous.

Note: There are a total of 13 activities under the 3 interventions. The detailed list of activities can be found in the Appendix.

Intervention 4: Data acquisition entrusted to EUMETSAT

Description of Activities

Includes activities related to operations and maintenance of Sentinel-3, -6 and Jason-3 satellites, access to data from its own and 3rd party missions, support of development activities, infrastructure upgrades of the Copernicus Space Infrastructure that are necessary to ensure continuity, and ensuring evolution of the data services and underlying systems. Additionally, it includes supporting development of upcoming missions including CRISTAL and CO2M and other Next Gen Sentinel missions.

Overview of Results

The activities entrusted to EUMETSAT under this intervention were completed on time and on budget, or have not started but are expected to be on time.

Intervention 4 Qualification	All activities implemented as per Contribution Agreement

Intervention 5: Data access and distribution entrusted to EUMETSAT

Description of Activities

Includes activities related to operate, upgrade, and manage Data Access and Distribution Services of Copernicus Data, ensuring the evolution of the EUMETSAT Multi-Mission Infrastructure and supporting the federation of the Copernicus financed infrastructures and services. It also includes operating in partnership with ECMWF, Mercator, and EEA as well as WEkEO to provide integrated access to data and information.

Overview of Results

The activities entrusted to EUMETSAT under this intervention were completed on time and on budget.

Intervention 5 Qualification	All activities implemented as per Contribution Agreement

Intervention 6: User uptake entrusted to EUMETSAT

Description of Activities

Includes activities to provide support to the Copernicus element on user uptake, market development, capacity building, and training services including support to the Commission.

Overview of Results

The activities entrusted to EUMETSAT under this intervention were completed on time and on budget.

Intervention 6 Qualification

All activities implemented as per Contribution Agreement

Summary of results assessment for EUMETSAT

EUMETSAT was responsible for continuous operations and maintenance of Sentinel-3, -6 and Jason-3 satellites with absolute availability to services, upgrades to the space infrastructure, and supporting development of upcoming missions. EUMETSAT is also responsible for the Multi-Mission Infrastructure and managing data access and distribution services for Copernicus, including operating in partnership with other relevant entrusted entities. **All interventions were or are expected to be implemented as per the contribution agreement** with no delays, budget overruns or consequences to the Copernicus services. In terms of future activities, EUMETSAT is also on schedule to support upcoming expansion missions such as CIMR, CO2M and CRISTAL in partnership with ESA.

EEA

The following four interventions were assessed under the scope of the CA with EEA. It is important to note that delays in signing the Contribution Agreement with EEA led to the majority of the activities in 2021 being delayed to 2022 or carried out under the previous delegation Agreement 2014-2021. Taking this into account, the activities entrusted in 2021 have not been considered under the scope of this assessment. This section therefore reflects activities carried out in 2022 and up to June 2023.

Note: There are a total of 55 activities under the 4 interventions. The detailed list of activities can be found in the Appendix.

Intervention 7: Data acquisition entrusted to EEA

Description of Activities

Including activities related to availability, accessibility and improving operational provision of essential in situ data needed for the production and validation of Copernicus data and information products. The objective is also to maintain a cross-cutting overview of Copernicus' in situ data requirements, uses, and challenges as well as provide support to the Commission and entrusted entities regarding in situ data activities.

Overview of Results

The activities entrusted to EEA under this intervention were completed on time and on/under budget.

Intervention 7 Qualification

All activities implemented as per Contribution Agreement

Intervention 8: Land Monitoring Service Provision entrusted to EEA

Description of Activities

Includes activities related to improve timeliness, better harmonisation, and integration of CLMS products, and ensure full quality control at production level. More specifically, these activities include call for tenders for various products, continuous production and release of products and overall operational activities for the service evolution.

Overview of Results

Approximately half of the activities are ongoing or were completed on time as per the contribution agreement. The activities that were delayed were primarily due to the late signing of the agreement, however there were no consequences as a result of these delays. All the activities entrusted to EEA under this intervention were completed on budget, and for some activities related to service provision in 2023 there's no set budget on how much will be spent until the framework contract is signed. However, this is not expected to affect the implementation of these activities.

Intervention 8 Qualification	12 out of the 25 activities (48%) were implemented as per the Contribution Agreement
	13 out of the 25 activities (52%) had one deviation from the Contribution Agreement with no consequences

Intervention 9: Data access and distribution entrusted to EEA

Description of Activities

Includes activities related to contributing and adhering to the Copernicus Integrated Data Management activities and implementing DIAS functionalities, and providing a user-oriented product and service access and distribution system. It also includes activities related to the operation of WEkEO including user support and ensuring overall that all data and information products from the CLMS portfolio can be easily searched and accessed.

Overview of Results

Over half of activities are ongoing or were completed on time as per the contribution agreement. The activities that were delayed were primarily due to the late signing of the agreement, however there were no consequences as a result of these delays. All the activities entrusted to EEA under this intervention were completed on budget.

Intervention 9 Qualification	5 out of the 8 activities (63%) were implemented as per the Contribution Agreement
	3 out of the 8 activities (37%) had one deviation from the Contribution Agreement with no consequences

Intervention 10: User uptake entrusted to EEA

Description of Activities

Includes activities related to user uptake, market development and capacity building in the area of land monitoring and in-situ data. Particularly, annual meetings for CLMS stakeholders, webinars, trainings and general communications and awareness raising. The activities also include support for Green Deal monitoring related policies.

Overview of Results

Most of the activities are ongoing or were completed on time as per the contribution agreement. The activities that were delayed were primarily due to the late signing of the CA, however there were no consequences as a result of these delays. All the activities entrusted to EEA under this intervention were completed on budget.

Intervention 10 Qualification	10 out of the 14 activities (71%) were implemented as per the Contribution Agreement
	4 out of the 14 activities (29%) had one deviation from the Contribution Agreement with no consequences

Summary of results assessment for EEA

EEA was responsible for provision of in-situ data, continuous production and release of products and overall operational activities for the CLMS including DIAS and WEkEO, and user uptake activities. **All entrusted tasks were completed in line with the Contribution Agreement without any consequences.** While some activities were delayed due to the late signing of the Contribution Agreement, there were no impacts on the Copernicus service.

MOI

The following three interventions were assessed under the scope of the agreement with MOI. This section reflects activities carried out in 2021, 2022 and up to June 2023.

Note: There are a total of 126 activities under the 3 interventions. The detailed list of activities can be found in the Appendix.

Intervention 11: Marine Environment Monitoring Service Provision entrusted to MOI

Description of Activities

Includes activities related to developing and maintaining digital ocean information products, preparation and release of tenders, development of ocean monitoring indicators, coordination & integration with other Copernicus services including land, emergency, and maritime surveillance, and operations of a new Marine Data Store (MDS) and Marine Information System (MIS) to disseminate ocean products. It also includes releases of new CMEMS portfolios and ensuring alignment of the portfolio to enhance continuity of the service and target relevant policy developments.

Overview of Results

A majority of the activities are ongoing or were completed on time as per the contribution agreement. Activities in 2021 related to launches of calls or evolution of services were slightly delayed since the agreement was signed later in July 2021 and priority was given to contracts related to critical activities such as ensuring continuity of service which were completed without delays. For services such as global real time forecasting, there were no consequences due to the delays since user satisfaction for the existing service was high, therefore it was not critical to prioritise the activity. For the Marine Data Store, the kick off of contracts was completed on time, however, the proof-of-concept launch was slightly delayed ensuring the focus was on the kick-off, which was time-sensitive and crucial for continuity of service, and also allow for more time to secure the right specifications for the future MDS. Overall, all the activities were completed and will not lead to any long-term delays or issues in the implementation of the activities. All the activities entrusted to MOI under this intervention were completed on budget.

Intervention 11 Qualification	64 out of the 71 activities (90%) were implemented as per the Contribution

	Agreement
	7 out of the 71 activities (10%) had one deviation from the Contribution Agreement with no consequences

Intervention 12: Data access and distribution entrusted to MOI

Description of Activities

Includes activities related to operations and improvements of the WEkEO services, ensuring the interfaces with the Copernicus services to integrate all portfolios updates and interfaces with a diverse number of users including developers, data managers, policy makers and national entities. It also includes development and implementation of dedicated communication, marketing, and training activities to guide and support users.

Overview of Results

All activities, except one, are ongoing or were completed on time as per the contribution agreement. All the activities entrusted to MOI under this intervention were completed on budget.

Intervention 12 Qualification	All activities implemented as per Contribution Agreement

Intervention 13: User uptake entrusted to MOI

Description of Activities

Includes activities related to promotion of latest versions of CMEMS portfolio, Ocean State Report, and ocean monitoring indicators, support on the international stage and continuous user engagement and outreach activities including training, workshops, and documentation. Additional activities include improvement of the web portal to better focus on specific user communities and policies and overall continued engagement with the Commission, member states, EUSPA, UNEP and EIB.

Overview of Results

All activities, except one, are ongoing or were completed on time as per the contribution agreement. One activity related to implementation of thematic portals was initially delayed due to a delay in receiving a formal confirmation from the Commission to move forward with the activity. This activity was however completed with no consequences after receipt of approval. All the activities entrusted to MOI under this intervention were completed on budget.

Intervention 13 Qualification	27 out of the 28 activities (96%) were implemented as per the Contribution Agreement
	1 out of the 28 activities (4%) had one deviation from the Contribution Agreement with no consequences

Summary of results assessment for MOI

MOI was responsible for the release of new versions of CMEMS, including development of digital ocean products and operations of a Marine Data Store (MDS) and Marine Information System (MIS) in cooperation with other relevant entities. MOI was also responsible for operations and improvements of the WEkEO services, and user uptake activities. **All entrusted tasks were completed in line with the Contribution Agreement without any consequences.** A few activities were delayed, however, all the activities were completed and

will not lead to any long-term issues in the implementation of the tasks. Specifically, all critical activities remained operational without any impacts or delays. With regards to the budget, all activities were on or under budget up to 2023. However, an important point was raised with regards to the budget for the second half of the MFF. To account for activities such as further evolution of services, including the Coastal and Arctic Hub, and inflation when renewing contracts, MOI is expecting to increase their budget to take these factors into consideration for the following years.

ECMWF

The following four interventions were assessed under the scope of the agreement with ECMWF. This section reflects activities carried out in 2021, 2022 and up to June 2023.

Note: There are a total of 85 activities under the 4 interventions. The detailed list of activities can be found in the Appendix.

Intervention 14: Atmosphere Monitoring Service Provision entrusted to ECMWF

Description of Activities

Includes activities related to managing and developing the service, including continual improvement of the products and service elements, provision of global and regional atmosphere products, emissions products and supplementary products (e.g., radiative forcings), and Evaluation and Quality Control for CAMS products.

Overview of Results

Most of the activities are ongoing or were completed on time as per the contribution agreement. An activity related to acquisition of in-situ data was delayed due to the political reason that Switzerland was not eligible for Copernicus funding. This delay in finalizing the led to a delay in the generation of some in-situ data, however, the data was not used for time critical applications and therefore there were no consequences. Activities related to the development of regional atmosphere products and air quality emissions were also slightly delayed however these were also additional products and therefore not critical. Overall, there were no consequences due to the delays in activities under this intervention.

Intervention 14 Qualification	27 out of the 30 activities (90%) were implemented as per the Contribution Agreement
	3 out of the 30 activities (10%) had one deviation from the Contribution Agreement with no consequences

Intervention 15: Climate Change Service Provision entrusted to ECMWF

Description of Activities

Includes activities related to collection, preservation, and quality control of observations, both in-situ and from space, managing expenditure and technical aspects, further improvement of the products offered by the service, as well as to deliver ECMWF’s contribution to technical activities, and Evaluation and Quality Control for C3S products.

Overview of Results

A majority of the activities are ongoing or were completed on time as per the contribution agreement. The delay of the extension of the ERA5 product to 1940 was related to Brexit and the migration of operations from the UK to Italy. However, there was no impact on the service due to this delay, and the activity was completed. Overall, there were no consequences due to the delay in activities under this intervention.

Intervention 15 Qualification	23 out of the 24 activities (96%) were Implemented as per the Contribution Agreement
	1 out of the 24 activities (4%) had one deviation from the Contribution Agreement with no consequences

Intervention 16: Data access and distribution entrusted to ECMWF

Description of Activities

Includes activities related to contribution towards the operations, maintenance and upgrade of WEkEO, supporting WEkEO and other DIASes by ensuring that all data and information products from C3S and CAMS portfolio (and the CO2 service element, once operational) can be easily searched and accessed, as well as ensuring robustness and enabling interoperability between platforms.

Overview of Results

The activities entrusted to ECMWF under this intervention were completed on time and on budget.

Intervention 16 Qualification	All activities implemented as per Contribution Agreement

Intervention 17: User uptake entrusted to ECMWF

Description of Activities

Includes activities related to increase user uptake and user satisfaction, to unlock new potential applications and to provide trainings with respect to climate related information and atmosphere monitoring, from the Climate Data Store, Atmosphere Data Store and the Sectoral Information System to the users. The activities also include increasing user uptake with EU Member States through a National Collaboration Programme (operational for CAMS and expected for C3S), and activities in collaboration with EUSPA, as well as European institutions to enhance cooperation and user uptake.

Overview of Results

Most of the activities are ongoing or were completed on time as per the contribution agreement. The activity related to the CAMS National Collaboration Programme was delayed, however, this was due to administrative processes taking more time than anticipated, and differences between the Member States. This delay has not led to any consequences on activities and has seen a positive trend in uptake over the last two years. Additionally, an activity that was not completed was the signing of the MoU with EUSPA, however this has had no effect of the relationship with EUSPA and all the activities in collaboration with EUSPA have been carried out as per the contribution agreement. Overall, there were no consequences due to the delay in activities under this intervention.

Intervention 17 Qualification	20 out of the 22 activities (91%) were Implemented as per the Contribution Agreement
	2 out of the 22 activities (9%) had one deviation from the Contribution Agreement with no consequences

Summary of results assessment for ECMWF

ECMWF was responsible for the development and maintenance of both the CAMS and C3S services, including continual improvement of products. For example, the ERA5 product

developed under C3S is a very successful and widely used product. It has become a standard within the Machine Learning community, with numerous articles referencing the product. ECMWF was also responsible for several other activities related to operations, maintenance, upgrade of WEkEO and user uptake, all of which were carried out with no issues. **All entrusted tasks were completed in line with the Contribution Agreement without any consequences.** While a few activities were delayed, they were typically due to external factors such as Brexit causing the migration of operations from UK to Italy, and issues in finalizing an in-situ data provider due to political reasons. However, none of these delays led to any impacts on critical services or products and were eventually completed as per the CA with no consequences. Additionally, there were some delays due to administrative processes of the CAMS National Collaboration Programme, but there has recently been a positive trend in uptake with 8 contracts signed, 4 under signature or negotiation, and 1 launched. ECMWF is expecting contracts from 4 more MS in 2023 and 12 in 2024. However, for increased uptake for both the CAMS and C3S, an increase in budget would be necessary to increase engagement.

EMSA

The following two interventions were assessed under the scope of the agreement with EMSA. The activities listed under 2021 of the Contribution Agreement are not within the scope of this assessment since the previous MFF was still in place until July 2021 and there was an interruption of service until October 2021 due to a lack of budget until the new MFF came into effect. This section therefore reflects activities carried out in 2022 and up to June 2023.

Note: There are a total of 8 activities under the 2 interventions. The detailed list of activities can be found in the Appendix.

Intervention 19: Security Service (Maritime Surveillance) Provision entrusted to EMSA

Description of Activities

Includes activities related to management of service provision, procurements, and contracts, ensuring service continuity and to support the sustainable growth of the user base across several maritime surveillance activities including the fisheries control service, maritime safety service, maritime security service, law enforcement service, customs service, and marine pollution monitoring service. Additionally, it includes cooperation and provision of support to international organisations.

Overview of Results

The activities entrusted to EMSA under this intervention are either ongoing or were completed on time and on budget.

Intervention 19 Qualification	All activities implemented as per Contribution Agreement

Intervention 20: User uptake entrusted to EMSA

Description of Activities

Includes activities related to training activities, e-learning materials and organising the Copernicus Maritime Surveillance User Group to gather feedback from existing users for improvements to the service, as well as to further refine user requirements.

Overview of Results

The activities entrusted to EMSA under this intervention are either ongoing or were completed on time and on budget. The execution of some activities related to communications were under budget due to Covid restrictions in 2022.

Intervention 20 Qualification

All activities implemented as per Contribution Agreement

Summary of results assessment for EMSA

EMSA was responsible for the provision and continuity of CMS across several maritime surveillance activities, as well as user uptake activities including organising the Copernicus Maritime Surveillance User Group and providing support to international organisations. **All interventions were or are expected to be implemented as per the contribution agreement** with no delays, budget overruns or consequences to the Copernicus services.

EUSPA

The following intervention was assessed under the scope of the agreement with EUSPA. This section reflects activities carried out in 2021, 2022 and up to June 2023.

Note: There are a total of 6 activities under the intervention. The detailed list of activities can be found in the Appendix.

Intervention 21: User uptake entrusted to EUSPA

Description of Activities

Include activities related to user uptake, market development, and capacity building, extension of the European GNSS User Consultation Platform to Other Copernicus users, and analysis of trends in user needs and requirements. Additional activities are related to the launch of calls supporting development of Copernicus solutions through use case demonstrators and pilot projects across market segments.

Overview of Results

Activities related to myEUSpace, and Space Academy are partially funded under the Copernicus budget, but they are reported under the Cassini Programme and therefore not evaluated in this section. Additionally, a portion of the funding under the CA is allocated to on-site consulting support at EUSPA, and is not considered within the scope of this assessment as it is not an entrusted activity.

All activities entrusted to EUSPA were carried out on budget. Most activities were carried out on time, or have not started but are expected to start without any delays. An activity related to supporting development of Copernicus demonstrators was delayed due to a large number of proposals received during the launch of the call, leading to an extended deadline and delays in project kick-offs. The delay in this activity has consequently led to delays in a second activity, the release of a call supporting the pilot projects, which is a continuation of the demonstrators. However, these delays will not have an impact on the overall implementation as the MFF budget will not be exceeded and the delay has given EUSPA additional time to expand on networking and awareness raising before the launch of the second call.

Intervention 21 Qualification

4 out of the 6 activities (67%) were Implemented as per the Contribution Agreement

2 out of the 6 activities (33%) had one deviation from the Contribution Agreement

Summary of results assessment for EUSPA

EUSPA was primarily focused on user uptake, market development and capacity building activities. EUSPA was also very actively engaged with all other entrusted entities within Copernicus as well as other programmes such as Cassini, in support of their user uptake activities. Overall, **EUSPA has carried out all the entrusted activities under the contribution agreement**, with minor delays that are not expected to impact the implementation of the programme.

3.1.3.2. Assessment of the performance of the Copernicus component

Copernicus has six key indicators to assess its performance. Several entrusted activities have been assessed under these six indicators. Detailed indicators can be found in the Appendix, this section provides an overview of the outcome of the KPIs at a service or Component level.

Table 8: Copernicus Performance Indicators

Indicator	KPI
Indicator 1: Number of Union users of Copernicus Services, Data and DIAS providing information such as the type of user, geographical distribution, and sector of activity (including number of EU or MS policies exploiting or benefiting from Copernicus and computing uptake of Copernicus Services by Copernicus core users)	# users
Indicator 2: Where applicable, number of activations of Copernicus Services requested or served	# activations # services delivered or % service delivery rate
Indicator 3: Union user satisfaction with respect to Copernicus Services and DIAS	% satisfaction of users % response rate
Indicator 4: Reliability, availability and continuity of the Copernicus Services and Copernicus data stream	% reliability % availability % continuity % uptime
Indicator 5: Number of new information products delivered in the portfolio of each Copernicus Service	# new products/services
Indicator 6: Amount of data generated by the Copernicus Sentinels	Amount of data generated

This assessment was focused on the performance of the Copernicus component and services as a whole, and not on the entrusted entities. The KPIs are extracted from the year 2022 because the indicators for 2023 will be available at the end of the year and several KPIs for 2021 are not available as the CA was signed later in the year, therefore, to provide a complete and consistent overview of the performance, the KPIs assessed below are only from 2022.

Indicator 1: Number of users

This indicator is measured based on the number of users of data, products, or services within Copernicus. Where no targets are provided for number of users a steady or growing number of users indicates a good performance of the Copernicus component.

Table 9: Indicator of number of Copernicus users

Service	KPI	Outcome
Transversal	# users	Number of users for Copernicus Services, Scientific/Other Access, National Collaborative Data Access, and International Agreements are higher than the targeted number of users

CLMS	# users	Total number of registered users and active users increasing over time
CAMS	# users	Total number of registered users and active users growing over time
C3S	# users	Total number of registered users and active users growing over time
Transversal	# users	Steady number of users over time
CMEMS	# users	Total number of users growing over time

Quantitative figures for KPIs are available in the Appendix

Overall, there is an increase in number of users, therefore an **increased user uptake** across the various Copernicus services which shows that the **Copernicus Component is performing well**.

Indicator 2: Number of activations

This indicator is measured based on the number of activations requested or served. Where no targets are provided, a high number of activations/services delivered, or high percentage of services delivered vs. ordered indicates a good performance of the Copernicus component.

Table 10: Indicator of number of activations or services delivered within Copernicus

Service	KPI	Outcome
CMS	% service delivery rate	High delivery rate of >90% for all services

Quantitative figures for KPIs are available in the Appendix

For CMS, the % of services delivered over orders received reaches **over 90% for all services** indicating that the **Copernicus service achieved a high performance**.

Indicator 3: User Satisfaction

This indicator is measured based on user satisfaction determined by user surveys conducted by the entrusted entities. Where there are no specific targets set, a user satisfaction above 85% indicates a relatively high satisfaction of the performance of the Copernicus component. Additionally, a high % response rate also translates to a good performance of the Copernicus component.

Table 11: Indicator of user satisfaction within Copernicus

Service	KPI	Outcome
Transversal	EU user satisfaction	High user satisfaction of >85%
Transversal	Sentinel data user satisfaction	High user satisfaction of >85%
CLMS	% response rate	% response rate targets achieved
CAMS	EU user satisfaction	High user satisfaction of >85%
C3S	EU user satisfaction	High user satisfaction >85%
CMEMS	EU user satisfaction	High user satisfaction >85%

Quantitative figures for KPIs are available in the Appendix

User satisfaction is greater than 85% across all services and **above 94% for a majority of services**, indicating a **very high satisfaction with the overall Copernicus component and services**.

Indicator 4: Reliability/ Availability/ Continuity

This indicator is measured based on reliability, availability or continuity of data, products, or services. A percentage reliability/availability/continuity that is equivalent to or higher than the outlined targets indicates a good performance of the Copernicus component.

Table 12: Indicator of reliability, availability or continuity of Copernicus

Service	KPI	Outcome
Transversal	End-to-end Absolute Availability of Copernicus Data Access Service	Sentinel-3 & Sentinel-6 % availability were higher than the targets. Jason-3 % availability, however negligible, was slightly lower than the target, due to interruption of service during an orbit manoeuvre
Transversal	End-to-end Absolute Availability of 3 rd party data	Overall % availability is above targets except S3 Land L2 for Africa STC and Suomi NPP Global Service. Their availability is dependent on infrastructure and services not under the control of EUMETSAT
Transversal	End-to-end Absolute Availability of Services implemented in coordination with CNES/CLS	Overall % availability is above targets
Transversal	Continuity of service	Sentinel-1, Sentinel-2, Sentinel-5P % continuity is higher than the target
CLMS	Service availability	% availability of services equivalent to targets
CAMS/C3S	Uptime	% uptime consistent with standards set
CAMS	Reliability (% of Copernicus Information and Data products generated that are non-conformant)	High % reliability
CAMS	Availability (% of time that Copernicus Information and Data products are accessible)	High % availability
C3S	Availability (% of time that Copernicus Information and Data products are accessible)	High % availability
CMEMS	Reliability in percentage of Copernicus Information and Data products	High % reliability
CMEMS	Availability in percentage of time that Copernicus Information and Data products are accessible	High % availability
CMEMS	% Continuity of Copernicus Information and Data deliveries	High % continuity

Quantitative figures for KPIs are available in the Appendix

Targets have been largely exceeded for reliability, availability, and continuity for Copernicus and 3rd party data. For the Copernicus services, reliability, availability, and continuity are, **on average, >98%**. This indicates that the **performance** of the Copernicus component **is higher than expected**.

Indicator 5: Number of new products

This indicator is measured based on the number of new products developed within a Copernicus Service. Where no targets are provided, if new products are being developed, or a number of products that is equivalent to or higher than outlined targets indicates a good performance of the Copernicus component.

Table 13: Indicator of new products within Copernicus

Service	KPI	Outcome
CLMS	Total number of products made available to users	New products delivered
Transversal	Total number of unique information products delivered in the portfolio	New products delivered
CAMS	Total number of unique products delivered in the portfolio	New products delivered

C3S	Total number of unique products delivered in the portfolio	New products delivered
CMEMS	Total number of unique products delivered in the portfolio	New products delivered

Quantitative figures for KPIs are available in the Appendix

Across the various Copernicus services, there are **several new products being delivered**, indicating an **overall good performance**.

Indicator 6: Volume of data generated

This indicator is measured based on the amount of data generated within Copernicus. Where no targets are provided, a nominal or increasing amount of data indicates a good performance of the component. For the Sentinels, the amount of data generated per day that is equivalent to or higher than the outlined targets indicates a good performance of the Copernicus component.

Table 14: Indicator of amount of data generated within Copernicus

Service	KPI	Outcome
Transversal	Amount of data generated by the Sentinels	Nominal amount of data generated by Sentinels
Transversal	Volume of Sentinel Data produced	Volume of data produced daily for Sentinels 1/2/3 are above average targets. For Sentinel 5P, it is lower than the target since S-5P delivered data (L1b/L2) is compressed and this reduces the actual data volume
Transversal	Total number of available datasets from CCMs	Number of new datasets is higher than the target outcome

Quantitative figures for KPIs are available in the Appendix

Across the Sentinels and 3rd party CCMs, the overall amount of **data generated is higher than the given targets**, showing that **Copernicus is performing exceedingly better than expected**.

3.1.3.3. Takeaways on the effectiveness of the implementation of Copernicus

The implementation of the entrusted tasks for each entrusted entity was evaluated across multiple interventions that are linked to the high-level Copernicus objectives. For ESA, a majority of the tasks were implemented with no deviations or consequences, and although there were some impacts on the Copernicus services due to a delay in launch after the unforeseen loss of a satellite, there were no critical impacts. For EUMETSAT and EMSA all tasks were implemented with no deviations or consequences. For EEA, all tasks were implemented, with a few delays due to the late signing of the agreement in 2021 and no consequences on the service. For ECMWF all tasks were implemented, with a few delays due to external political factors, however there were no consequences on the services. For MOI a few activities were delayed, however, all critical activities remained operational without any impacts or delays. For EUSPA, all tasks were implemented, with some delays that were not expected to impact the implementation of remaining activities. **The implementation of the entrusted tasks by the entrusted entities is, overall, very well aligned with the Contribution Agreement**, and despite a few minor delays, there were no impacts on the overall implementation, timeline, or budget of the Copernicus Component and services.

The performance of the entire Copernicus component and services was evaluated across six key indicators. The number of users of Copernicus is growing, with a high user satisfaction across all services. Additionally, new unique products are being developed and delivered within all Copernicus services as expected. The performance of the services and Sentinel satellites in terms of reliability, availability and continuity is excellent, and higher than

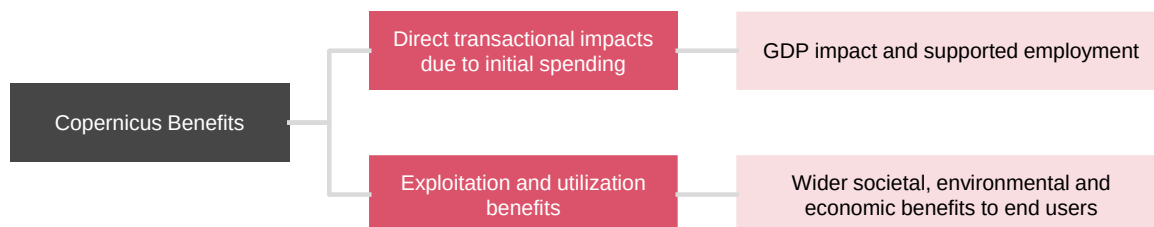
expected targets in several cases. Targets were also exceeded for volume of data generated from the Sentinels. The overall positive trend and exceeded targets across the six indicators demonstrates that **the performance of the Copernicus Component is well above expectations.**

Based on the results of the evaluation of the implementation of entrusted tasks and performance of the Copernicus component, it can be established that the **Copernicus Component has been effectively implemented between 2021-2023** under the 2021-2027 MFF largely due to the efforts and roles of the entrusted entities.

3.1.4. Benefits assessment of the Copernicus Component

As mentioned in the methodology section, benefits of a component of the Space Programme can be identified at two levels. The first level of benefits includes the direct transactional impacts resulting from the investment and spending to develop the infrastructure. The second level of impacts includes the wider socio-economic benefits resulting from the utilization and exploitation of the infrastructure developed, as demonstrated in the figure below:

Figure 19: demonstration of the types of benefits



3.1.4.1. The transactional (GDP) impacts

Introduction to the transactional benefits: GDP impact Assessment

GDP impact assessment is performed to measure transactional impacts which are immediate impacts resulting from engaging a simple transaction. In this study it is the immediate economic impact resulting from public funding into Copernicus by giving money to several stakeholders (private companies, academic entities...etc.) to contribute to certain developments. The impact of this money injected into the economy through Copernicus, is measured by assessing the overall impact on European GDP. Therefore, all in all, the objective of the GDP impact assessment is to assess the impact of spending in the space sector on the European economy, and 3 types of economic impacts are usually evaluated in the GDP IA: Gross Value Added (GVA), Employment and Government Tax Revenues.

However, for the purpose of this study, the team only reports on the GVA and employment impacts due to the availability of the data that can enable this assessment.

The three types of GDP impact can be described as follow:

- **Direct GDP Impact:** The GDP impact of direct spending into the space industry, which typically initiated in upstream manufacturing, is the economic activity stimulated in the space industry itself; it represents the Gross Value Added (GVA) realised in the industrial sector receiving the initial spending.
- **Indirect GDP Impact:** The indirect impact represents the economic activity (i.e., GVA) supported by the spending made in the space industry. To fulfil a contract, space companies need to procure equipment (i.e., electronic equipment, computers, etc.) and/or material (i.e., raw metal, plastic) from non-space industrial sectors. These secondary or “2nd round” impacts would not occur if the upstream space industry operations had not required the support to fulfil their orders.

- **Induced GDP Impact:** The induced impact represents the economic activity (i.e., GVA) supported by those people directly (i.e., jobs supported by space suppliers) or indirectly employed (i.e. jobs supported by non-space suppliers) thanks to the initial injection of spending into the economy. Induced impact illustrates the economic impact of these people when they spend their incomes on goods and services in the wider European economy. This induced spending supports the industries that supply these non-space purchases, and includes housing, retail outlets, companies producing consumer goods and a variety of service industries.

Approach to calculate the GDP impact

The GDP impact assessment is based on previous assessments done on European EO programs. The objective of this section is to re-use the multipliers calculated in previous studies and apply them to the new total spending on Copernicus to obtain the updated GVA and Employment impacts. Two previous studies in particular can be highlighted, one is the impact assessment of the Copernicus done in 2015 that evaluated the GDP impacts of Copernicus, and another is the EOEP impact assessment done in 2019, that computed the GDP impacts of the EOEP programme. While the latter is a more recent study, PwC proposes to use the multipliers from the 2015 study because the spending structure of EOEP is different from that of Copernicus. It has little focus on downstream and strong focus on upstream and innovation. The GDP impact is recalculated by utilizing multipliers that were assessed in 2015.

The multipliers are dependent on sectoral distribution in which the initial investment was spent, and in the country distribution of these sectors and the size of spending in each region. Additionally, it depends on the characteristics of these industries in each region at the point in time that the spending was made (i.e., how much they typically spend on labour, profit and supply chain, and what their supply chain looks like). Therefore, it is not expected that the multiplier stays constant over time however this will be the assumption that the team will adopt because in any case, the multiplier is not expected to change drastically.

The previous PwC studies computing and modelling GDP impacts of spending in the space sector used an approach based on a static macro-economic Input Output Matrix model developed and owned by Cambridge Econometrics – for the modelling of the wider knock-on effects on the European economy and carries out dedicated modelling of the space supply chain in order to provide the model with spending inputs associated to non-space industrial sectors. The Two steps that consisted of the methodology used in older studies are:

- **First step – Modelling of the space activities:** This step takes as input the institutional spending in space, and produces as output the space Gross Value Added (equal to labour plus profit) based on statistical information and models available on the Space sector that PwC has gathered historically, and the spending into a number of non-space industrial sectors that are modelled in the IO matrix “E3ME model”
- **Second step – Feeding the E3ME model with spending:** The spending into non-space industrial sector is fed into the IO model, producing as output the overall GDP impact (total GVA), employment impact and government revenues.

The key to the methodology definition is the approach taken to model the space activities, i.e., the part that is complementary to the IO model.

GVA (Gross Value Added) impact

For this assessment, all values are in current prices.

The Gross Value Added is a measure of the value created in the economy due to the public spending. The main objective of this indicator is to measure the impact that the initial public spending had on creating value in the space sector and in the wider European economy.

When this approach and the E3ME model was utilized, and the GVA and Employment impacts were deduced, multipliers were calculated.

One of these multipliers is the **type 2 return multiplier** and it is calculated according to the following formula:

$$\text{Type 2 RETURN multiplier} = \frac{\text{Direct}_{GVA} + \text{Indirect}_{GVA} + \text{Induced}_{GVA}}{\text{Initial Spending}}$$

and it was found to be 1,4¹²

Therefore, assuming the Multiplier is a constant, and provided that we have the total spending on Copernicus, the team is able to deduct the total GVA.

The total Copernicus spending over 2014 – 2020 period amounted to a total of 4145 M EUR (data received from European Commission), additionally the new MFF 2021 – 2027 committed 5073 M EUR for Copernicus. Therefore, total spending of 2014 – 2027 is expected to be 9218 M EUR (from the European Commission itself, i.e. not accounting to the ESA allocated budget to Copernicus).

$$\begin{aligned} \text{Total GVA} &= \text{Initial Spending (2014 – 2027)} \times \text{Type 2 return multiplier} \\ &= 9218 \text{ M EUR} \times 1,4 \end{aligned}$$

Therefore, according to this approach, the total GVA of Copernicus is expected to be 12.9 B EUR

Furthermore, the team can deduce the expected Direct GVA (i.e. the GVA in the Space sector) from a different type of multiplier which is the type 2 multiplier defined as such:

$$\text{Type 2 multiplier} = \frac{\text{Direct}_{GVA} + \text{Indirect}_{GVA} + \text{Induced}_{GVA}}{\text{Direct}_{GVA}}$$

which was found to be 2.49¹³

Assuming a constant multiplier over time, and having obtained the updated expected total GVA, the new updated expected Direct GVA is assumed to be:

$$\text{Direct}_{GVA} = \frac{12,9}{2,39} = 5,40 \text{ B EUR}$$

Employment

In the previous PwC studies, the employment estimations carried out in the modelling of the first stages of the space supply chain were based on assumptions on FTE/revenues ratios for different companies made on the basis of ratios retrieved by primary research and on the basis of statistical data available from Cambridge Econometrics. Beyond these stages, the employment impact was calculated using the E3ME model, incorporating the additional

¹² PwC, 2016. Study to examine the socioeconomic impact of Copernicus in the EU

¹³ PwC, 2016. Study to examine the socioeconomic impact of Copernicus in the EU

employment further along the supply chain and that stimulated in the wider economy, supported by the increased economic activity reflected in the additional gross value added.

The 2015 study provided the following results:

- The 1.6 B EUR of the 2008 – 2013 spending on Copernicus supported 11750 Person years of employment in the Space sector, and an additional 3830 Person years in the further supply chain.
- 60% of that 1.6 B was Space GVA therefore it can be assumed that 60% of 1.6 B of Space GVA can lead to 11750 Person years. The ratio between Jobs supported in space sector and Space GVA becomes 12 Person Years supported per 1 M EUR of spending.

Another ratio that can be extracted from the 2015 study is the ratio between jobs supported in the non-space sector and those of the space sector, $3830/11750 = 0,32$. This means that each person year supported in the space sector due to initial spending, 0.32 Person years are supported in the non-space sector from the supply chain engaged.

Utilizing the first ratio on the Space GVA expected from the 2014 – 2027 spending would provide a value for **Jobs Supported in the space sector of: $12 \times 5400 = 64\ 800$ person years**. Utilizing the ratio between space and non-space jobs supported would lead to 20736 Person years supported in the non-space sectors.

The total employment impact from the initial spending for 2014 – 2027 is expected to be supporting 85 536 Person Years.

3.1.4.2. The end user benefits (Copernicus D&I exploitation benefits)

Introduction to the end-user benefits

The exploitation benefits are the ones expected to occur once end-users begin exploiting and utilizing the Copernicus Data and Services in downstream applications and VAS. It looks at the societal, economic, and environmental benefits that the utilization of Copernicus could bring to end-users and the EU community and society from different vertical markets and sectors.

The end user benefits assessment of Copernicus builds on research and evaluation from different sources. The analysed impacts are taken from two main studies that were previously performed by PwC: the Copernicus ex-ante impact assessment and the Copernicus environmental footprint assessment. Starting from the results of these two studies, the most relevant impacts were further updated in light of the recent changes and more available data. This section develops on the identification of the impacts, with a high-level description, and the assessment of their value from 2017 to 2035. The value is discounted to the year 2023. Lastly, a summary table that shows all the benefits of Copernicus is presented.

As mentioned before, some impacts have been updated with respect to the ones calculated in 2017 due to multiple reasons.

First of all, since 2017 the world has witnessed many drastic disruptions such as the Covid-19 pandemic and the invasion of Ukraine. As a result, some parameters (impacted by these events) that were used in the calculations, such as the energy price or the hospitalization costs, required updating from previous forecasts. Secondly, it is important to highlight that from 6 years ago to-date the Copernicus infrastructure has grown with the launch of the new satellites Sentinels 5P, 6A and 3B, that increased focus on atmosphere and marine services. Therefore, these impacted applications by the Copernicus growth were also considered for the update. Overall, the benefits chosen for the update were among the most impactful, i.e., the ones with a higher economic value.

It should be noted that this section contains a brief description of the benefits generated by Copernicus. For more information and details, please refer to the original report Copernicus Ex-ante impact assessment.

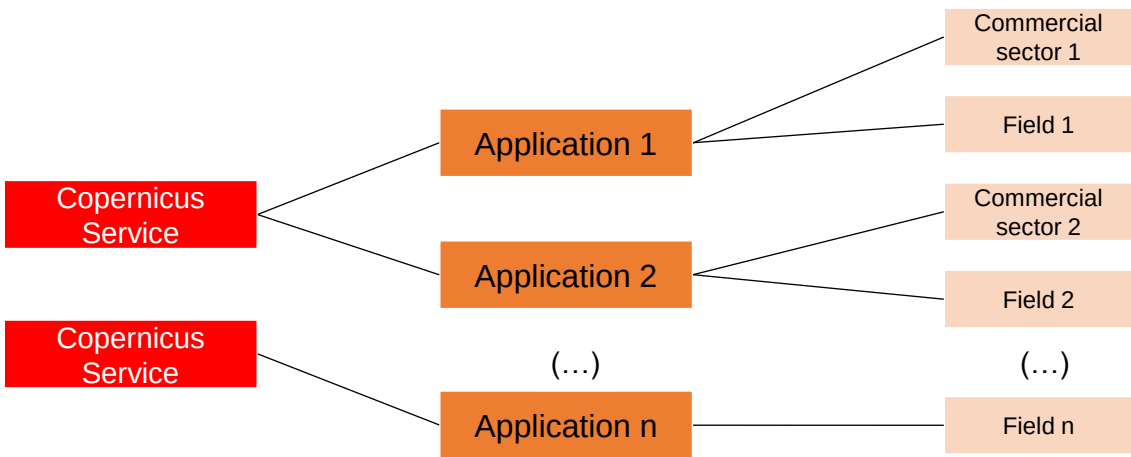
Approach Adopted by previous study for the Copernicus Impact Assessment

This section provides a high-level overview of the approach that was adopted in the Copernicus Ex-Ante impact assessment in 2017 whose results are being used and updated in this current study. The approach from the ex-ante study was divided into 4 phases.

PHASE 1: MAPPING OF APPLICATIONS

This task started from the 6 core services of Copernicus, and then mapped to an exhaustive list of applications enabled by each core service and the different sectors they are used in. To do so, each core service was analysed to identify different sub-services offered, isolating the range of Copernicus products portfolio produced by each of them. Identification of applications is directly linked to the products provided by the six core services and raw data. Targeted stakeholder consultation took place with experts from the different Copernicus core services and entrusted entities to confirm and validate the roadmap of applications enabled by Copernicus data and information. This approach is demonstrated in the figure below:

Figure 20: Mapping of applications process



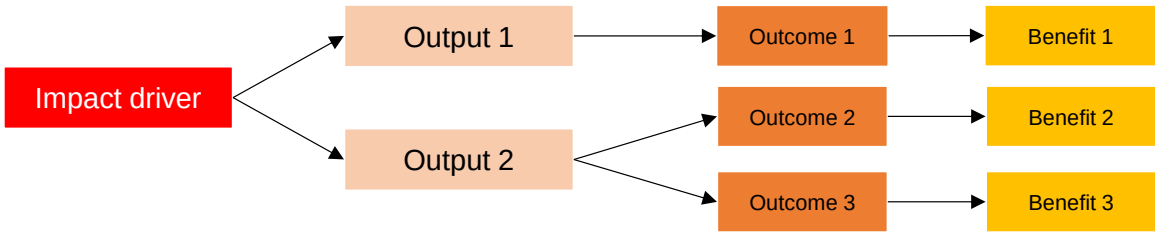
PHASE 2: BUILDING IMPACT PATHWAYS TO IDENTIFY AND SELECT IMPACTS

A dedicated framework was developed to assess the impact of Copernicus D&I on end-users in each thematic sector, using an impact-pathway approach. This started from the applications identified in the first phase, also referred to as impact drivers, and an impact-pathway was developed for each application.

The pathway shows how each of the applications is expected to result in changed outcomes for industry, society, the economy, and the environment. In particular they map the effect of specific events or actions, ‘impact drivers’, through to “outputs” and “outcomes” to specific “impacts”. Further to this the impact pathway then maps these ‘impacts’ through ‘societal outcomes’ to the impact on society called ‘societal value’. Note that these granular impacts are not illustrated in the impact pathway chart of all impacts. An impact pathway is thereby mapping the causal chain for every application with quantitatively assessable impacts considered in this study. The approach also aids thinking about which impacts can be assessed quantitatively and qualitatively. The chart below gives an example of an illustrative impact pathway approach.

An impact pathway is demonstrated in the figure below:

Figure 21: Pathway identification process



PHASE 3: DOWN- SELECTION OF BENEFITS OR IMPACTS

Starting from the list of extensive **potential impacts** that were developed in phases 1 and 2, this list was calibrated and enhanced through stakeholder consultation with experts from the EC and Copernicus core services. As a following step, this list was scrutinized through further research to assess which of the impacts were in fact **more likely to occur**. This was assessed through the actual possibility to conclude that there was some potential causal relationship between the Copernicus Data & Information being available and an outcome. The final stage in deciding which impacts would be in-scope was through applying the filters of **desirability, feasibility, and materiality**.

Desirability was determined on the basis of importance of illustrating certain impacts for the European Commission and the Copernicus core services. Feasibility was determined through research on the basis of data availability and quality of that data to assess the impacts. Materiality was determined through research on the basis of the likely magnitude of the impacts when valued. After the application of the filters the likely impacts were categorized in to three groups: quantitatively assessable impacts (in monetary terms), qualitatively assessable impacts, and impacts to be considered out-of-scope. Decision was then made to **focus only on quantitatively assessable impacts**.

Following this exercise, the list of assessable in scope impacts was identified.

PHASE 4: ASSESSING THE IMPACTS

For each impact in a given domain or sector, heavy desk research was performed with exhaustive consultations with end – users and Copernicus stakeholders to define a specific model to quantify and value the benefit, and to identify the necessary parameters or proxies to evaluate and monetize it.

Important note: the benefit list is non-exhaustive, as it is calculated starting from uses cases developed in 2017 with the collaboration of different stakeholders, including the European Commission. Potentially, nowadays the estimated benefits are higher since more and more impacts have been generated by the industry by exploiting Copernicus free data.

Atmosphere Service

The Atmosphere service is the first family of impacts described in this study, for Copernicus. In particular, there are two impact driver that are relevant. The air quality and pollution monitoring and forecasting, which holds the hugest impact in terms of value, helps fight the environmental risk to health represented by the air pollution. At the same time, it is helpful also for setting, monitoring, and reaching environmental objectives at EU level. The solar energy monitoring and forecasting helps in reducing both the costs of energy and the CO₂ emissions due to a lower reliance on fossil fuels and a better infrastructure management.

Here below is a summary table of the impacts presented in this chapter with their cumulative value in a 2017-2035 timeframe, for the neutral scenario. Details of the pessimistic and optimistic benefits projections are shown later on for each individual impact.

Table 15: summary table of the impacts for the Atmosphere service

Impact driver	Impact	Cumulative value 2017-2035	Update

(Neutral scenario)			
Air quality and pollution monitoring and forecasting	Decreased exposure to air pollution from air pollution alert services	10 406 047€	YES
Air quality and pollution monitoring and forecasting	Increased ability to meet EU air pollution targets	13 158 470 599€	NO
Solar energy monitoring and forecasting	Reduced CO2 emissions due to a decrease in reliance on fossil fuel energy sources	7 329 952€	NO
Solar energy monitoring and forecasting	Reduced costs of energy (infrastructure management)	103 797 048€	NO

Decreased exposure to air pollution from air pollution alert services

This impact has been extracted from the Copernicus ex-ante study (2017) and updated (2023). The value of this impact is calculated on a EU scale.

Air pollution is one of the largest environmental risk to health. Although in Europe air quality has improved significantly in past decades, air pollution concentrations remain high, and a large proportion of Europe's population lives in areas with air pollution above EU limits. Monitoring air quality is key to determine whether areas are meeting pollution targets and to assess the impact of air pollution policies. Through CAMS (Copernicus Atmosphere Monitoring Service), the state of the atmosphere is estimated daily, and forecasts are provided based on models and observations. CAMS uses a wide range of satellite data, ground measurements and models. One of the CAMS products provides air quality forecasts for Europe (resolution of 10km) 4 days in advance and globally (resolution of 40km) 5 days in advance. CAMS provides information at national and regional level which is included in local air quality analysis and forecast models. Whilst local on-ground measurements provide highly localized information of pollution, CAMS data provides regional effects and forecasts which are used to improve the accuracy of air pollution forecasts.

The impacts from air quality and pollution warning systems, such as airTEXT, are valued by calculating the reduced exposure to air pollution in populations living in high pollution areas. CAMS regional air pollution forecast data is used as a key input in the models that provide the airTEXT warnings. Reduced exposure to air results in improved health, which is measured by the health valuations of asthma and chronic obstructive pulmonary disease (COPD) cases and includes saved treatment costs and valuations of quality of life. As the quality of forecasts has been estimated to be improved by 10-20% thanks to Copernicus, it is assumed that Copernicus contributes 15% to the improved health impacts of the airTEXT service.

Figure 22: Methodological approach to decreased air pollution exposure

Methodological approach to decreased air pollution exposure
Our approach is based on studies of air alert services and saved costs from avoided hospitalization from people taking action to reduce their exposure to air pollution. The steps are: 1. Determine the number of people using airTEXT and taking action based on these alerts. 2. Calculate the prevalence of COPD and asthma to find the avoided hospitalizations from reduced exposure to air pollution. 3. Multiply by the contribution of Copernicus in improving air pollution forecasts of airTEXT. 4. Apply the contribution of Copernicus to this reduction.

$$\text{Impact (EUR)} = \text{Avoided hospitalization from COPD and asthma} \times \text{Health values of hospital admissions and COPD cases} \times \text{Contribution of Copernicus to air pollution forecasts}$$

From the report redacted in 2017, some datapoints have changed with respect to the predictions done. For example, the number of people living in polluted areas in EU has diminished, and the same stands for the number of people exposed to CO₂, PM_{2.5}, P₁₀ and O₃. Moreover, a very important parameter in the model that leads to the valorisation of this benefit is the cost of hospitalization. In different areas of the world this cost has changed, particularly with an increasing trend¹⁴.

Table 16: Size of the Copernicus benefits of decreased exposure to air pollution, 3 different scenarios

IMPACT: Decreased exposure to air pollution from air pollution alert services	Pessimistic scenario	Neutral scenario	Optimistic scenario
Cumulative: 2017-2022 (EUR)	317 882€	367 155€	394 576€
Cumulative: 2023-2035 (EUR)	5 549 412€	10 038 892€	14 070 040€
Cumulative: total (EUR)	5 867 295€	10 406 047€	14 464 616€
Updated for this study	YES		

Increased ability to meet EU air pollution targets

This impact has been extracted from the Copernicus ex-ante study (2017) without updating.

The value of this impact is calculated on a EU scale.

CAMS provides air quality forecasts for the EU (resolution of 10km) 4 days in advance. This provides policymakers with information to pre-emptively mitigate or reduce the impacts of severe air pollution episodes a few days in advance, rather than solely relying on real time observations. CAMS allows decision makers to select emission reduction strategies most adapted to each situation, enabling more effective public decision making on reducing air pollution. This can enable policies such as restricting traffic through cities, temporary speed reductions on motorways, changes in airplane schedules or compensating industrial energy users to reduce capacity during periods of high air pollution. CAMS provides policy support for the management of air pollution episodes through its green scenario tool, by forecasting the impact of air pollutant emissions reduction scenarios on air pollutant concentrations. This allows an evaluation of the effectiveness of pollution reduction strategies. Potential reductions in air pollution predominantly benefit health, but also agricultural productivity (as certain pollutants negatively impact the growth of crops) and visibility (air emissions can form smog which affects navigation and enjoyment of recreational sites).

Figure 23: Methodological approach to increased ability to meet EU air pollution targets

Methodological approach to increased ability to meet EU air pollution targets
Our approach is based on the increased ability to meet EU National Emission Ceilings as a result of better air pollution forecasts improving the effectiveness of policy actions.

¹⁴ World Health Organization report

$$\text{Impact (EUR)} = \text{Reduction in air pollution emissions under NECs (national emission ceiling)} \times \text{Valuation of air pollution, impacts in health, agriculture \& visibility} \times \text{Contribution of Copernicus to meeting NECs}$$

In the 2017 study, following consultation with stakeholders, the assumption has been taken that CAMS will contribute between 2.5-5% of the ability to meet the National Emission Ceilings under this legislation in 2017 and 5-10% contribution in 2035. This is due to improved information and data which can assist countries in evaluating and improving their policies to reduce air pollution.

To assess the benefits of Copernicus, the air pollution emissions level under Directive 2016/2284/EU is compared to a baseline. This baseline has been constructed by taking the 2017 level of pollutants NH₃, NO_x, SO_x, PM₁₀, PM_{2.5} and VOC and projecting forward this level based on the decrease in these pollutants since 2000 across the EU-27. The difference between the baseline levels of pollution and those involving policy intervention has been quantified using the PwC valuation methodology on air pollution¹⁵. This methodology values the costs from air pollution in monetary terms, from impacts on human health, agriculture, and visibility.

Table 17: Size of the Copernicus benefits of increased ability to meet EU air pollution targets

IMPACT: Increased ability to meet EU air pollution targets	Pessimistic scenario	Neutral scenario	Optimistic scenario
Cumulative: 2017-2022 (EUR)	2 176 757 203€	3 265 135 805€	4 353 514 406€
Cumulative: 2023-2035 (EUR)	6 599 023 706€	9 893 334 795€	13 158 470 599€
Cumulative: total (EUR)	8 775 780 910€	13 158 470 599€	17 544 627 466€
<i>Updated for this study</i>	<i>NO</i>		

Reduced costs as a result of better solar panels infrastructure management

This impact has been extracted from the Copernicus ex-ante study (2017) without updating.

The value of this impact is calculated for EU28.

The profitability of the solar energy is increasing. There are several reasons for this: the costs of solar infrastructures are slowly decreasing; European and often national directives push forward for a larger share of renewable energy in the energy mix, of which solar, along with wind, is crucial; and environmental awareness of citizens has brought attention upon renewable energy sources as opposed to fossil fuel energy sources. As such, Copernicus can play a part in the increase in profitability through its ability to help improve site selection and farm design. Indeed, the development of new technologies has improved the capacity of solar panels making them able to generate more than before: technological innovations therefore impact the cost to produce energy from solar PV infrastructure. Site location has a particular role to play: in fact, depending on the solar irradiance and potential pollution in a specific area, different types of solar panels should be installed. Copernicus enables the tracking these two factors and enables the solar PV producer to choose to install the solar PV type with the right characteristics depending on its location.

¹⁵ PwC, 2015. Available at: <http://pdf.pwc.co.uk/pwc-environmental-valuation-methodologies.pdf>

Figure 24: Methodological approach to reduced costs as a result of better solar panels infrastructure management

Methodological approach to reduced costs as a result of better solar panels infrastructure management	
Our model is based on the evolution of the Levelized Cost of Energy (LCOE) for solar power electricity and the yearly increase in energy generation. The steps are:	
1.	Determine the volume of new electricity generated every year.
2.	Calculate the LCOE (Levelized Cost of Energy) evolution over the years.
3.	Assess the cost reduction to produce new solar electricity.
4.	Apply the contribution of Copernicus to this cost reduction.

$$\text{Impact (EUR)} = \text{Cost reduction to produce new solar electricity} \times \text{New solar capacity installed} \times \text{Contribution of Copernicus to site location and farm design}$$

The LCOE is the cost to produce electricity taking into account, among others, the initial capital invested in the facility as well as the cost of operations and of maintenance of the infrastructure in the long run. This cost will decrease over the years and part of this reduction is attributed to Copernicus: the cost of supplying a given amount of solar capacity decreases, and, in parallel, the quantity of solar capacity that can be supplied at a given price increases. Demand for new solar farms being neither perfectly elastic nor perfectly inelastic, both price and quantity of solar capacity are therefore evolving. Price reduction in LCOE is not only attributable to Copernicus. However, site location is one of the main elements that leads to this decrease in price: as Copernicus can provide data on solar irradiance and pollution in specific locations, it contributes to the improvement of choice of farm design in specific location. The Copernicus contribution is assumed to range between 0.5% and 1% in 2017, rising to between 2% and 5% in 2020, up to between 5% and 10% by 2030. Below are the results of the impact assessment.

Table 18: Size of Copernicus benefits for reduced costs as a result of better solar panels infrastructure management

IMPACT: Reduced costs as a result of better solar panels infrastructure management	Pessimistic scenario	Neutral scenario	Optimistic scenario
Cumulative: 2017-2022 (EUR)	1 452 978€	2 164 026€	3 490 714€
Cumulative: 2023-2035 (EUR)	3 656 584€	5 165 925€	7 546 708€
Cumulative: total (EUR)	5 109 562€	7 329 952€	11 037 422€
Updated for this study	NO		

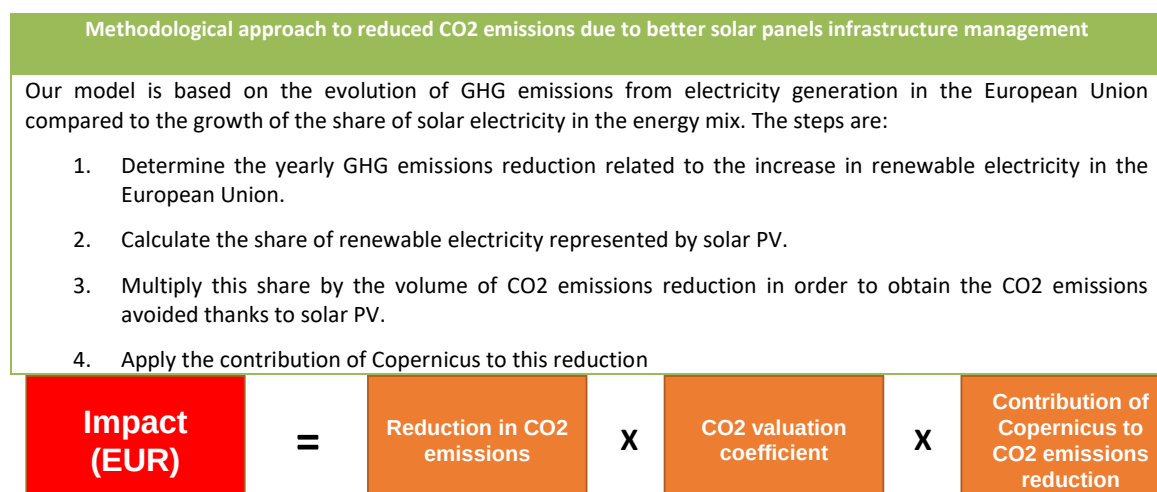
Reduced CO2 emissions due to better solar panels infrastructure management

This impact has been extracted from the Copernicus ex-ante study (2017) without updating.

The value of this impact is calculated on a EU scale.

An increase in supply of solar energy usually displaces other carbon energy sources, leading to a reduction in CO2 emissions. Indeed, better site location and adapted farm design facilitate the increase in solar energy generation and CO2 emissions that would have come from other polluting energy sources are therefore avoided. As such, reduction of CO2 emissions is an indirect benefit of Copernicus.

Figure 25: Methodological approach to reduced CO2 emissions due to better solar panels infrastructure management



The attribution of Copernicus to CO2 emissions reduction is directly linked to the reduction of energy costs. The increase in renewable energy sources generation, and as such of solar energy generation, has for indirect consequence to decrease the reliance on fossil fuel energy sources, thus on CO2 emitting energy sources. Part of this decrease in CO2 emissions is thus enabled by Copernicus. Copernicus contribution is assumed to range between 0.5% and 1% in 2017, rising to between 2% and 5% in 2020, up to between 5% and 10% by 2030. Below are the results of the assessment.

Table 19: Size of Copernicus benefits for reduced CO2 emissions due to a decrease in reliance on fossil fuel energy sources

IMPACT: Reduced CO2 emissions due to a decrease in reliance on fossil fuel energy sources	Pessimistic scenario	Neutral scenario	Optimistic scenario
Cumulative: 2017-2022 (EUR)	23 740 720€	35 412 625€	57 196 419€
Cumulative: 2023-2035 (EUR)	48 392 817€	68 384 422€	99 958 023€
Cumulative: total (EUR)	72 133 538€	103 797 048€	157 154 442€
Updated for this study	NO		

Land Service

The benefits of Copernicus regarding the Land Service are due to the provision of geographical information on land cover, land use, land cover-use changes over the years, and several biophysical variables related to vegetation state or water cycle. The impact driver that are analysed in this section are mainly related to crops monitoring, urban monitoring, the management of forests and water utilization, the monitoring of wetlands, ground elevation and motion, and finally the management of infrastructures for offshore wind, oil and gas.

Here below a summary table of the impacts presented in this chapter with their cumulative value in a 2017-2035 timeframe, considering a neutral scenario (neither optimistic, nor pessimistic). Details of the pessimistic and optimistic benefits projections are shown later on for each individual impact.

Table 20: summary table of the impacts for the Land service

Impact Driver	Impact	Cumulative value 2017-2035	Updated (Y/N)

(Neutral scenario)				
Crops monitoring	Improved food security	9 378 658 108€	NO	
Crops monitoring	Improved profitability and efficiency in agriculture and cost	7 001 770 664€	YES	
Crops monitoring	Reduce the negative impact on environment	3 829 693 349€	NO	
Urban monitoring	Reduced traffic accidents	143 325 191€	NO	
Forestry management and protection	Cost reduction for forest agencies	28 881 114€	NO	
Forestry management and protection	Improve yields in forest industry thanks to sustainable management	725 603 642€	NO	
Forestry management and protection	Improve and restore forest ecosystems and green infrastructures	6 025 361 406€	NO	
Water management resources	Improve profitability in the Hydropower sector	732 296 638€	NO	
Water management resources	Improved productivity through better irrigation management in agriculture	1 774 906 522€	NO	
Water management resources	Reduce groundwater depletion	244 790 650€	NO	
Wetlands monitoring	Improved restoration of wetlands ecosystems	6 017 268 860€	NO	
Ground elevation and ground motion monitoring	Reduced maintenance costs and improved safety thanks to efficient monitoring of subsidence	765 669 206€	NO	
Offshore infrastructure management (offshore wind)	Reduced toxic emissions and avoided waste of water	5 808 143 358€	YES	
Offshore infrastructure management (offshore wind)	Increased revenues due improved offshore wind energy production	2 584 380 132€	YES	

O&G management	infrastructure	Reduced cost and increased revenues for the European Oil and Gas industry	8 546 455 159€	NO

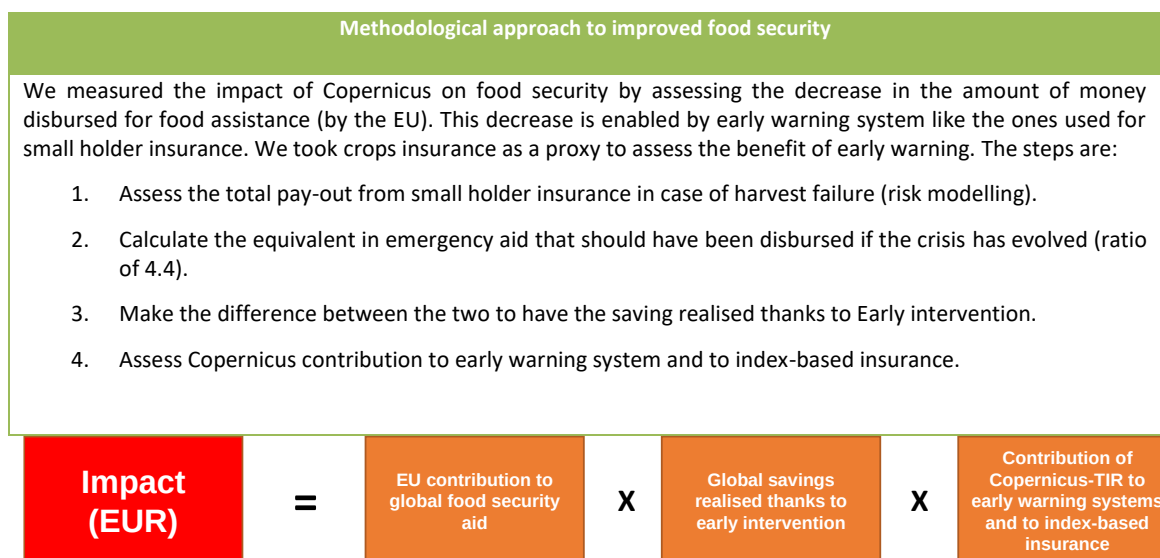
Improved food security

This impact has been extracted from the Copernicus ex-ante study (2017) without updating.

This impact is calculated from a Global perspective.

The main benefit of Copernicus related to food security is Early Warning for situation of crop stress or failure that can lead to humanitarian crisis (hunger). Satellite data provide information like soil moisture, DMP (Dry Matter Productivity), NDVI (Normalized Difference Vegetation Index), WRSI (Water Requirements Satisfaction Index), grassland production (for herders) and rainfall estimation that support early forecasting of drought, floods or extreme weather events leading to harvest failure. The benefits of an early reaction after detecting a harvest failure that may potentially lead to a hunger issue, has been evaluated and is clearly illustrated by crops insurance or climate risk insurance (Weather Index based). Indeed, the development of small holders' insurance against climate risk in vulnerable countries is seen as a powerful tool against hunger, and it is a clear example of the benefit of early warning.

Figure 26: Methodological approach to improved food security



Our model is based on this ratio of USD 1 to USD 4.4 between the money invested in early assistance (through insurance) and the money disbursed in the current pattern of emergency aid. Given this ratio of USD 1 to USD 4.4, we assumed the total crops insurance payout per year (based on an average payout per beneficiary), we multiplied it by 4.4 to have the equivalent in “emergency aid” that should have been disbursed and obtained the savings thanks to early warning. Copernicus contribution to these savings is relatively low in 2017 (around 6%) because Copernicus products and programs dedicated to food security matter (GMFS, SIG Sahel or RIICE project for example), are focused only on certain areas (Sahel, Southeastern Asia). Moreover, weather index-based insurance need historical data to develop their risk model, and Copernicus archives are short for the moment. On the contrary Landsat and MODIS have 35 years of historical data (but less qualitative). However, we can reasonably assume that Copernicus contribution will increase quickly in the coming years, as it perfectly meets the requirements for small holder insurance and other NGOs early warning systems. The major changes assumed to occur between 2017 and 2035 are the contribution of

Copernicus to early warning and index-based insurance (from 6% to 40%), and the number of people covered by a crop's insurance in poor countries (from 100 million in 2017 to 500 million in 2023).

Table 21: Size of Copernicus benefits for improved food security

IMPACT: Improved food security	Pessimistic scenario	Neutral scenario	Optimistic scenario
Cumulative: 2017-2022	591 402 827€	971 626 631€	1 342 720 425€
Cumulative: 2023-2035	5 992 296 686€	8 407 031 477€	1 038 555 268€
Cumulative: total	6 583 699 514€	9 378 658 108€	11 728 273 108€
Updated for this study	NO		

Improved agriculture profitability and cost efficiency

This impact has been extracted from the Copernicus ex-ante study (2017) and updated (2023).

This impact is calculated from a Global perspective.

The main benefit of Copernicus for farmers is linked to the savings enabled by precision farming. Thanks to EO data and information such as NDVI (Normalized Difference Vegetation Index), soil moisture or biomass, it is possible to measure accurately intra-field variability in crops and site specificities. Indeed, crops needs for inputs vary across the time and inside a same field. Based on these accurate measures and on agronomist expertise, applications have been developed to supply intra-field level recommendation maps to farmers, in order to optimize input placement. Therefore, farmers can adapt the rate of inputs to the exact site-specific crops needs. This technique is called Variable Rate Technologies and it requires access to recommendation maps and a variable rate control system with application equipment, in order to put the right input, in the right place, in the right amount by analysing past and in-season field behaviour. Copernicus data are used to develop these recommendation maps (Farmstar for example). Varying the application of inputs - especially nitrogen fertilizer - can reduce the costs, improve the nutritional quality of the crops and maximize productivity. It also reduces the impact over-application of nitrogen may have on yields (stem lodging) and on the environment (Nitrogen leaching, GHG...). Therefore, we can say that Copernicus applications for crops monitoring lead to more profitability and cost efficiency in the agriculture sector.

Figure 27: Methodological approach to improved agriculture profitability and cost efficiency

Methodological approach to improved agriculture profitability and cost efficiency
Our model is based on the amount of savings per hectare a farmer can achieve using Earth Observation data for precision farming application (variable rate technologies for fertilizer spreading, in this case). The steps are: 1. Assess the surface of crops monitored/exploited with precision farming techniques like VRT (Cereals and Canola represent the vast majority of crops monitored with PF techniques). 2. Assess the gain per hectare enabled by this technology. 3. Assess Copernicus contribution to precision farming, i.e., to what extent intermediate users develop PF applications based on Copernicus data. And multiply the three.

$$\text{Impact (EUR)} = \text{Savings enabled by precision farming on cereals and granola} \times \text{Crop monitoring with precision agriculture} \times \text{Contribution of Copernicus to precision farming}$$

Differently from the forecasts made in 2017, the utilized agricultural area in EU28 has been less than predicted during the years 2017-2022¹⁶. The consequent growth rate is therefore influenced until 2035.

Table 22: Size of Copernicus benefits for improved agriculture profitability and cost efficiency

IMPACT: Improved agriculture profitability and cost efficiency	Pessimistic scenario	Neutral scenario	Optimistic scenario
Cumulative: 2017-2022	862 061 093€	1 179 353 866€	1 433 002 370€
Cumulative: 2023-2035	3 698 638 481€	5 822 416 798€	8 252 719 029€
Cumulative: total	4 560 699 575€	7 001 770 664€	9 685 721 399€
Updated for this study	YES		

Reduce the negative impact on environment

This impact has been extracted from the Copernicus ex-ante study (2017) without updating.

This impact is calculated from a Global perspective.

Thanks to precision farming enabled by Copernicus, farmers are using less fertilizers for their crops without reducing their yield. There is a broad recognition that above-optimal applications of fertilizer nutrients lead to an enhanced risk of pollution. Fertilizers contain mainly Nitrogen (N) which is responsible for:

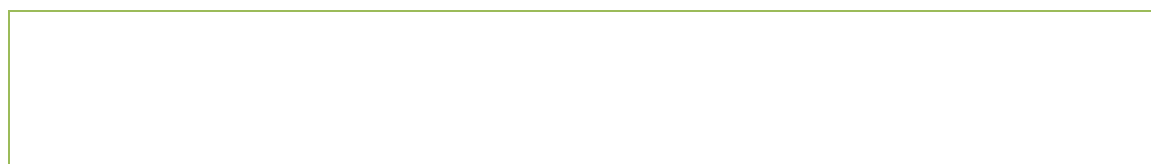
- Nitrogen leaching leading to underground water pollution.
- Chemical reaction with air components leading to GHG emission (N₂O), and air pollution with NO_x and NH₃.

This environmental benefit can be evaluated, knowing the extent of the decrease in pollution due to precision farming. The valuation of this impact is based on a valuation coefficient assessing the avoided cost associated with this pollution (human health cost).

Figure 28: Methodological approach to reduce the negative impact on environment

Methodological approach to reduce the negative impact on environment
Our model is based on the volume of Surplus Nitrogen that can be saved thanks to Earth Observation data for precision farming application (variable rate technologies for fertilizer spreading, in this case). The steps are: 1. Assess the volume of nitrogen used on crops monitored by PF/satellite data-based tools (kg per Ha). 2. Assess the percentage of surplus Nitrogen (i.e., not absorbed by the crops) that can be saved thanks to VRT. 3. Assess Copernicus contribution to precision farming, i.e., to what extent intermediate users develop PF applications based on Copernicus data. And multiply the three. 4. Multiply by the costs avoided associated with this pollution.

¹⁶ Land use overview, Eurostat



$$\text{Impact (EUR)} = \text{Cost of pollution from N}_2\text{O, NO}_x, \text{NH}_3 \text{ and N-leaching in water} \times \text{Volume of surplus Nitrogen saved thanks to precision farming} \times \text{Contribution of Copernicus to precision farming}$$

This environmental benefit can be evaluated, knowing the extent of the decrease in pollution due to precision farming. The valuation of this impact is based on a valuation coefficient assessing the avoided cost associated with this pollution (human health cost).

Table 23: Reduce the negative impact on environment

IMPACT: Reduce the negative impact on environment	Pessimistic scenario	Neutral scenario	Optimistic scenario
Cumulative: 2017-2022	496 043 817€	593 932 019€	793 372 612€
Cumulative: 2023-2035	2 471 791 171€	3 235 761 329€	4 836 186 449€
Cumulative: total	2 967 834 989€	3 829 693 349€	5 629 559 062€
Updated for this study	NO		

Reduced traffic accidents

This impact has been extracted from the Copernicus ex-ante study (2017) without updating.

The value of this impact is calculated on a EU scale.

Spatial imagery provided by Sentinel-2A, 2B and HR and VHR spatial imagery delivered by contributing missions belonging to Mission Group 2 can support better decision making in designing and maintaining sustainable urban transportation. The quantification approach developed to measure the benefits brought by the Copernicus to the reduction of traffic accidents is primarily based on the annual evolution of the number of road fatalities causing fatalities and serious injuries to EU citizens. As it is practically impossible to precisely estimate the yearly number of fatalities caused by road accidents until 2035, the compound annual growth rate of the number of people killed by road accidents in Europe since 1991 was calculated and applied to the forecasted period (2017 – 2035), the same compound annual growth rate was applied to forecast the evolution of the number of serious injuries caused by traffic accidents. The impact of Copernicus was then measured on the difference between two consecutive years of the number of fatalities. It is assumed that Copernicus plays a role in supporting the decision-making process leading to different measures preventing road fatalities. Finally, the number of fatalities and serious injuries avoided thanks to Copernicus was converted into an economic value by using the statistical value of life (economic impact of an avoided fatality).

Figure 29: Methodological approach to reduced traffic accidents

Methodological approach to reduced traffic accidents
Our model based on the economic impact of the number of serious injuries and fatalities caused by road incidents in urban areas. The steps are:
1. Assessment of the yearly evolution of the number of road accidents fatalities avoided in urban areas.

2. Application of the average value of life for EU citizens to the results obtained from step 1
3. Assessment of the yearly evolution of the number of serious injuries road accidents avoided in urban areas.
4. Application of the average cost for major incident for EU citizens to the results obtained from step 3.
5. Assessment and application of the contribution of Copernicus to the aggregation of the results obtained in steps 2 and 4.

$$\text{Impact (EUR)} = \text{Copernicus contribution to the improvement of road security} \times \left(\text{Number of road accidents fatalities avoided in urban area} \times \text{Average economic impact of EU fatality} + \text{Number of serious injuries road accidents avoided in urban area} \times \text{Average economic impact of EU fatality} \right)$$

As no quantitative data was found to establish the precise contribution of Copernicus on the reduction of fatalities caused by traffic accidents, the contribution was measured through the qualitative analysis of the value of Earth observation data among other elements enabling traffic accidents prevention. Literature review has indicated that the main factor triggering a reduction of traffic accidents is user's road behaviour, and that Copernicus plays a minor yet unneglectable role in informing road administration and policy makers in establishing sanctions preventing abusive and irresponsible road behaviour.

Table 24: Size of Copernicus impact for Reduced traffic accidents

IMPACT: Reduced traffic accidents	Pessimistic scenario	Neutral scenario	Optimistic scenario
Cumulative: 2017-2022	24 148 994€	52 508 831€	85 615 547€
Cumulative: 2023-2035	34 863 094€	90 816 360€	176 478 270€
Cumulative: total	59 012 089€	143 325 191€	262 093 817€
Updated for this study	NO		

Cost reduction for forest agencies

This impact has been extracted from the Copernicus ex-ante study (2017) without updating.

The value of this impact is calculated on a EU scale.

Due to the fact that in Europe 60% of forests are privately owned, EO data is mostly used by national forest agencies to monitor the compliance of the forest owners to the law. Indeed, rules have been implemented to prevent private owners of forest from depleting this national asset. For example, in Sweden (similar in France), when a forest owner wishes to fell an area of forest over 0.3 ha in size, he or she is obliged to notify the Sweden Forest Agency (SFA) of his intention to do so. Afterwards the owner has 3 years to replant the trees, and within 10 years of re-planting, a first thinning ought to take place ("pre-commercial thinning"). Without satellite imagery the SFA has no means to know directly whether the forest area has been cleared or not according to the notification and, when it has been, whether the area has been replanted or not. EO data is clearly the optimal tool to develop clear-cut map which will enable the authorities to enforce the rules in forestry sector. Forest agencies in other European countries face the same issues in monitoring clear cut area. Like SFA, they used to use commercial satellite imagery to prepare their clear-cut map. The cost of purchasing these satellite images has significantly fallen as commercial data are gradually replaced by Sentinel 2 data which are free of charge.

Figure 30: Methodological approach to cost reduction for forest agencies

Methodological approach to cost reduction for forest agencies	
Our model is based on the cost reduction resulting from the fact that Copernicus data are free of charge, whereas authorities used to pay for commercial data. The steps are:	
1.	Calculate the cost to cover EU28 forest area with commercial satellite images.
2.	Assess the percentage of commercial data replaced by Copernicus data (progressive increase).
3.	Multiply the two.

$$\text{Impact (EUR)} = \text{Percentage of commercial data replaced by Copernicus data} \times \text{Cost of purchasing commercial satellite imagery to cover European forests}$$

The cost of commercial EO data to cover 1ha of forest was given by the EARSC case study (0,016 euros). We assumed Copernicus data will gradually replace the commercial data as they meet the requirements for clear cut maps development (resolution, re-visit time, spectral band) and they are free. Major evolution occurring in this model is the percentage of Copernicus data used to prepare the clear-cut map: from 15% in 2016 to 75% in 2035 (VHR will still be needed in some case).

Table 25: Size of Copernicus benefits for cost reduction for forest agencies

IMPACT: Cost reduction for forest agencies	Pessimistic scenario	Neutral scenario	Optimistic scenario
Cumulative: 2017-2022	7 648 747€	9 133 699€	10 618 651€
Cumulative: 2023-2035	17 029 701€	19 747 414€	22 465 127€
Cumulative: total	24 678 449€	28 881 114€	33 083 779€
Updated for this study	NO		

Improve yields in forest industry thanks to sustainable management

This impact has been extracted from the Copernicus ex-ante study (2017) without updating.

The value of this impact is calculated on a EU scale.

Copernicus helps monitor the compliance to good practices in forestry. Sustainable management of forest requires certain activities like replanting within 3 years after the clear-cut and one (or even two) pre-commercial thinning within the 10 years after replanting. These are costly investments for private owners if they only looked at short-term optimization of returns. However, on the long term (approximately 80 years) the profitability of the forest is improved as this sound asset management results in more wood for the final clear-cut (80 years old wood is more expensive). Therefore, we can say that Copernicus leads to improved yields in the forest sector, by monitoring forest owners' compliance to sustainable practices.

Figure 31: Methodological approach to improve yields in forest industry thanks to sustainable management

Methodological approach to improve yields in forest industry thanks to sustainable management

Our model relies on the progress made in forest management thanks to Copernicus. Clear-cut areas not replanted or not notified, are spotted with EO and authorities can remind the owners to manage their assets better. The steps are:

1. Assess the percentage of clear-cut areas spotted as uncompliant regarding sustainable management (not replanted, no pre-commercial thinning).
2. Derive from it the clear-cut areas being managed better thanks to authorities' reminder.
3. Multiply by the additional yield resulting from sustainable forest management practices.
4. Multiply by the Copernicus contribution to this benefit i.e., the percentage of Copernicus data used to develop reliable clear-cut maps.

$$\text{Impact (EUR)} = \text{Percentage of commercial data replaced by Copernicus data} \times \text{Additional yield per Ha of forest} \times \text{Clear cut area being managed better thanks to satellite monitoring}$$

According to the EARSC case study on forest management in Sweden, EO imagery revealed that nearly 10% of the clear-cut areas were not cut in accordance with the notifications i.e., the boundaries of the cut area were not as they were supposed to be according to the notification or, there was no notification at all for this cut area. Access to this information has allowed for a diametrical change in forest management by the SFA (Swedish Forest Agency). Indeed, breaking the rules does no longer make sense for private owners: the SFA will notice. Moreover, the SFA can now monitor the owners' compliance with replanting and thinning obligations, leading eventually to improved yields for the forest sector. We took the information of this Case study in Sweden, as a proxy for 40% of the forest in the EU. It was considered, after consultation with experts, that forests similar to the Swedish one represents 40% of the whole European forests. Therefore, we can extrapolate the case study to 40% of European Forests. The impact results are shown below.

Table 26: Size of Copernicus benefits for improve yields in forest industry thanks to sustainable management

IMPACT: Improve yields in forest industry thanks to sustainable management	Pessimistic scenario	Neutral scenario	Optimistic scenario
Cumulative: 2017-2022	120 698 334€	142 852 938€	165 007 543€
Cumulative: 2023-2035	502 732 781€	582 750 703€	662 768 625€
Cumulative: total	623 431 115€	725 603 642€	827 776 169€
Updated for this study	NO		

Improve and restore forest ecosystems and green infrastructures

This impact has been extracted from the Copernicus ex-ante study (2017) without updating.

The value of this impact is calculated on a EU scale.

Forests and other wooded land within the EU covered 176 million ha which represents around 42% of EU land area (2017). They are hosting a significant proportion of the EU's rich biodiversity, and they provide very important benefits to society and the economy via the provision of ecosystem services (soils erosion protection, watershed regulation, climate regulation, carbon storage and water/air purification). Hence preserving forest ecosystems and green infrastructure is crucial for our well-being. Copernicus Land Monitoring Services provide a common framework for a frequently updated monitoring system of environmental change at EU scale. In 1992, in response to the alarming status of biodiversity in Europe, EU governments unanimously adopted the Habitats Directive. Its purpose was to safeguard the

most threatened species and habitats across the EU and one of the main components of this directive was the development of a vast network of protected areas: the Natura 2000 project. Copernicus products portfolio is clearly relevant and useful to monitor the Natura 2000 network and to meet the requirements of the Habitats Directive Article 17. Article 17 requires a report to be sent to the European Commission every 6 years assessing the conservation status of the habitats and species targeted by the directive. The following Copernicus products can clearly contribute to this assessment: High Resolution Layers (HRL) Forest Type/Density, HRL natural and semi-natural grasslands, HRL imperviousness and other HRL (wetlands, permanent water bodies); Urban atlas; Riparian Zones; Natura 2000 specific grassland types only. By combining these products information, one could establish a high-resolution land cover map to populate Natura 2000 areas and their surroundings. Hence Copernicus products are mainly suitable to refine a range of different analyses previously performed at coarser spatial resolution. They enhance assessment of the conservation status by covering more areas, and analysis of pressures in and outside Natura 2000 (urbanization, agricultural intensification) by detecting change earlier.

Figure 32: Methodological approach to improve and restore forest ecosystems and green infrastructures

Methodological approach to improve and restore forest ecosystems and green infrastructures

Our model is based on Copernicus contribution to the implementation of the Habitats Directive through the monitoring of Natura 2000 areas. Thanks to these initiatives forests in favourable conservation status are restored every year. The steps are:

1. Assess the additional forest area restored each year thanks to Nature 2000 i.e., the surface of forest which goes from “unfavourable” to “favourable” status.
2. Multiply it by the valuation coefficient of 1ha of forest in good health. It corresponds to the economic value of lost ecosystem services associated with the conversion and/or degradation of forest areas (erosion control, water filtration...).
3. Assess the contribution of Copernicus to the Habitats Directive: [Natura 2000 areas covered by Copernicus products x effective use of Copernicus by authorities x quality requirements fulfilled by Copernicus].
4. Then multiply the rest by it.

Impact
(EUR)

=

Copernicus contribution to the Habitats Directive and Natura 2000 network

X

Restored forest area in favorable conservation status

X

Cost avoided by restoring 1Ha of forest

Approximately 21% of the total forest resource in the EU is in the Natura 2000 network, and forests represent around 50% of the total area in Natura 2000. It has been assessed that in 2015, only 17% of the Forest habitats are in a favourable conservation. We can calculate how much forest area is restored each year thanks to the Habitats Directive and multiplied it by the value of forest ecosystem services (developed by PwC). The major changes assumed to occur between 2016 and 2035 are the percentage of forest in “favourable conservation status” (from 19% in 2016 to 70% in 2035) and the Copernicus contribution to these improvement (from 2% to around 9%) as the coverage of Copernicus products portfolio will extend and more Environment Agencies will use it.

Table 27: Size of Copernicus Benefits for improve and restore forest ecosystems and green infrastructures

IMPACT: Improve and restore forest ecosystems and green infrastructures	Pessimistic scenario	Neutral scenario	Optimistic scenario

Cumulative: 2017-2022	314 124 285€	628 248 570€	942 372 855€
Cumulative: 2023-2035	2 698 556 418€	5 397 112 836€	8 095 669 255€
Cumulative: total	3 012 680 703€	6 025 361 406€	9 038 042 110€
Updated for this study	NO		

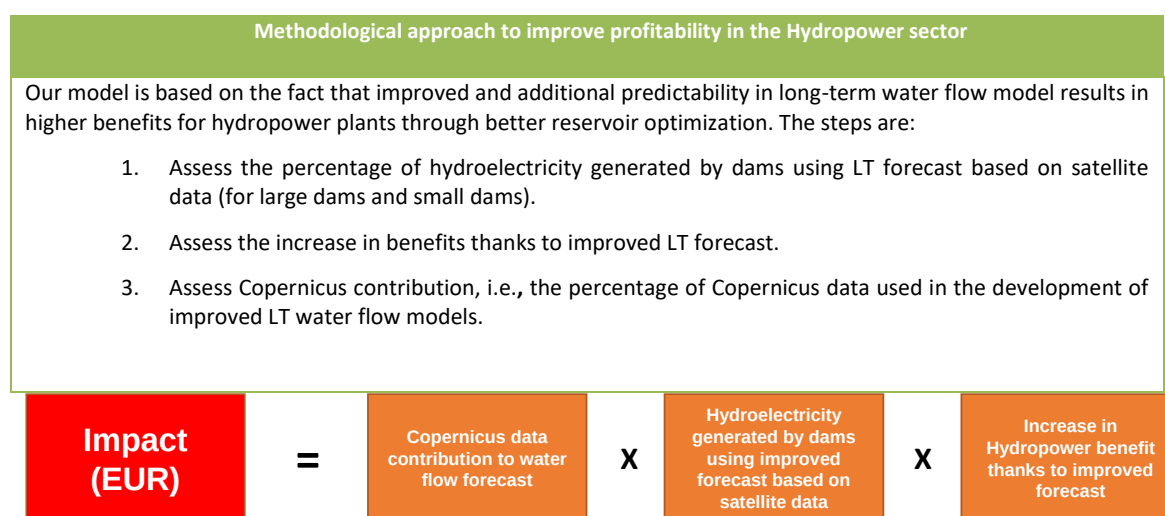
Improve profitability in the Hydropower sector

This impact has been extracted from the Copernicus ex-ante study (2017) without updating.

This impact is calculated from a Global perspective.

Copernicus data support hydroelectric plant management, by providing information on water catchment properties, precipitation and the amount of snow stored during winter. These are extremely useful to energy providers for optimizing hydroelectric power production, regulating dam levels and setting electricity prices. A typical goal of water management is to keep reservoirs as full as possible, while minimizing spill, to maintain maximum hydropower production. Hydropower's operational flexibility and its unique ability to change output allows water managers to respond effectively to forecast data. Therefore, improved, and additional predictability in hydro models, reduces uncertainty in flow volumes and eventually translates into greater hydropower benefits.

Figure 33: Methodological approach to improve profitability in the Hydropower sector



The major changes assumed to occur between 2017 and 2035 are the contribution of Copernicus to hydrologic model for energy sector (from 0.5% to 50%, medium scenario, as special product like SWICCA are designed for that) and the adoption of stream flow model derived from satellite based data by the Hydropower sector (from 10% in 2017 to 60% in 2035, medium scenario).

Table 28: Size of the Copernicus Benefits for improve profitability in the Hydropower sector

IMPACT: Improve profitability in the Hydropower sector	Pessimistic scenario	Neutral scenario	Optimistic scenario
Cumulative: 2017-2022	21 356 075€	40 438 488€	70 337 564€
Cumulative: 2023-2035	438 496 811€	691 858 149€	1 125 191 522€
Cumulative: total	459 852 886€	732 296 638€	1 195 529 087€

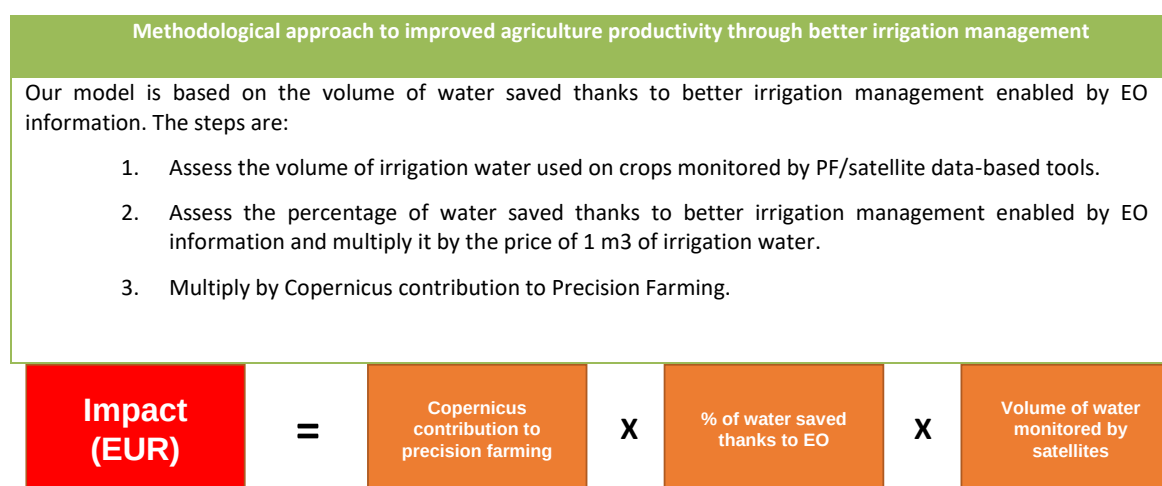
Improved agriculture productivity through better irrigation management

This impact has been extracted from the Copernicus ex-ante study (2017) without updating.

The value of this impact is calculated on a EU scale.

The largest use of freshwater resources is for agriculture irrigation. It accounts for, on average, 70% of all water withdrawal globally. EO technology is widely used for precision farming. For example, with recommendation map for fertilizer dosage inside a same field, optimized water inputs can be deducted from EO data. Having access to this information, farmers can reduce the overall level of irrigation, while maintaining the same yield. Therefore, we can say that Copernicus leads to improve productivity in the agriculture by enabling a better irrigation management through precision farming techniques.

Figure 34: Methodological approach to improved agriculture productivity through better irrigation management



We assume that crops surface monitored with satellite-based tool is approximately 25%. Knowing the volume of irrigation water for 1ha we can derive the total volume of irrigation water monitored with satellite-based systems, 10% of this volume is saved thanks to EO services. Given the cost of 1 cubic meter of irrigation water, we calculate the money saved. Then we multiply the total savings by Copernicus contribution to Precision Farming.

Table 29: Size of Copernicus benefits for improved agriculture productivity through better irrigation management

IMPACT: Improved agriculture productivity through better irrigation management	Pessimistic scenario	Neutral scenario	Optimistic scenario
Cumulative: 2017-2022	321 235 387€	383 374 426€	509 441 995€
Cumulative: 2023-2035	1 098 923 802€	1 391 532 096€	2 002 035 952€
Cumulative: total	1 420 159 190€	1 774 906 522€	2 511 477 948€
Updated for this study	NO		

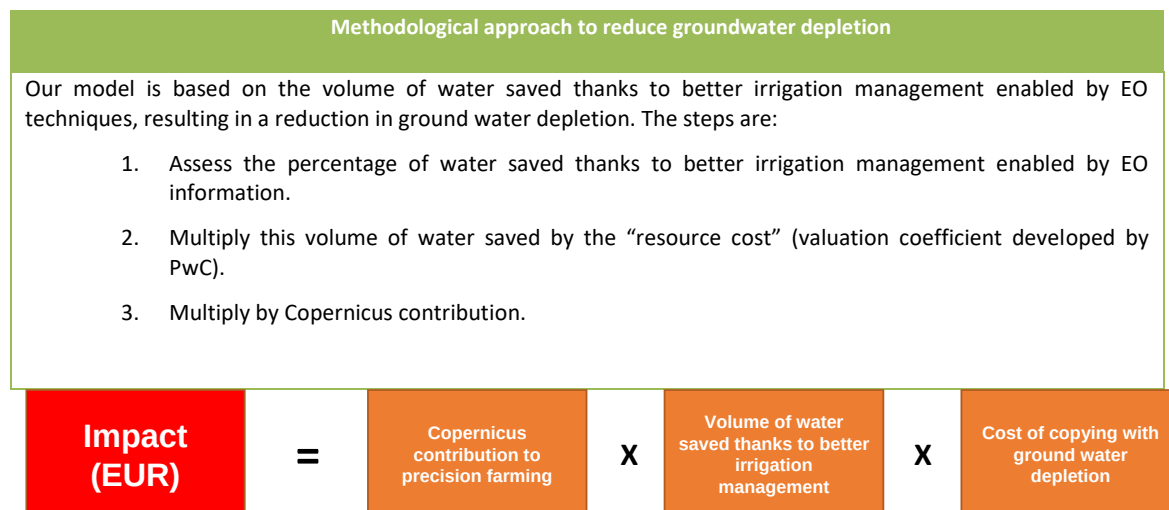
Reduce groundwater depletion

This impact has been extracted from the Copernicus ex-ante study (2017) without updating.

The value of this impact is calculated on a EU scale.

Using less water for irrigation reduce the need for pumping underground water. Hence underground water depletion is reduced, and environmental resources are saved for other services (industry, citizen health...). Therefore, we can say that Copernicus leads to environmental benefit by saving water resources thanks to EO information.

Figure 35: Methodological approach to reduce groundwater depletion



Given the volume of water saved thanks to satellite-based data, we multiply it by a valuation coefficient (€/m³, developed by PwC) to obtain the "resource cost" i.e., the average cost of coping with groundwater depletion. These costs have been avoided (saved) thanks to satellite-based resource management.

Table 30: Size of Copernicus benefits for reduce groundwater depletion

IMPACT: Reduce groundwater depletion	Pessimistic scenario	Neutral scenario	Optimistic scenario
Cumulative: 2017-2022	43 841 339€	52 308 890€	69 491 523€
Cumulative: 2023-2035	152 007 122€	192 481 760€	276 928 869€
Cumulative: total	195 848 461€	244 790 650€	346 420 392€
Updated for this study	NO		

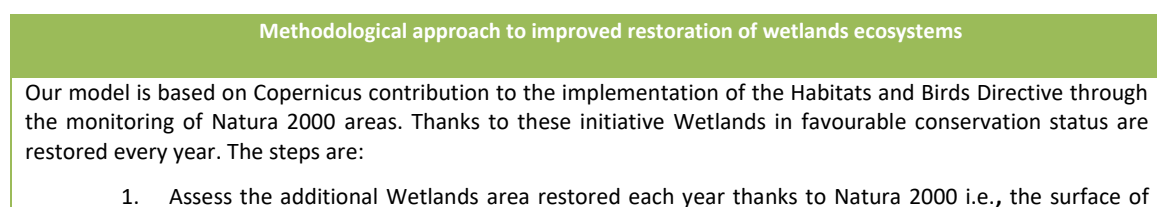
Improved restoration of wetlands ecosystems

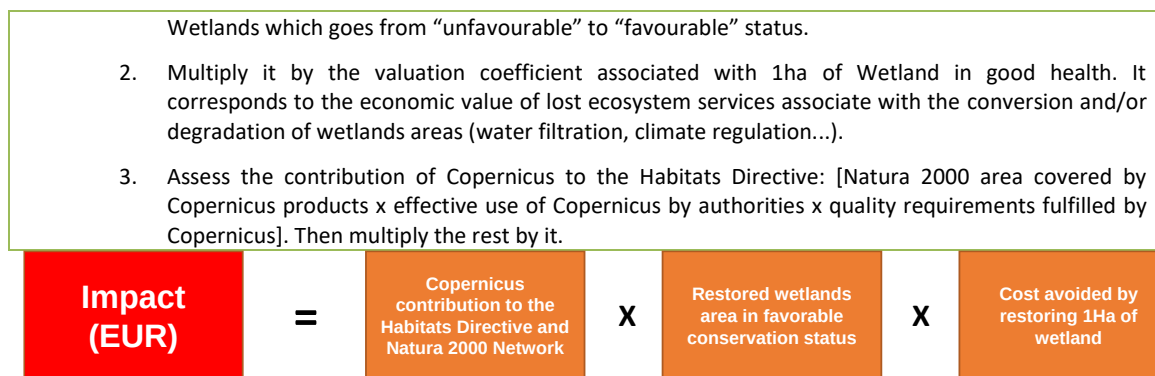
This impact has been extracted from the Copernicus ex-ante study (2017) without updating.

The value of this impact is calculated on a EU scale.

Copernicus leads to improve restoration of wetlands ecosystems, by supporting Natura 2000 network and Habitats & Birds Directives implementation. Most of all Copernicus provide a valuable tool for the assessment of the ecosystem's status required by the Article 17 directive.

Figure 36: Methodological approach to improved restoration of wetlands ecosystems





Wetlands represent approximately 2% of the EU territory. We can assume reasonably that, given their high ecological value and their fragile status, all of the wetland’s area in the EU are protected by the Habitats directive. It has been assessed that in 2011, only 10% of the Wetlands habitats are in a favourable conservation status. We assumed that in 2020, the EU Biodiversity Strategy will achieve (approximately) its target by reaching 35% of favourable assessment within the wetlands. The improvements will continue at the same path. We can then calculate how much wetland area is restored each year thanks to the Habitats Directive and multiplied it by the value of wetland ecosystem services (developed by PwC).

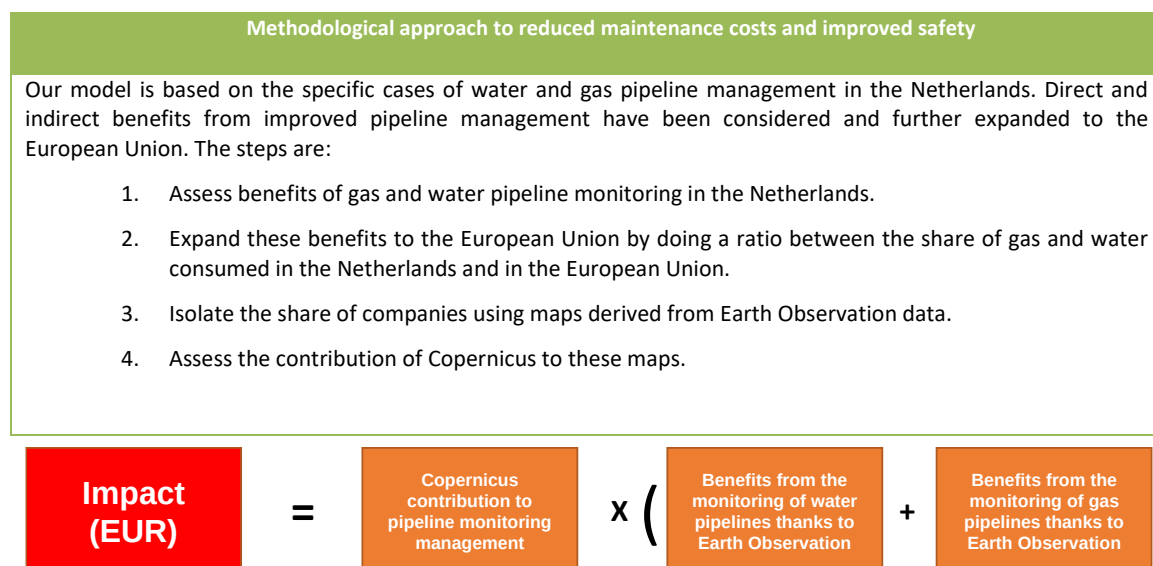
Table 31: Size of Copernicus benefits for improved restoration of wetlands ecosystems

IMPACT: restoration of ecosystems	Improved wetlands	Pessimistic scenario	Neutral scenario	Optimistic scenario
Cumulative: 2017-2022		305 535 473€	509 225 788€	712 916 104€
Cumulative: 2023-2035		3 304 825 843€	5 508 043 072€	7 711 260 300€
Cumulative: total		3 610 361 316€	6 017 268 860€	8 424 176 405€
Updated for this study		NO		

Reduced maintenance costs and improved safety

This impact has been extracted from the Copernicus ex-ante study (2017) without updating. The value of this impact is calculated on a EU scale.

Avoiding pipeline incidents due to ground subsidence is a major stake considering the damages that could be caused by a gas pipeline break for instance. To help support pipeline management, the use of InSAR (Interferometric SAR) maps can be very useful. These maps are based on SAR (Synthetic Aperture Radar) images, such as images provided by Sentinel-1, which enable to detect the changes in height of the surface of the Earth and thus of ground movement. The map works as follows: each scene of satellite images contains points that have coherent reflections; the reflections remain the same in each radar image, no matter the time. As such, it is possible to compare the position of these points throughout time. This technique only works accurately if the images are less than 20 days apart. As such Sentinel-1 data provide a perfect revisit frequency, considering that from a 10-day revisit period, this technique of point comparison is considered optimum. However, Sentinel-1 data cannot be used alone to build such maps. Considering its resolution, 5x20m, it only enables to detect areas considered at risk and then Very High Resolution (VHR) data such as Radarsat-2 or TerraSAR-X, which has a 3x3m resolution are used to get more details on the hot spots. The two are fully complementary: Sentinel-1 gives information at the scale of a street, and VHR data at the scale of a building; Sentinel-1 has a wider coverage than VHR data (e.g., 10km for TerraSAR-X).

Figure 37: Methodological approach to reduced maintenance costs and improved safety

The analysis is based on EARSC case study which looks at the benefits of Copernicus to water and gas pipeline monitoring in the Rotterdam and Gouda area before expanding it to the whole of Netherlands. Several types of benefits are included: the benefits in terms of employment for the companies in charge of processing Copernicus data with other satellite data as well as the companies in charge of analysing these data; the benefits related to the reduction of costs linked to failures and replacements of pipelines; and the benefits for citizens, due to the fact of not being hassled for no reason by the replacement of a pipeline that was in fact working and due to the reduction of odds of major calamities.

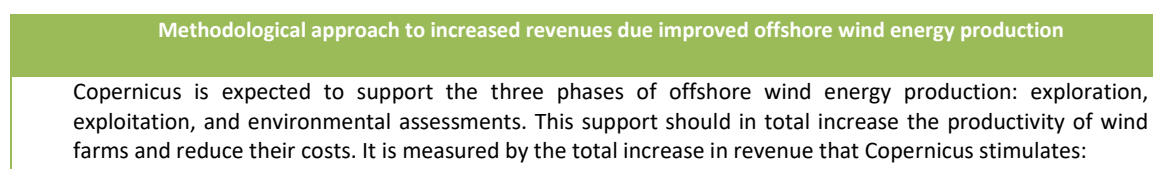
Table 32: Size of Copernicus benefits for reduced maintenance costs and improved safety

IMPACT: Reduced maintenance costs and improved safety	Pessimistic scenario	Neutral scenario	Optimistic scenario
Cumulative: 2017-2022	236 132 456€	259 883 177	283 633 897€
Cumulative: 2023-2035	459 642 458€	505 786 029€	551 929 600€
Cumulative: total	695 774 915€	765 669 206€	835 563 497€
Updated for this study	NO		

Increased revenues due improved offshore wind energy production

This impact has been extracted from the Copernicus ex-ante study (2017) and updated (2023). The value of this impact is calculated on a EU scale.

Thanks to the optimized locations of wind farm sites and the assessments provided by Copernicus, higher production rates from farms can be expected leading to the required productivity of wind energy being achieved at smaller costs. Thus, the revenues of offshore wind renewable energy increase.

Figure 38: Methodological approach to increased revenues due improved offshore wind energy production

1. Projection of expected installed capacity for offshore wind energy up to 2035 according to EU binding targets.
2. Calculation of the revenues coming from these installations.
3. Attribution of the Copernicus contribution to this increased revenue.

$$\text{Impact (EUR)} = \text{Installation of offshore wind energy capacity} \times \text{Attribution of part of this increased generation to Copernicus} \times \text{Reduced toxic emissions and saved water per KWh of wind energy} \times \text{Valuation coefficients of toxic emissions and wasted water}$$

The impact has been updated due to unpredictable events that happened during the last 6 years. For instance, the electricity price¹⁷ (and its growth) forecasted in 2017 is not valid anymore, mainly due to the increase during the invasion of Ukraine. Moreover, the gigawatt of offshore energy production estimated by the EU for the six years are different than the ones which were effectively installed¹⁸; on this side, the goals for 2030 have also changed. For these reasons, we show here below the updated numbers, discounted at year 2023.

Table 33: Size of Copernicus benefits for increased revenues due improved offshore wind energy production

IMPACT: Increased revenues due improved offshore wind energy production	Pessimistic scenario	Neutral scenario	Optimistic scenario
Cumulative: 2017-2022	297 640 464€	671 197 473€	1 594 539 832€
Cumulative: 2023-2035	2 667 479 219€	5 136 945 885€	12 439 213 980€
Cumulative: total	2 965 119 684€	5 808 143 358€	14 033 753 812€
Updated for this study	YES		

Reduced toxic emissions and avoided waste of water

This impact has been extracted from the Copernicus ex-ante study (2017) and updated (2023). The value of this impact is calculated on a EU scale.

When more of the European need for generated power is satisfied by renewable energy sources, less generation from fossil fuels is required. Therefore, to look at the environmental benefits of offshore wind energy, the displaced toxic emissions of a KWh thanks to clean energy generated can be calculated from the difference with what a KWh of fossil fuel energy production emits. The health impacts are by far the largest of these impacts in terms of social cost (impact to society).

Figure 39: Methodological approach to reduced toxic emissions and avoided waste of water

Methodological approach to reduced toxic emissions and avoided waste of water

¹⁷ Ember Climate report

¹⁸ Wind Europe, report 2023

The increased installations in offshore wind energy will lead to a decreased fossil fuel combustion and thus reduced toxic emissions and water consumed after for the cooling of the combustion. The steps to value these environmental benefits are:

1. Project the expected installed capacity for offshore wind energy up to 2035 according to EU binding targets.
2. Calculate the displaced CO₂, NO_x, SO_x, and water gallons from the power provided by these installations.
3. Multiply by the attribution of the Copernicus contribution to the installations.
4. Multiply by the valuation coefficients of the toxic emissions and water waste on public health, morbidity and the environment.

$$\text{Impact (EUR)} = \text{Installation of off-shore wind energy capacity} \times \text{Attribution of part of this increased generation to Copernicus} \times \text{Reduced toxic emissions and saved water per KWh of wind energy} \times \text{Valuation coefficients of toxic emissions and wasted water} \times \text{Coefficient transfer energy capacity to electricity power (TWh)}$$

As the previous, this impact has also been updated because of the unpredictable events happened during the last 6 years mainly involving changes in the electricity price and its growth¹⁹, and the actual production of offshore energy in Europe²⁰, different from the one estimated by the EU in 2017.

Table 34: Size of Copernicus benefits for reduced toxic emissions and avoided waste of water

IMPACT: Reduced toxic emissions and avoided waste of water	Pessimistic scenario	Neutral scenario	Optimistic scenario
Cumulative: 2017-2022	129 307 747€	304 630 987€	721 073 533€
Cumulative: 2023-2035	1 183 866 008€	2 279 749 145€	5 479 604 183€
Cumulative: total	1 313 173 755€	2 584 380 132€	6 200 677 716€
Updated for this study	YES		

Reduced cost and increased revenues for the European Oil and Gas industry

This impact has been extracted from the Copernicus ex-ante study (2017) without updating.

The value of this impact is calculated on a EU scale.

Copernicus D&I enables the O&G industry to save costs for the O&G sector, which makes it cheaper to supply O&G. The use of O&G has a negative impact on the environment, thus cheaper supply of O&G should have negative impact on the environment. Nevertheless, the O&G demand is completely inelastic, meaning that a lower or higher price of oil does not impact its level of consumption. In this context, having a cheaper supply of O&G thanks to Copernicus will not lead to additional negative externalities for the environment.

Figure 40: Methodological approach to reduced cost and increased revenues for the European Oil and Gas industry

¹⁹ Ember Climate report

²⁰ Wind Europe, report 2023

Methodological approach to reduced cost and increased revenues for the European Oil and Gas industry

The assessment is performed on the two key type of companies on this market: the large integrated operators (majors) and oilfield services. The methodological approach is explained step by step:

1. Assessment of European majors and oil field services overall revenues (for majors and oilfield services).
2. Isolation of the split of revenues related to exploration and infrastructure development (for majors only).
3. Assessment of the share of exploration and infrastructure development revenues derived from geospatial data (for majors and oilfield services).
4. Among the revenues attributed to geospatial data, isolation of the split attributed to Copernicus data and information (for majors and oilfield services).
5. Assessment of the overall revenues enabled by Copernicus data and information using the following formula: (for majors and oilfield services).

$$\text{Impact (EUR)} = \text{Overall exploration and infrastructure development revenues} \times \text{Share of revenues derived from geospatial D\&I} \times \text{Share of geospatial D\&I revenues attributed to Copernicus D\&I}$$

The first step aims to assess overall revenues, using Rusted Energy and Bloomberg data bases. Exploration revenues being fully driven by a highly volatile oil price, its evolution over the next 20 years (up to 2035) is impossible. We have decided to assess an average value over the years 2011-2016 for majors and oilfield companies, and to use these values up to 2035. Exploration and upstream exploitation activities were then isolated for majors, using public information available in annual financial statement of companies such as BP, Statoil or Total.

In 2016, this split was ranging between 5% and 8% for majors and 2% and 5% for oilfield services. In both cases, these proportions are respectively expected to reach a maturity of 8–10% (majors) and 6–10% (oilfield services) by 2020, remaining constant up to 2035. This choice was motivated by the fact the use of geospatial data is already quite mature in the O&G industry and it is a complementary tool to drilling activities and infrastructure development. On these splits of revenues based on geospatial data, stakeholders were asked to assess the contribution of Copernicus data and information among revenues attributed to geospatial data. For 2016, the assessment ranges between 4.25% and 6% for majors and 2% and 5% for oilfield services, respectively reaching:

- 6–8% for majors and 6–10% for oilfield services by 2020,
- 8–10% for majors and 10–13% for oilfield services by 2030, remaining constant afterwards.

Revenues over the period 2017-2035 are then obtained by multiplying all these information together for the majors and for the oilfield services companies.

Table 35: Size of Copernicus benefits for reduced cost and increased revenues for the European Oil and Gas industry

IMPACT: Reduced cost and increased revenues for the European Oil and Gas industry	Pessimistic scenario	Neutral scenario	Optimistic scenario
Cumulative: 2017-2022	1 667 281 220€	2 576 434 229€	3 621 606 426€
Cumulative: 2023-2035	4 370 149 810€	5 970 020 931€	7 820 912 221€
Cumulative: total	6 037 431 030€	8 546 455 159€	11 442 518 647€

Climate Change Service

The Climate Change service, or C3S, was introduced in 2018. Its role is extremely important in different fields, such as climate intelligence, indicators, data stores. In particular, the analysed impacts are related to climate modelling and urban monitoring that started already before the formal introduction of the service.

Here below a summary table of the impacts presented in this chapter with their cumulative value in a 2017-2035 timeframe, considering a neutral scenario. Details of the pessimistic and optimistic benefits projections are shown later on for each individual impact.

Table 36: summary table of the impacts for the Climate Change service

Impact driver	Impact	Cumulative value 2017-2035 (Neutral scenario)	Update
Climate modelling	Avoided economic losses from climate related extreme weather events	329 299 650€	YES
Urban monitoring	Reduced fatalities caused by urban heat islands	766 693 703€	YES

Avoided economic losses from climate related extreme weather events

This impact has been extracted from the Copernicus ex-ante study (2017) and updated (2023).

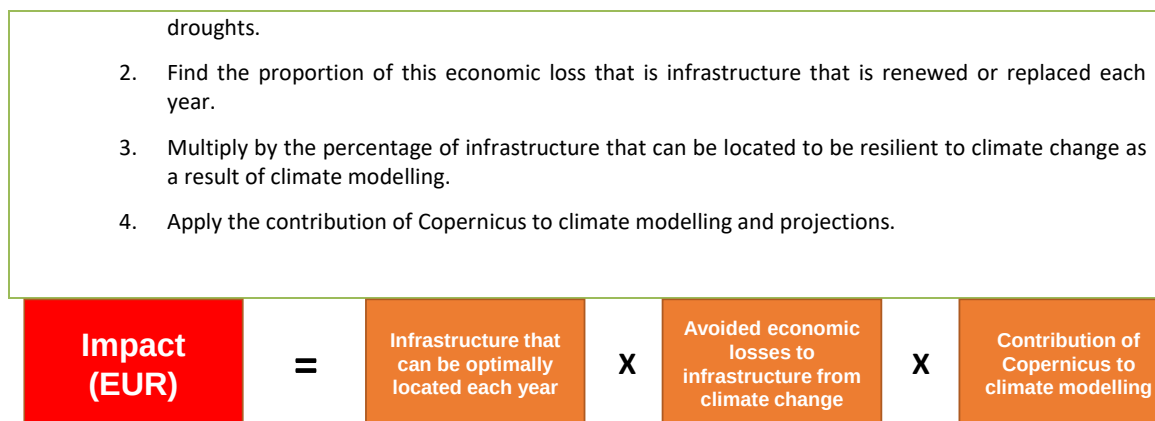
The value of this impact is calculated on a EU scale.

The Copernicus Climate Change Service (C3S) provides comprehensive climate information on key climate variables, such as surface air temperature, sea-ice changes as well as on a variety of other hydro-climatic variables. C3S also conducts global and regional analysis to provide detailed information on historical changes in the climate. C3S climate modelling rely on the climate simulations developed the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). The information is made available for free which national and local decision makers as well as users in different sectors, such as water management, agriculture, energy and infrastructure, can use it to support the EU adaptation and mitigation response to climate change.

The availability and ease of access to quality-controlled climate data through C3S is key to improving the accuracy of climate projections and forecasts. The benefits from improved climate modelling are difficult to assess as it depends on the response taken to projections. In this study, the approach has been taken (based on stakeholder consultations) that more reliable climate projections will improve the effectiveness and efficiency of the adaptation response to climate change, particularly by informing the planning of climate resilient infrastructure. As a result of C3S climate modelling, greater accuracy in climate projections and forecasts is assumed, which policymakers can use to enhance climate change adaptation efforts. In particular, infrastructure can be located more effectively and efficiently in order to be resilient to future climate change.

Figure 41: Methodological approach to avoided economic losses from climate related extreme weather events

Methodological approach to avoided economic losses from climate related extreme weather events
Our approach is based on avoided damages from extreme weather events to infrastructure that can be relocated in a climate resilient location due to better climate projections and forecasts. The steps are: 1. Determine the economic losses to infrastructure from climate change related floods, storms and



The main updated data on this impact regard the economic losses to infrastructure from climate change related events. Indeed, it is possible to find accurate data relative to the period 2017-2021²¹, which were only forecasted in 2017, and recalculate the average annual increase of natural catastrophes losses. Assuming 5-10% of this benefit globally can be attributed to C3S data, due to a larger availability of other climate information and data, due to the larger number of other climate models available, the benefit of Copernicus in terms of avoided economic losses are shown below.

Table 37: Size of Copernicus benefit related to avoided economic losses from climate related extreme weather events

IMPACT: Avoided economic losses from climate related extreme weather events	Pessimistic scenario	Neutral scenario	Optimistic scenario
Cumulative: 2017-2022	6 985 764€	10 478 646€	18 628 705€
Cumulative: 2023-2035	212 547 335€	318 821 003€	564 298 750€
Cumulative: total	219 533 100€	329 299 650€	582 927 457€
<i>Updated for this study</i>	YES		

Reduced fatalities caused by urban heat islands

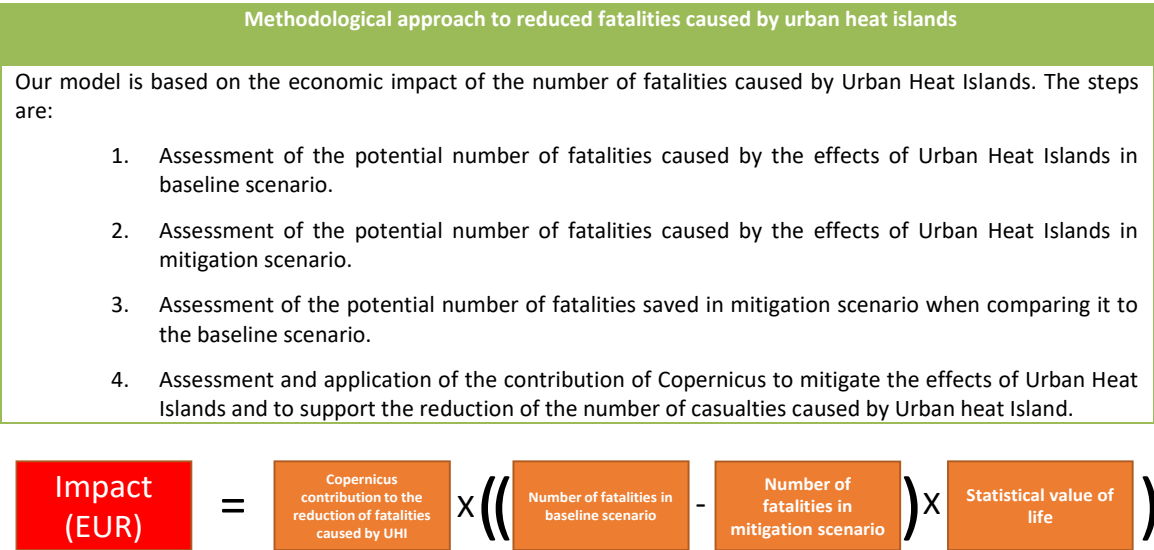
This impact has been extracted from the Copernicus ex-ante study (2017) and updated (2023). The value of this impact is calculated on a EU scale.

Urban Heat Islands occur when air temperatures in urban areas are higher than in surrounding rural areas. Urban Heat Islands are mainly provoked by the density of buildings, the absence of green spaces and the accumulation of anthropogenic heat. Several Copernicus products provide data enabling the analysis of the factors listed above, a better understanding of Urban Heat Islands and therefore ways to design smarter cities which avoid the occurrence of this phenomenon. Copernicus' participation to the reduction of mortality rate caused by Urban Heat Islands can be quantified by comparing the baseline scenario evolution of the number of fatalities caused by extreme heat temperatures with a mitigation scenario which comprises the stabilization of global temperature change at 2 degrees Celsius above pre-industrial levels. The difference in terms of fatalities between the two scenarios is considered and it is assumed that Copernicus is included in the mitigation actions leading to the reduction of fatalities. The

²¹ Sigma Explorer, catastrophes

impact of Copernicus is then measured on the difference between the two scenarios. The number of fatalities avoided by actions supported by Copernicus data is converted into an economic value by using the statistical value of life (economic impact of an avoided fatality) for EU citizens.

Figure 42: Methodological approach to reduced fatalities caused by urban heat islands



The impact has been updated because of some relevant trends. For example, the Covid-19 pandemic has increased the awareness of UHI in many cities, which have taken actions for creating greener and more loveable areas. Moreover, the urbanization’s trend has a steeper increase during the past years, and governments and majors are taking more actions for improving the living conditions of their cities. With a rising global warming, the need of Copernicus service on this side becomes paramount.

Table 38: Size of Copernicus benefits for reduced fatalities caused by urban heat islands

IMPACT: Reduced fatalities caused by urban heat islands	Pessimistic scenario	Neutral scenario	Optimistic scenario
Cumulative: 2017-2022	3 248 948€	7 025 056€	111 64 453€
Cumulative: 2023-2035	322 864 349€	759 668 646€	1 313 970 471€
Cumulative: total	326 113 298€	766 693 703€	1 325 134 924€
Updated for this study	YES		

Marine Service

The Marine service is extremely relevant for the amount of value that it brings in terms of benefits to the end-users. Indeed, the applications are many and the impact drivers vary between coastal area monitoring, water quality monitoring, the management of marine resources, the support to navigation given from ice monitoring, and maritime navigation.

Here below a summary table of the impacts presented in this chapter with their cumulative value in a 2017-2035 timeframe, considering a neutral scenario (neither optimistic, nor pessimistic). Details of the pessimistic and optimistic benefits projections are shown later on for each individual impact.

Table 39: summary table of the impacts for the Marine service

Impact Driver	Impact	Cumulative value 2017-2035 (Neutral scenario)	Updated (Y/N)
Coastal area monitoring	Reduced costs of land planning	1 610 693 065€	YES
Coastal area monitoring	Prevent loss of land	399 744 522€	NO
Coastal area monitoring	Protected coastal population against natural disasters	139 234 252€	YES
Coastal area monitoring	Protection of agriculture	180 429 695€	YES
Marine resources management	Increased productivity associated with reduced search time	476 296 539 €	NO
Water quality monitoring	Reduced plastics in the oceans	17 024 526 €	NO
Water quality monitoring	Increased productivity associated with harmful algal blooms	417 949 €	NO
Water quality monitoring	Reduced illnesses associated with harmful algal blooms	70 631 102 €	NO
Water quality monitoring	Reduced treatment costs associated with jellyfish sting	7 916 080 €	NO
Ice monitoring to support navigation	Reduced costs of navigation	755 154 423 €	NO
Ice monitoring to support navigation	Avoided ecological impact/marine pollution	50 508 261 €	NO
Maritime navigation	Avoided loss of goods	174 511 990 €	YES
Maritime navigation	Fuel savings reached through optimized navigation routes	35 342 800€	NO

Reduced costs of land planning

This impact has been extracted from the Copernicus ex-ante study (2017) without updating.

The value of this impact is calculated on a EU scale.

Early detection of erosion and corrosion is highly important to prevent the phenomenon from growing into an important threat to coastal infrastructures. The average annual public expenditure dedicated to EU coastline protection is worth EUR 5 billion (2017) and is expected to reach EUR 7 billion by 2035. Satellite imagery data is key in understanding the various trends of coastal erosion and accurately forecast its evolution. Therefore, better informed decision making is enabled thanks to Copernicus data, which leads to optimized expenditures dedicated to coastline protection. The quantification approach employed to measure the benefits of Copernicus which enable the reduction of costs for land planning in

coastal zones is built upon the assessment of the average annual public expenditure dedicated to coastline protection in the EU between 2017 and 2035. To this result has been applied the contribution rate of Copernicus to obtain the value the cost reduction of land planning in coastal areas.

Figure 43: Methodological approach to reduced costs of land planning

Methodological approach to reduced costs of land planning

Our model is based on the quantification of savings enabled by Copernicus in the field o coastal land planning. The steps are:

1. Assess the average annual public expenditure dedicated to coastline protection in the EU.
2. Apply the contribution of Copernicus through the different CEMS products enabling better decision making and therefore cost reduction of land planning.
3. Proxy of Cost/Benefit Ratio of coastal public spending.

Impact (EUR)

=

Copernicus contribution enabling savings

X

Annual public expenditure dedicated to EU coastline protection

X

Proxy of Cost/Benefit Ratio of coastal public spending

Copernicus data are not the only inputs that are required to optimize expenditure, as data from other sources, other technologies and human effort are also required. Conservatively has been assumed that Copernicus’s contribution to the expenditure savings starts between 0.51% and 2% in 2016 and grows to reach between 0.61% and 2.43% in 2035.

The impact has been updated in light of the proxy for the cost/benefit ratio for the coastal protection expenditure, ranging from 1.23 to 1.40, following an Irish case expressed by the minister of public expenditure²².

Table 40: Size of Copernicus benefits related to reduced costs of land planning

IMPACT: Reduced costs of land planning	Pessimistic scenario	Neutral scenario	Optimistic scenario
Cumulative: 2017-2022	244 947 141€	517 774 444€	1 115 206 496€
Cumulative: 2023-2035	517 034 578€	1 092 918 620€	2 353 978 566€
Cumulative: total	761 981 719€	1 610 693 065€	3 469 185 062€
Updated for this study	YES		

Prevent loss of land

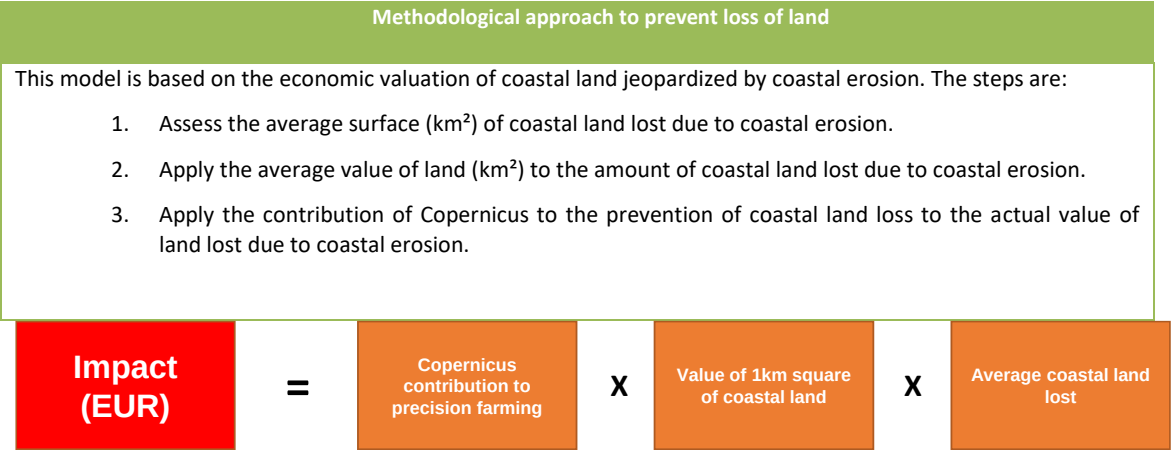
This impact has been extracted from the Copernicus ex-ante study (2017) without updating. The value of this impact is calculated on a EU scale.

Coastal erosion threatens 20% of the entire EU coastline and despite the protection efforts mentioned in the previous paragraph, the phenomenon leads to an average loss of 15km² of land per year. Such yearly loss implies that nearly EUR 900 M worth of EU coastal infrastructures are jeopardized by erosion. By supporting better decision making and planning

²² www.oireachtas.ie

measures for the coastal infrastructure, Copernicus data allows the reduction or at least the containment of coastal loss.

Figure 44: Methodological approach to prevent loss of land



The contribution of Copernicus on the prevention of coastal land loss was assumed to be ranging between 0.5% and 2.5% and reach between 1% and 4.4% in 2035. Such contribution values and evolution are built upon assumptions based on the analysis of several qualitative parameters such as the place of Copernicus data among the value chain of components leading to coastal erosion modelling.

Table 41: Size of Copernicus benefits for prevent loss of land

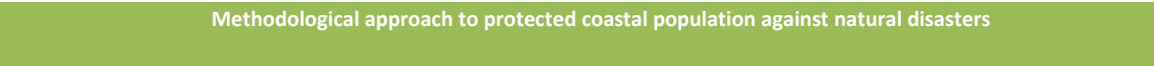
IMPACT: Prevent loss of land	Pessimistic scenario	Neutral scenario	Optimistic scenario
Cumulative: 2017-2022	39 785 766€	119 357 298€	198 928 831€
Cumulative: 2023-2035	93 462 408€	280 387 224€	467 312 040€
Cumulative: total	133 248 174€	399 744 522€	666 240 871€
Updated for this study	NO		

Protected coastal population against natural disasters

*This impact has been extracted from the Copernicus ex-ante study (2017) without updating.
The value of this impact is calculated on a EU scale.*

Coastal areas are considered to be part of the most productive zones in the world and are particularly exposed to environmental hazards and climate changes involving storms and floods. In 2016, it was estimated that one third of the total EU population was living within 50km of EU coasts. Considering the importance and vulnerability of coastal zones, efficient and performant means of protection must be put in place to sustain coastal productivity while preserving coastal ecosystems and their biodiversity. Assuming that 30% of severe storms and floods occur in coastal regions and taking into account that an average amount of 6 casualties befall during both severe storms and flood events, it was estimated that 94 people perished in environmental hazards occurring in EU coastal zones in 2016.

Figure 45: Methodological approach to protected coastal population against natural disasters



This model is based on the economic impact of fatalities caused by natural disasters in coastal zones. The steps are:

1. Assess the average number of fatalities caused by natural disasters in coastal areas.
2. Assess the economic impact of these fatalities.
3. Apply the contribution of Copernicus to the mitigation of fatalities caused by natural disasters in coastal areas.

$$\text{Impact (EUR)} = \text{Copernicus contribution enabling savings} \times \text{Annual public expenditure dedicated to EU coastline protection}$$

Assuming that Copernicus data would have an impact rate of 1.5% in 2016 reaching 2.4% in 2035, the benefit is updated with more recent data on average yearly deaths for floods in EU (139)²³, and the yearly growth is kept from the 2017 study.

Table 42: Size of Copernicus for protected coastal population against natural disasters

IMPACT: Protected coastal population against natural disasters	Pessimistic scenario	Neutral scenario	Optimistic scenario
Cumulative: 2017-2022	16 608 730€	44 289 947€	99 652 382€
Cumulative: 2023-2035	35 604 114€	94 944 305€	213 624 686€
Cumulative: total	52 212 844€	139 234 252€	313 277 069€
Updated for this study	YES		

Protection of agriculture

*This impact has been extracted from the Copernicus ex-ante study (2017) without updating.
The value of this impact is calculated on a EU scale.*

Marine activities and excessive exploitation of natural resources undermine coastal regions and lead to issues such as saltwater intrusion into groundwater sources. Today coastal agriculture is threatened by this issue as groundwater sources provide 41% of the water utilized for irrigation in the EU.

Table 43: Methodological approach to protection of agriculture

Methodological approach to protection of agriculture
This model is based on the economic value of water contaminated by salt intrusion. The steps are: 1. Assess the percentage and amount (m3) of irrigation water coming from groundwater sources jeopardised by salt intrusion. 2. Assess the cost of water utilised for agriculture irrigation (€/m3). 3. Apply the economic value of water utilised for irrigation to the amount of irrigation water coming from groundwater sources and jeopardised by salt intrusion. 4. Apply the contribution of Copernicus to the economic value of water threatened by salt intrusion.

²³ Marine.Copernicus.eu

$$\text{Impact (EUR)} = \text{Copernicus contribution to the mitigation of salty water intrusion} \times \text{M3 of groundwater utilised for irrigation and jeopardised by salt intrusion} \times \text{Cost of water utilised for agriculture irrigation}$$

Because of its indirect impact on seawater intrusion containment, the contribution of Copernicus for the protection of agriculture conducted in coastal area was estimated between 0.75% and 3% in 2016 raising between 1% and 3.5% in 2035.

The study was updated following data about a higher impact of the contribution of Copernicus to cost saving in agriculture, considering a future shortage of freshwater that could rise up the average irrigation price per hectare²⁴.

Table 44: Size of Copernicus benefits for protection of agriculture

IMPACT: Protection of agriculture	Pessimistic scenario	Neutral scenario	Optimistic scenario
Cumulative: 2017-2022	43 365 243€	65 047 865€	86 730 487€
Cumulative: 2023-2035	76 046 150€	115 381 830€	157 342 720€
Cumulative: total	119 411 393€	180 429 695€	244 073 208€
Updated for this study	YES		

Increased productivity associated with reduced search time

This impact has been extracted from the Copernicus ex-ante study (2017) without updating.

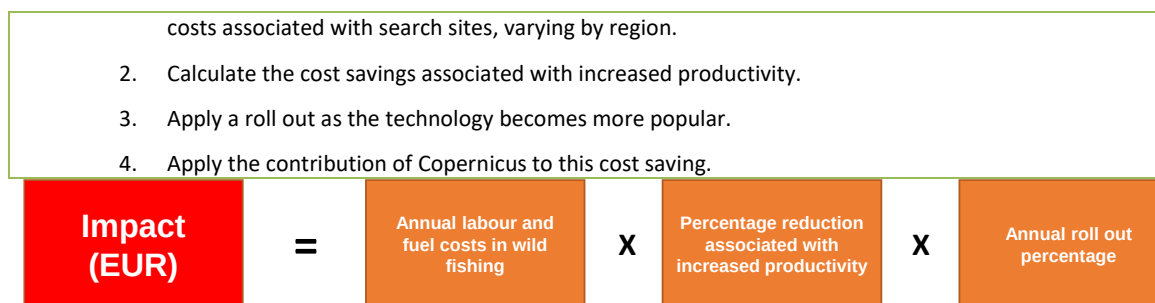
The value of this impact is calculated on a EU scale.

Fisheries and aquaculture directly employed over 56.6 million people globally in 2014, with over 65% employed as fishermen in wild fisheries. The analysis to value this impact is based on productivity improvements in fishing harvests in West Bengal, India. Empirical evidence for this region has shown that satellite derived ocean colour (chlorophyll-a) and sea surface temperature data can be used for prediction of Potential Fishing Zones (PFZ). Due to lack of robust data on the proportion of benefits which could be associated to Copernicus satellites, we have assumed that the proportional contribution of Copernicus should be estimated to be between 6% and 12%. Due to the lack of robust data in the area, we have used the Copernicus EO revenue share for the ocean monitoring section as our baseline assumption on the proportion of benefits to be attributed to Copernicus. However, we expect that as an open data product, the market share may underrepresent this proportion, and there may be advantages of Copernicus products compared to other providers not fully reflected in current market share. We have therefore assumed a 12% contribution of Copernicus as a high scenario.

Figure 46: Methodological approach to increased productivity associated with reduced search time

Methodological approach to increased productivity associated with reduced search time
Our model is based on the calculation of the labour and fuel costs saved should the production associated with 50% of global fishing sites be optimized. The steps are:
1. Determine the labour costs associated with persons directly employed by wild fisheries and fuel

²⁴ Agricultural Water Management Journal



Assuming that 50% of global fishing sites can be located and optimized using satellite derived data, total benefits for EU in terms of saved labour and fuel costs of operations from search site optimization are shown below.

Table 45: Size of Copernicus benefits for increased productivity associated with reduced search time

IMPACT: Increased productivity associated with reduced search time	Pessimistic scenario	Neutral scenario	Optimistic scenario
Cumulative: 2017-2022	66 321 188€	99 481 782€	132 642 377€
Cumulative: 2023-2035	251 209 837€	376 814 756€	502 419 675€
Cumulative: total	317 531 026€	476 296 539€	635 062 053€
<i>Updated for this study</i>	NO		

Reduced plastics in the oceans

This impact has been extracted from the Copernicus ex-ante study (2017) without updating.

This impact is calculated from a Global perspective.

The total natural capital cost to marine ecosystems of plastic littering per year is estimated to be between USD 650 and USD 1,300 per ton. As a result of ocean currents, plastic pollution often converges in accumulation zones known as gyres. Using data on ocean currents and ocean current models, surface plastic pollution can be identified and removal mechanisms more effective. Over two thirds of plastic litter end up on the seabed, with half of the remainder washed up on beaches. The remaining half is floating on or under the surface, according to a report from UNEP. Our analysis focuses on these surface marine plastics, due to limited data in this area. It is estimated that the current global mass of floating plastic is 500,000 tons. However, there is significant uncertainty on the amount of marine surface plastics. We recognize that these estimates may be conservative, particularly our current analysis does not take into consideration any year-on-year increase in global surface plastics. Should there be robust data available, incorporating this growth would further increase the benefits associated with this impact. Major marine plastic pollution removal organizations expect that due to the available technologies, including ocean current models, schemes involving plastic pollution collection barriers can remove plastics at an effectiveness of 4.2% annually. The used models (2017) assume a clean-up start date of 2018, with full implementation in 2020. Therefore, for the purpose of this study, analysis was conducted on the global surface plastics to forecast the total tonnage to be removed and the respective natural capital costs saved. The natural capital cost is an estimate of the damage caused by annual plastic pollution to the marine environment, which we used to derive a value per ton of plastic pollution.

Figure 47: Methodological approach to reduced plastics in the oceans

Methodological approach to reduced plastics in the oceans

Our model is based on the natural capital cost to marine ecosystems of plastic pollution, and the associated reduction in accumulation zones. The steps are:

1. Determine the annual plastic pollution able to be removed with current technologies.
2. Calculate the reduction in plastic pollution using these technologies.
3. Calculate the natural capital cost associated with the removed plastics.
4. Apply the contribution of Copernicus to this cost saving.

Impact (EUR)

=

Tonnes of plastic able to be removed from oceans

X

Natural capital cost per tone of plastic pollution

X

Annual roll out percentage

Due to lack of robust data on the proportion of benefits which could be associated to Copernicus satellites, we have assumed that the proportional contribution of Copernicus should be estimated at 6%.

Table 46: Size of Copernicus benefits for reduced plastics in the oceans

IMPACT: Reduced plastics in the oceans	Pessimistic scenario	Neutral scenario	Optimistic scenario
Cumulative: 2017-2022	3 058 699€	7 378 063€	11 697 426€
Cumulative: 2023-2035	5 380 788€	9 646 463€	13 912 139€
Cumulative: total	8 439 487€	17 024 526€	25 609 566€
Updated for this study	NO		

Increased productivity associated with harmful algal blooms

This impact has been extracted from the Copernicus ex-ante study (2017) without updating. The value of this impact is calculated on a EU scale.

The analysis is done for Portugal, France, Spain, Ireland, and Scotland which account for 25% of the EU’s aquaculture production and 1% of the world’s production by weight. The benefits are then extrapolated to the EU and the world by aquaculture production, with the assumption that the same factors play a similar part in the other countries. However, we recognize and note the limitations of transferability of this study, as a wider data set was not available. For these five countries, a study was conducted showing that access to the harmful algal bloom forecasts gave a direct benefit of 5% productivity increase in the affected farmers, with the aim of a 12.5% productivity increase should the necessary technologies be implemented across the farms, such as oxygenation system. From consultation with experts, it was suggested that Copernicus data provides a 25% increase in quality compared to other available sources. Therefore, we have assumed a proportional contribution of Copernicus to achieving this benefit of 25%. User update was modelled as proportional to the user uptake as demonstrated in the original case study.

Figure 48: Methodological approach to increased productivity associated with harmful algal blooms

Methodological approach to increased productivity associated with harmful algal blooms

Our model is based on the increase in productivity and the value of additional production. The steps are:

1. Determine the tonnage of production in aquaculture.
2. Calculate the value of the additional production associated with increased productivity.
3. Apply a roll out as technology becomes more popular and available.
4. Apply the contribution of Copernicus to this cost saving.

$$\text{Impact (EUR)} = \text{Value of production in aquaculture} \times \text{Percentage increase in productivity} \times \text{Annual roll out percentage}$$

Assuming an EU roll out in 2017, total benefits for EU in terms of increased productivity from algal bloom forecasts are shown below.

Table 47: Size of Copernicus benefits for increased productivity associated with harmful algal blooms

IMPACT: Increased productivity associated with harmful algal blooms	Pessimistic scenario	Neutral scenario	Optimistic scenario
Cumulative: 2017-2022	30 572€	53 502€	76 431€
Cumulative: 2023-2035	208 255€	364 446€	520 638€
Cumulative: total	238 828€	417 949€	597 070€
Updated for this study	NO		

Reduced illnesses associated with harmful algal blooms

This impact has been extracted from the Copernicus ex-ante study (2017) without updating.

The value of this impact is calculated on a EU scale.

The analysis for this impact area is underpinned by studies in the US, where it has been estimated that the annual economic impact of harmful algal blooms on public health is approximately USD 20 million. The studies calculate the economic impact of harmful algal bloom illnesses using both the treatment costs and productivity decrease due to toxic finfish and shellfish consumption. The impact is then extrapolated to the EU and worldwide, to assess the impact by region. As harmful algal bloom related illnesses are transmitted by consumption of seafood, this was a factor in our modelling. In order to correctly scale associated treatment costs and productivity decreases, healthcare and labour costs were also key modelling inputs. We also note that user uptake was modelled as proportional to the user uptake as demonstrated in the study.

Figure 49: Methodological approach to reduced illnesses associated with harmful algal blooms

Methodological approach to reduced illnesses associated with harmful algal blooms
Our model is based on the economic impact of harmful algal blooms, associated with treatment costs and lost time. This was extrapolated from the US by seafood consumption and healthcare costs by country, and the associated fall in illnesses calculated in line with increased testing. The steps are: 1. Determine the economic impact of harmful algal blooms in the US. 2. Scale the economic impact to develop a global economic impact. 3. Calculate the associated reduction in illnesses (and associated impact) as a result to increased testing.

4. Apply a roll out as technology becomes more popular and available.
5. Apply the contribution of Copernicus to this cost saving.

$$\text{Impact (EUR)} = \text{Percentage reduction in illnesses associated with increased testing} \times \text{Total economic impact of harmful algal blooms} \times \text{Annual roll out percentage}$$

Assuming an EU roll out of a forecasting system in 2017, total benefits for EU in terms of saved treatments costs and losses from reduced productivity costs from algal bloom forecasting are shown below.

Table 48: Size of Copernicus benefit for reduced illnesses associated with harmful algal blooms

IMPACT: Reduced illnesses associated with harmful algal blooms	Pessimistic scenario	Neutral scenario	Optimistic scenario
Cumulative: 2017-2022	11 064 802€	12 294 224€	13 523 646€
Cumulative: 2023-2035	52 503 189€	58 336 877€	64 170 565€
Cumulative: total	63 567 991€	70 631 102€	77 694 212€
Updated for this study	NO		

Reduced treatment costs associated with jellyfish sting

This impact has been extracted from the Copernicus ex-ante study (2017) without updating.

The value of this impact is calculated on a EU scale.

Med-JellyRisk, a project assessing the socio-economic impacts of jellyfish blooms and the implementation of mitigation countermeasures, addresses an integrated coastal management approach into 10 Marine Coastal Zones faced with increased jellyfish proliferations. In these areas, jellyfish outbreaks represent a growing threat for humans and coastal activities (including leisure and aquaculture). Using Copernicus data, the Med-JellyRisk project monitors jellyfish risk at beaches and communicates this to beach users through its mobile application. Analysis was conducted on a study of the South Italian Coast, which estimates the costs associated with jellyfish stings to the Italian Health Service. The study estimates a cost of EUR 225 to national health services per instance of medical assistance sought due to a jellyfish sting. To extrapolate the economic impact to the EU, predicted jellyfish stings are modelled to increase the costs proportionately. Furthermore, due to the differing healthcare costs in EU countries, the National Health Service healthcare costs were used to adjust the economic impacts on healthcare by country. Following the scaling of the impacts by predicted jellyfish stings and healthcare costs, the impact of jellyfish stings in the EU can be modelled.

Figure 50: Methodological approach to reduced treatment costs associated with jellyfish sting

Methodological approach to reduced treatment costs associated with jellyfish sting

Our model is based on the economic impact of jellyfish stings, associated with first aid treatment costs. This was extrapolated from the South Italian Coast by coastal tourism visitors and healthcare costs by country, and the associated fall in stings calculated in line with increased awareness. The steps are:

1. Determine the economic impact of jellyfish stings in the South Italian Coast.
2. Scale the economic impact by healthcare costs to develop an EU-wide economic impact.
3. Calculate the associated reduction in stings (and associated impact) as a result of increased awareness.
4. Apply a roll out as technology becomes more popular and available.
5. Apply the contribution of Copernicus to this cost saving.

Impact (EUR)	=	Percentage reduction in sting associated with increased awareness	X	Total economic impact of jellyfish stings	X	Annual roll out percentage

As with other marine benefits, there is a lack of data on the proportion of benefits which could be attributed to Copernicus satellites, however given that the Med-JellyRisk project names Copernicus, we have assumed that the proportional contribution of Copernicus should be estimated at 50%. As a result, assuming an EU-wide roll out in 2020 of the mobile application, total benefits for EU in terms of saved treatments costs from jellyfish monitoring are shown below.

Table 49: Size of Copernicus benefits for reduced treatment costs associated with jellyfish sting

IMPACT: Reduced treatment costs associated with jellyfish sting	Pessimistic scenario	Neutral scenario	Optimistic scenario
Cumulative: 2017-2022	1 510 301€	1 678 113€	1 845 924€
Cumulative: 2023-2035	5 614 170€	6 237 967€	6 861 763€
Cumulative: total	7 124 472€	7 916 080€	8 707 688€
<i>Updated for this study</i>	<i>NO</i>		

Reduced costs of navigation

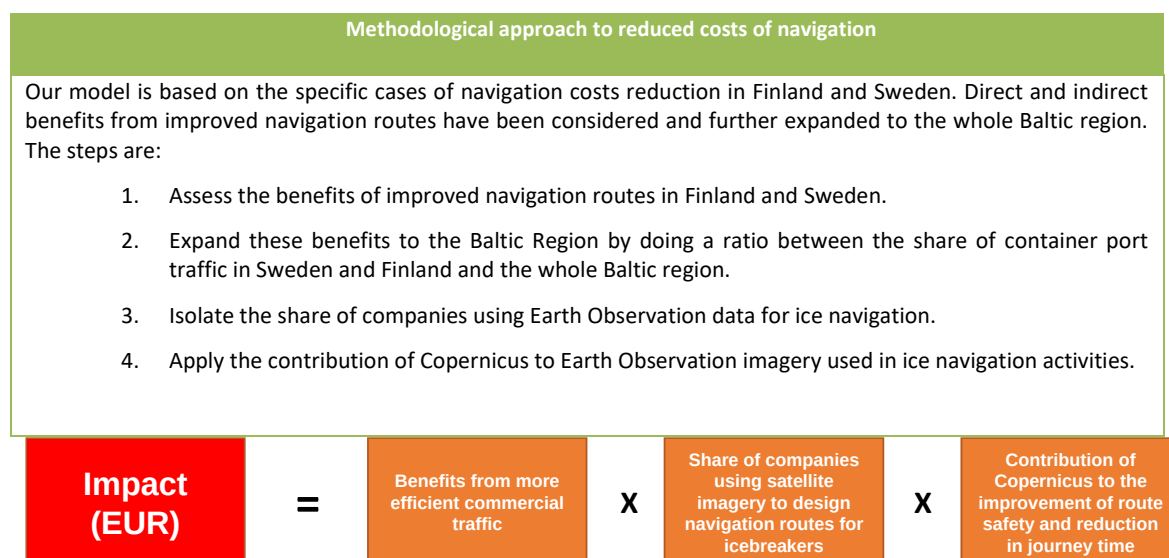
This impact has been extracted from the Copernicus ex-ante study (2017) without updating.

The value of this impact is calculated on a EU scale.

Satellite imagery have been used to improve navigation routes that icebreakers are supposed to make safe. Before the availability of satellite imagery, icebreakers used to rely on helicopters that would provide several pictures of the sea and detect potential ice charts to warn the icebreaker. However, these helicopters had a cost and the reliability was not entirely guaranteed: the helicopters could not fly when the weather was too bad nor at night (whereas Sentinel-1 can provide data under all weather conditions and at night); they provided several pictures that needed to be analysed altogether (instead of a single global map as Sentinel-1 can provide); and the limited speed of helicopters made it possible for weather conditions to change before the icebreakers could be warned and react. Before Sentinel-1, SAR imagery was already used through Envisat or Radarsat-2 to pave the way for icebreakers, though Copernicus provide better data quality than Envisat, whose mission was older and has currently ended. However, satellite imagery is not sufficient in itself and needs to be complemented by on-field expertise of icebreaker captains. Moreover, during summer there are few navigation issues due to the melting of ice but in winter weather conditions might

change and routes might remain open for only few hours after the icebreaker passed. As such, the more often satellite images are taken, the better the quality of the information provided will be. Currently, images are taken every two or three days but optimally, it should be every day at the same time to gain in accuracy.

Figure 51: Methodological approach to reduced costs of navigation



Copernicus has a major role to play in ice navigation. However, Sentinel-1 images have only been available since 2014, and former satellite imagery that could provide similar information came from commercial satellites. As such, and conversely to the case of Finland and Sweden where the full transition from helicopters to Earth Observation images occurred at the beginning of the 21th century, thanks to supportive public authorities facilitating the uptake of satellite data, it is not necessarily the case in the whole Baltic region countries; as such, the uptake of satellite data for ice navigation is assumed to be of 70% at the time of the launch of Sentinel-1 and is expected to increase to 90% in 2035, once all Sentinel-1 (C and D) will be operational. As for the Copernicus contribution for users of Earth Observation imagery, it is assumed to be of 0.5% in 2014 as Sentinel-1 would barely have been launched, drastically increasing up to between 40% and 90% in 2030 when user uptake is complete. This increase is indeed quite high but can be explained. In 2014, the uptake is very small as the Sentinel-1 satellite has barely been launched. However, Sentinel-1 data are sufficiently satisfying for ice navigation: knowing this element and that Copernicus data is free, uptake could theoretically reach 100%. As other sources of data can still be used when specific sea ice information is needed (such as Very High Resolution (VHR) data or tailored sea ice modelling), Copernicus contribution is not of 100% but is expected to be between 40% and 90% although Sentinel-1 data are sufficiently satisfying for ice navigation. The low scenario corresponds to ships that have very specific needs for their navigation hence need to complement Sentinel-1 data by other data; the high scenario corresponds to a theoretical best-case scenario where ships would not have specific needs.

Table 50: Size of Copernicus benefits for reduced costs of navigation

IMPACT: Reduced costs of navigation	Pessimistic scenario	Neutral scenario	Optimistic scenario
Cumulative: 2017-2022	39 875 316€	75 577 119€	146 902 820€
Cumulative: 2023-2035	485 774 974€	679 577 304€	1 230 168 156€
Cumulative: total	525 650 290€	755 154 423€	1 377 070 976€

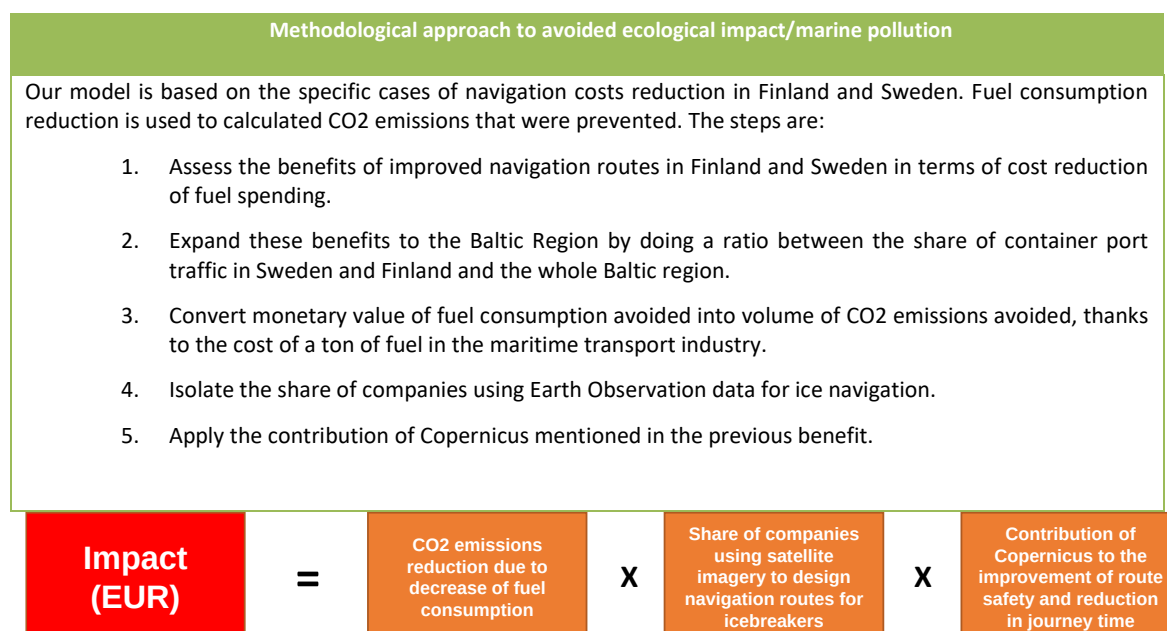
Avoided ecological impact/marine pollution

This impact has been extracted from the Copernicus ex-ante study (2017) without updating.

The value of this impact is calculated on a EU scale.

The analysis mostly relies on CO₂ emissions reductions due to decrease in fuel consumption from icebreakers and ship operators. As for marine accidents requiring repairs, their number had already decreased since the introduction of satellite imagery for ice navigation and the resulting products on winds, currents, or waves. Having a low number of accidents associated with the inability to judge on the ecological impact of each accident, which may drastically vary, led this factor considered negligible in comparison to CO₂ emissions from fuel combustion of vessels. Satellite imagery involved in fuel reduction, and thus CO₂ emissions reduction, is exactly the same as for the previous benefit. Indeed, it is because of the gain in timer of 5 to 8 hours per journey that fuel consumption is reduced.

Figure 52: Methodological approach to avoided ecological impact/marine pollution



The analysis is based on fuel reduction of icebreakers and ship operators thanks to the improvement of navigation routes as presented in the previous benefit. Navigation routes have been optimized thanks to satellite imagery, leading to ships gaining between 5 and 8 hours during a journey. As such, it implies fuel consumed is decreasing. After having calculated how much money can be saved by not buying fuel, this monetary value is transformed in the volume of fuel it corresponds to by taking into account the yearly evolution of fuel prices in the maritime transport industry. The volume of fuel that should have been consumed is then converted into the energy generated by ships in MWh (12.2 MWh are generated by a ton of fuel) and into CO₂ that is emitted by this amount of energy (0.264 kg of CO₂ is emitted per KWh of fuel generated). This value is then multiplied by a valuation coefficient which gives the value in terms of environmental benefits to the economy per kg of CO₂ emissions not generated. The Copernicus contribution is then applied to these values. As CO₂ emissions reduction is directly to the fact that faster routes are taken, the Copernicus contribution is the same as in the previous benefits. What differs between the two benefits is that, here, it is an environmental benefit that is presented whereas it was an economic one in the previous case.

Table 51: Size of Copernicus benefits for avoided ecological impact/marine pollution

IMPACT: Avoided ecological impact/marine pollution	Pessimistic scenario	Neutral scenario	Optimistic scenario
Cumulative: 2017-2022	3 672 483€	5 054 707€	9 825 072€
Cumulative: 2023-2035	36 131 125€	45 453 553€	82 279 831€
Cumulative: total	39 803 609€	50 508 261€	92 104 903€
Updated for this study	NO		

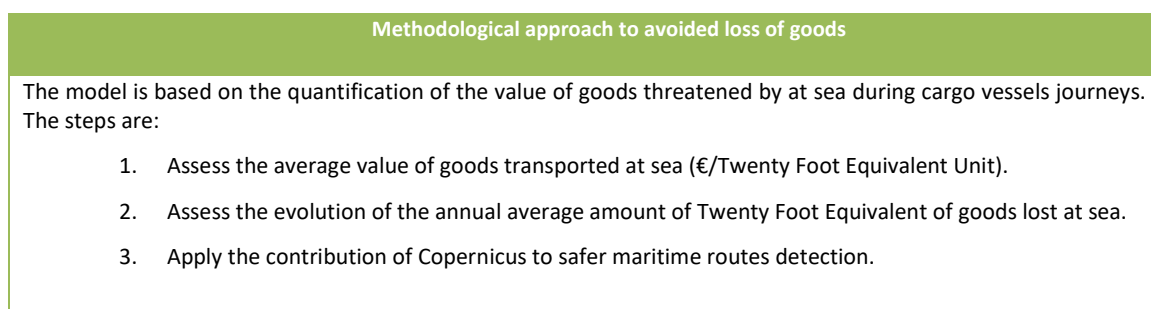
Avoided loss of goods

This impact has been extracted from the Copernicus ex-ante study (2017) and updated (2023).

The value of this impact is calculated on a EU scale.

Cargo ships are often confronted to difficult sea and weather conditions which in some cases may result in violent rolling, pitching and heaving motion of ships which greatly endangers the containers carried on board. The European Maritime Safety Agency (EMSA) has stated in its annual overview report of marine casualties and incidents issued in 2015, that 3% of casualties at sea were caused by environmental conditions and that 3% were caused by a lack of safety and environment management. To estimate the impact of Copernicus Maritime Safety products on the reduction of goods lost at sea, the annual value of goods lost at sea due to environmental issues and to a lack of safety and environment management was calculated over the period of 2016 to 2035.

Figure 53: Methodological approach to avoided loss of goods



The impact has been updated in 2023 with new data regarding three main topics²⁵:

- Number of Very serious casualty provoked by collision and contact.
- % of casualties caused by environmental conditions.
- % of casualties caused by safety and environment management.
- The new values are shown below.

Table 52: Size of Copernicus benefits for avoided loss of goods

²⁵ EMSA report 2022

IMPACT: Avoided loss of goods	Pessimistic scenario	Neutral scenario	Optimistic scenario
Cumulative: 2017-2022	12 216 415€	37 143 273€	63 392 065€
Cumulative: 2023-2035	43 144 329€	137 368 716€	256 625 158€
Cumulative: total	55 360 744€	174 511 990€	320 017 224€
Updated for this study	YES		

Fuel savings reached through optimized navigation routes

This impact has been extracted from the Copernicus ex-ante study (2017) and updated (2023).

This impact is calculated from a Global perspective.

Shipping companies have an economic interest in reducing the fuel consumption of their cargo ships fleet. The forecast of marine currents can enable cargo ships to use current routing for their voyage and therefore reduce their fuel consumption. The average level of savings reached by current routing is estimated at 0.4% which corresponds to 24 000 tons of fuel. The improvement of current forecasts modelling should lead to an average level of fuel savings of 1% by 2020 and represent 60.000 tons of fuel saved annually (in the model developed to quantify the benefits of Copernicus on fuel savings, this trend stays constant between 2020 and 2035). As it is difficult to estimate the precise annual price of fuel in the maritime transport industry until 2035, the average fuel price in USD per ton between 2004 and 2017 was utilized as constant (418,42\$/ton) to simulate a value utilized in this model. Thus, the number of tons of fuel saved thanks to current routing was multiplied by the average annual price of fuel to obtain a monetized value.

Figure 54: Methodological approach to fuel savings reached through optimized navigation routes

Methodological approach to fuel savings reached through optimized navigation routes	
This model examines the amount of fuel that can be yearly spared thanks to the identification and use of current routes for cargo ship journeys. The steps are:	
1.	Assess the yearly amount of fuel (tons) saved when using currents routes for cargo ships journeys.
2.	Forecast the average annual cost of fuel (€/ton).
3.	Apply the contribution of Copernicus to the identification of current routes enabling fuel saving.

$$\text{Impact (EUR)} = \text{Contribution of Copernicus to the identification of current routes} \times \text{Yearly amount of fuel saved thanks to current routes} \times \text{Average annual cost of fuel}$$

Table 53: Size of Copernicus benefits for fuel savings reached through optimized navigation routes

IMPACT: Fuel savings reached through optimized navigation routes	Pessimistic scenario	Neutral scenario	Optimistic scenario
Cumulative: 2017-2022	7 407 471€	11 273 168€	15 420 935€
Cumulative: 2023-2035	15 154 885€	24 069 631€	35 911 212€
Cumulative: total	22 562 356€	35 342 800€	51 332 148€

Emergency Service

The Emergency Service provides important benefits, especially when we refer to environmental impacts or pandemics. In particular, the benefits in this section refer to the impact drivers of fire and flood monitoring and forecasting.

Here below a summary table of the impacts presented in this chapter with their cumulative value in a 2017-2035 timeframe, considering a neutral scenario (neither optimistic, nor pessimistic). Details of the pessimistic and optimistic benefits projections are shown later on for each individual impact.

Table 54: summary table of the impacts for the Emergency service

Impact Driver	Impact	Cumulative value 2017-2035 (Neutral scenario)	Updated (Y/N)
Fire detection and monitoring	Reduced forest fire area	1 069 877 303 €	NO
Fire detection and monitoring	Reduced toxic emissions to reduced forest fire area	1 333 960 421 €	NO
Fire detection and monitoring	Reduced economic damages in forestry	5 504 015 399 €	NO
Floods monitoring and forecasting	Reduced economic damages thanks to flood forecasting	17 033 389 273 €	NO
Floods monitoring and forecasting	Reduced economic damages thanks to improved response	2 322 734 901 €	NO
Floods monitoring and forecasting	Avoided fatalities and injuries thanks to flood forecasting	909 702 918 €	NO
Floods monitoring and forecasting	Avoided fatalities and injuries thanks to improved response	76 246 776 €	NO

Reduced forest fire area

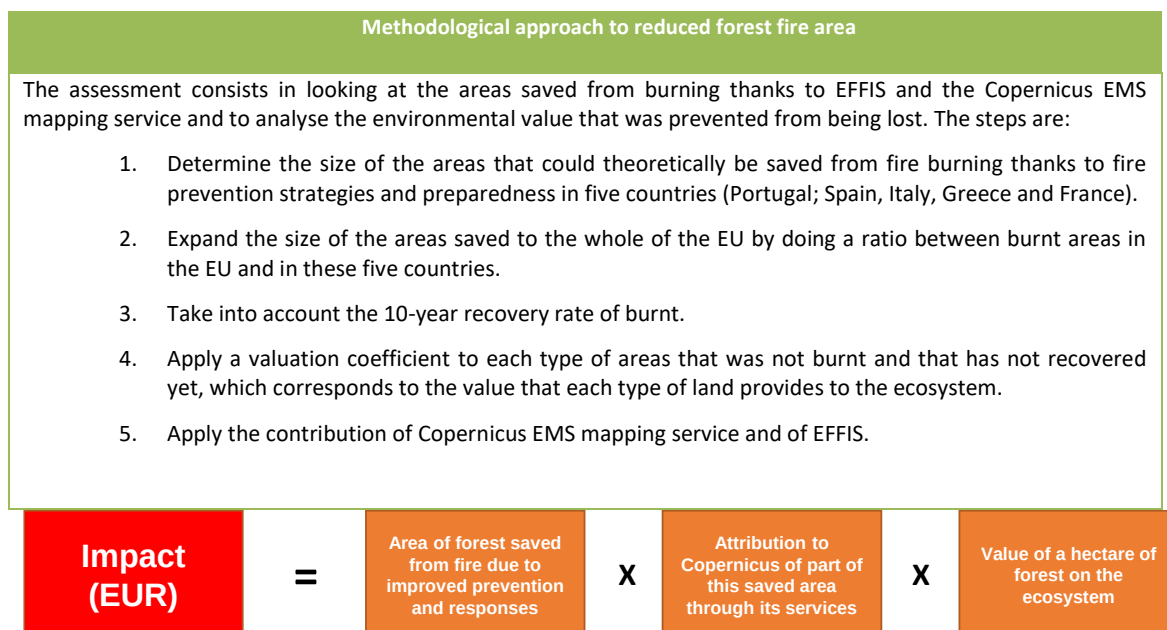
This impact has been extracted from the Copernicus ex-ante study (2017) without updating.

The value of this impact is calculated on a EU scale.

The first benefit of detecting and monitoring fires consists in the protection of the environment. The different varieties of land have different values to the ecosystem. This value comes from non-market services such as recreation, watershed, soil protection, biodiversity, pollination, etc. Different types of land are affected by fires: as such, the loss of forest does not have the same environmental consequences as the loss of artificial surfaces for instance. Copernicus has a double contribution in the fight against environmental damages

consequential to fires: first, the prevention and mitigation of fires and second, the preparedness and response to fires through mapping.

Figure 55: Methodological approach to reduced forest fire area



After an extrapolation to the whole of Europe, based on the fact that burnt areas in these countries account for 85% of the European burnt areas, hence saved areas are similarly proportional, it appears that the yearly average of saved areas is 229,412 ha in 2017-2025 and 282,353 ha in 2026-2035. Besides, in order to get a sense of the environmental cost of forest fires, it is not sufficient to simply look at yearly burnt areas. Indeed, it takes time for burnt areas to regrow and regenerate. Recovery time of forests and land differs greatly depending on the type or size of trees, on their location and on the environmental conditions. However, in the model the regeneration period was assumed to be 10 years. Once the benefits of saving areas from fires thanks to adaptation has been calculated, the contribution of Copernicus to this adaptation is extracted.

Table 55: Size of Copernicus benefits for reduced forest fire area

IMPACT: Reduced forest fire area	Pessimistic scenario	Neutral scenario	Optimistic scenario
Cumulative: 2017-2022	252 258 736€	313 482 401€	374 706 066€
Cumulative: 2023-2035	611 866 807€	756 394 901€	900 922 996€
Cumulative: total	864 125 544€	1 069 877 303€	1 275 629 063€
Updated for this study	NO		

Reduced toxic emissions to reduced forest fire area

This impact has been extracted from the Copernicus ex-ante study (2017) without updating.

The value of this impact is calculated for EU28.

This benefit consists in the reduction of carbon emissions released by fire events. By saving areas from burning, it is possible to avoid the release of several toxic emissions.

Figure 56: Methodological approach reduced toxic emissions to reduced forest fire area

Methodological approach reduced toxic emissions to reduced forest fire area

The assessment consists in looking at the areas saved from burning thanks to EFFIS and the Copernicus EMS mapping service and to analyse the environmental value that was prevented from being lost. The steps are:

1. Determine the size of the areas that could theoretically be saved from fire burning thanks to fire prevention strategies and preparedness in five countries (Portugal; Spain, Italy, Greece and France).
2. Expand the size of the areas saved to the whole of Europe by doing a ratio between burnt areas in Europe and in these five countries.
3. Apply a CO₂ valuation coefficient based on the CO₂ mass that is emitted per ha of forest.
4. Apply the contribution of Copernicus EMS mapping service and of EFFIS.

$$\text{Impact (EUR)} = \text{Area of forest saved from fire due to improved prevention and responses} \times \text{Attribution to Copernicus of part of this saved area through its services} \times \text{CO}_2 \text{ emitted per hectare of forest fires} \times \text{Valuation coefficient of CO}_2 \text{ emissions}$$

A methodology similar to the one of the previous benefit is applied here. The same size of saved areas is considered, however, the recovery is not taken into account: indeed, toxic emissions only happen once, when forest is burning but does not have longer term impact in terms of emissions. On a yearly average computed between 1980 and 2008, it appeared that 13.6 Mt of CO₂ were emitted from around 480,000 ha of burnt area. From these values, an estimate of emitted CO₂ from 1 ha of burned forest fire can be calculated. This value is then multiplied by the total saved area from forest fires.

Table 56: Size of Copernicus benefits for reduced toxic emissions to reduced forest fire area

IMPACT: Reduced toxic emissions to reduced forest fire area	Pessimistic scenario	Neutral scenario	Optimistic scenario
Cumulative: 2017-2022	377 562 406€	468 929 657€	560 296 908€
Cumulative: 2023-2035	701 059 539€	865 030 764€	1 029 001 989€
Cumulative: total	1 078 621 946€	1 333 960 421€	1 589 298 897€
Updated for this study	NO		

Reduced economic damages in forestry

This impact has been extracted from the Copernicus ex-ante study (2017) without updating. The value of this impact is calculated on a EU scale.

Besides environmental damages linked to toxic emissions and damages to the ecosystem, forest fires also have an economic impact: for instance, there is an impact on wood production or on hunting activities. the size of burning areas can be really changing and is not always proportionally linked to the economic damages. The estimated economic damages in the EU are presented below.

Figure 57: Methodological approach reduced toxic emissions to reduced forest fire area

Methodological approach reduced toxic emissions to reduced forest fire area

The assessment consists in looking at the areas saved from burning thanks to EFFIS and the Copernicus EMS mapping service and to analyse the environmental value that was prevented from being lost. The steps are:

1. Determine the size of the areas that could theoretically be saved from fire burning thanks to fire prevention strategies and preparedness in five countries (Portugal; Spain, Italy, Greece and France).
2. Expand the size of the areas saved to the whole of Europe by doing a ratio between burnt areas in Europe and in these five countries.
3. Apply the economic cost of a hectare of forest lost.
4. Apply the contribution of Copernicus EMS mapping service and of EFFIS.

$$\text{Impact (EUR)} = \text{Area of forest saved from fire due to improved prevention and responses} \times \text{Attribution to Copernicus of part of this saved area through its services} \times \text{Cost of reconstruction and restoration of a hectare of forest}$$

The methodology applied here is similar to the one of the previous benefit. The same size of saved areas is considered, without taking into account the recovery time: indeed, economic damages are calculated for each new hectare lost but cannot be applied twice to the same area. Based on the estimated economic damages presented on the map above, a value was extracted for economic damages: these are estimated at EUR 9,020 per hectare in 2017. This value is then multiplied by the size of the areas that were saved.

Table 57: Size of Copernicus benefits for reduced economic damages in forestry

IMPACT: Reduced economic damages in forestry	Pessimistic scenario	Neutral scenario	Optimistic scenario
Cumulative: 2017-2022	1 557 849 293€	1 934 837 056€	2 311 824 819€
Cumulative: 2023-2035	2 892 621 429€	3 569 178 343€	4 245 735 258€
Cumulative: total	4 450 470 722€	5 504 015 399€	6 557 560 077€
Updated for this study	NO		

Reduced economic damages thanks to flood forecasting

*This impact has been extracted from the Copernicus ex-ante study (2017) without updating.
The value of this impact is calculated on a EU scale.*

This assessment is done based on the paper of Pappenberger et al. (2015) to determine how much benefits EFAS and Copernicus mapping services will give for flood monitoring and forecasting services. Several studies have been performed on the methods of reducing disaster risks, and the most efficient was found to be flood forecasting.

Figure 58: Methodological approach to reduced economic damages thanks to flood forecasting

Methodological approach to reduced economic damages thanks to flood forecasting
This assessment follows the assumptions taken in the previous part to attribute these benefits to Copernicus. The steps are: 1. Determining annual fatalities and injuries from flood events up to 2035. 2. Estimating the percentage of casualties that can be avoided due to early warning and projecting to be 67% in 2035 (which is taken from a linear growth to achieve the computed 99% in 2085). 3. Filtering that value by EFAS penetration ratio based on its performance and efficiency. 4. Attributing the percentage of dependency on EFAS for that filtered value from the same scenarios as in the previous part.

5. Valuation of the avoided fatalities and injuries thanks to EFAS using the PwC developed valuation coefficients.

$$\text{Impact (EUR)} = \text{Economic damages due to floods} \times \% \text{ reduction in damages due to early warning} \times \% \text{ success of EFAS in forecasting floods} \times \% \text{ of EFAS data used among other sources}$$

Early warning of floods could reduce up to almost 32.85% of the economic damages of a flooding event. Therefore, with a perfect forecasting system for all the floods in the EU, the economic damages would be reduced by 32.85% every year up to 2035. Hence the value of economic damages in the EU would be estimated to EUR 2 B in 2017 up to EUR 5 B in 2035, in the case where 100% of flood events are correctly forecasted. But EFAS is not able to forecast 100% of flood events. So, the reduction in economic damages must be multiplied by the EFAS “success rate” or “efficiency rate”. This is defined as the number of hits EFAS had over the total number of hits and misses, which is 55% in 2015 (i.e., the percentage of times it managed to forecast a flood from all the times there was a flood risk). Naturally with the continuous improvement of EFAS has and the follow up of the service and its efficiency, its performance will improve over time and is calculated to improve by 20 to 30% every 10 years.

Table 58: Size of Copernicus benefits for reduced economic damages thanks to flood forecasting

IMPACT: Reduced economic damages thanks to flood forecasting	Pessimistic scenario	Neutral scenario	Optimistic scenario
Cumulative: 2017-2022	1 504 881 572€	2 164 091 906€	2 823 302 239€
Cumulative: 2023-2035	10 364 193 681€	14 869 297 368€	19 374 401 054€
Cumulative: total	11 869 075 253€	17 033 389 273€	22 197 703 293€
Updated for this study	NO		

Reduced economic damages thanks to improved response

This impact has been extracted from the Copernicus ex-ante study (2017) without updating.

The value of this impact is calculated on a EU scale.

Through the rapid, risk areas and recovery maps provided by Copernicus Mapping Services, on-ground authorities and entities responding to floods will be more informed on a larger picture and will be able to create better and more efficient response plans and strategies. These maps can be critical for civil protection entities to intervene and rescue people for most endangered areas, to know the extent of the damages and not overlook or miss certain areas where help might be needed. Such mapping services help entities to plan their logistics, locate their evacuation areas, deploy first aid tents, or settle temporary medical care areas. Beforehand or after a disaster, they are used for several purposes such as improving preparedness to potential events or supporting the recovery and reconstruction phase.

Figure 59: Methodological approach to reduced economic damages thanks to improved response

Methodological approach to reduced economic damages thanks to improved response
This assessment follows the assumptions taken in the previous part to attribute these benefits to Copernicus. The

steps are:

1. Determining annual fatalities and injuries from flood events up to 2035.
2. Estimating the percentage of casualties that can be avoided due to early warning and projecting to be 67% in 2035 (which is taken from a linear growth to achieve the computed 99% in 2085).
3. Filtering that value by EFAS penetration ratio based on its performance and efficiency.
4. Attributing the percentage of dependency on EFAS for that filtered value from the same scenarios as in the previous part.
5. Valuation of the avoided fatalities and injuries thanks to EFAS using the PwC developed valuation coefficients.

$$\text{Impact (EUR)} = \text{Economic damages due to floods} \times \text{\% reduction in damages due to improved response} \times \text{\% of floods events mapped by Copernicus}$$

From the reduction in economic losses due to floods, a very small percentage is considered rescuable due to improved response, however data for a precise value was not found, and it is thus assumed to be a 0,5% decrease in damages. The contribution of Copernicus mapping services was determined by the percentage of flood events that authorized users requested to map, out of the total amount of flood events in the EU. The values were taken from EMDAT bases and the Copernicus mapping services web portal. This value averaged over the past 3 years was 78% and projected to become 100% in 2035. Therefore, the contribution of Copernicus Mapping services to flood monitoring can be calculated and applied on both the economic and societal benefits.

Table 59: Size of Copernicus benefits for reduced economic damages thanks to flood forecast

IMPACT: damages forecast	Reduced economic thanks to flood	Pessimistic scenario	Neutral scenario	Optimistic scenario
Cumulative: 2017-2022		205 211 123€	295 103 441€	384 995 759€
Cumulative: 2023-2035		1 413 299 138€	2 027 631 459€	2 641 963 780€
Cumulative: total		1 618 510 262€	2 322 734 901€	3 026 959 540€
Updated for this study		NO		

Avoided fatalities and injuries thanks to flood forecasting

This impact has been extracted from the Copernicus ex-ante study (2017) without updating.

The value of this impact is calculated on a EU scale.

As Copernicus Mapping Services and EFAS contribute to a better preparedness and early warning system for floods, we can say that Copernicus enable to avoid fatalities and injuries in case of flood event.

Figure 60: Methodological approach to avoided fatalities and injuries thanks to flood forecasting

Methodological approach to avoided fatalities and injuries thanks to flood forecasting
This assessment follows the assumptions taken in the previous part to attribute these benefits to Copernicus. The

steps are:

1. Determining annual fatalities and injuries from flood events up to 2035.
2. Estimating the percentage of casualties that can be avoided due to early warning and projecting to be 67% in 2035 (which is taken from a linear growth to achieve the computed 99% in 2085).
3. Filtering that value by EFAS penetration ratio based on its performance and efficiency.
4. Attributing the percentage of dependency on EFAS for that filtered value from the same scenarios as in the previous part.
5. Valuation of the avoided fatalities and injuries thanks to EFAS using the PwC developed valuation coefficients.

$$\text{Impact (EUR)} = \text{Number of fatalities and injuries avoided thanks to early warning} \times \text{Valuation coefficient of avoided fatalities and injuries} \times \text{\% success of EFAS in forecasting floods} \times \text{\% of EFAS data used among other sources}$$

To calculate the number of fatalities and injuries over the years 2017-2035, we estimate the number of floods events in 2035 (based on the volume of economic damages expected in 2035), and multiplied it by the average amount of fatalities and injuries per flood event. Hence having the number of fatalities and injuries for the year 2035 and in 2017 (EM-DAT data bases), a linear growth was assumed between 2017 and 2035. As mentioned earlier the percentage of reduction among the number of fatalities and injuries thanks to preparedness and early warning, can be estimated at 99% decrease per year in the number of people affected by floods. Then the number of avoided fatalities and injuries thanks to early warning and adaptation, is multiplied by the EFAS success rate, and by the percentage of dependence on EFAS (depending on scenario, see above) to get a final attributed value to Copernicus EMS. Valuation coefficient were used to monetize the benefit of an avoided fatality (statistical value of life) and of avoided injuries (hospitalization costs avoided).

Table 60: Size of Copernicus benefits for avoided fatalities and injuries thanks to flood forecasting

IMPACT: Avoided fatalities and injuries thanks to flood forecasting	Pessimistic scenario	Neutral scenario	Optimistic scenario
Cumulative: 2017-2022	45 762 911€	64 996 316€	84 229 721€
Cumulative: 2023-2035	587 439 190€	844 706 602€	1 101 974 015€
Cumulative: total	633 202 101€	909 702 918€	1 186 203 736€
Updated for this study	NO		

Avoided fatalities and injuries thanks to improved response

This impact has been extracted from the Copernicus ex-ante study (2017) without updating.

The value of this impact is calculated on a EU scale.

As for societal benefits, the contribution of mapping services to damage reductions can be applied on fatalities and injuries. This will give the number of saved lives and avoided injuries thanks to the service and multiplying it by the valuation coefficients for fatalities and injuries (hospitalization costs and statistical value of life), we end up with the monetization of the benefit.

Figure 61: Methodological approach to avoided fatalities and injuries thanks to improved response

Methodological approach to avoided fatalities and injuries thanks to improved response

This assessment follows the assumptions taken in the previous part to attribute these benefits to Copernicus. The steps are:

1. Determining annual fatalities and injuries from flood events up to 2035.
2. Estimating the percentage of casualties that can be avoided due to early warning and projecting to be 67% in 2035 (which is taken from a linear growth to achieve the computed 99% in 2085).
3. Filtering that value by EFAS penetration ratio based on its performance and efficiency.
4. Attributing the percentage of dependency on EFAS for that filtered value from the same scenarios as in the previous part.
5. Valuation of the avoided fatalities and injuries thanks to EFAS using the PwC developed valuation coefficients.

$$\text{Impact (EUR)} = \text{Number of fatalities and injuries due to the floods} \times \text{Valuation coefficient of avoided fatalities and injuries} \times \text{\% reduction in casualties due to improved response} \times \text{\% of floods events mapped with Copernicus}$$

The percentage of floods events mapped with Copernicus services represents the Copernicus contribution to this benefit and amounts to 78% in 2017 up to 100% in 2035. The total is then multiplied by the valuation coefficient attributed to one person injured or dead (PwC methodology based on statistical value of life and hospitalization costs).

Table 61: Size of Copernicus benefits for avoided fatalities and injuries thanks to improved response

IMPACT: Avoided fatalities and injuries thanks to improved response	Pessimistic scenario	Neutral scenario	Optimistic scenario
Cumulative: 2017-2022	3 835 619€	5 447 668€	7 059 716€
Cumulative: 2023-2035	49 236 232€	70 799 108€	92 361 983€
Cumulative: total	53 071 852€	76 246 776€	99 421 700€
<i>Updated for this study</i>	NO		

Security Service

The entrusted entity SatCen is excluded from this benefit assessment, which only refers to Maritime and Border Surveillance.

The Security service is often employed for monitoring, rescuing, and controlling some activities. For these reasons its impacts are very relevant. More specifically, the main impact drivers analysed in this study are the control of IUU fishing activities, the maritime safety, the monitoring of oil pollution, law enforcement and the surveillance of borders.

Here below a summary table of the impacts presented in this chapter with their cumulative value in a 2017-2035 timeframe, considering a neutral scenario (neither optimistic, nor pessimistic). Details of the pessimistic and optimistic benefits projections are shown later on for each individual impact.

Table 62: summary table of the impacts for the Security service

Impact Driver	Impact	Cumulative value 2017-2035 (Neutral scenario)	Updated (Y/N)

Control of IUU fishing activities	Increase revenues for the fishing industry	3 927 179€	NO
Control of IUU fishing activities	Preservation of fish stocks sustainability on the long term	2 979 239 €	NO
Control of IUU fishing activities	Increased penalties perceived by MS	2 302 139 €	NO
Maritime safety - Search & rescue	Reduction of casualties in maritime disasters – Regular maritime traffic	670 288 927 €	NO
Maritime safety - Search & rescue	Reduction of casualties in maritime disasters – Refugees boats	136 581 801 €	NO
Oil Pollution monitoring	Reduced economic damage due to oil spills	369 825 134 €	NO
Oil Pollution monitoring	Reduced environmental damage due to oil spills	176 107 207 €	NO
Law enforcement	Increased interception of illegal goods in law enforcement	7 119 160 310 €	NO
Law enforcement	Increased interception of victims of THB	191 214 938 €	NO
Border control	Increased interception of illegal goods in border surveillance	18 057 301 €	NO

Increase revenues for the fishing industry

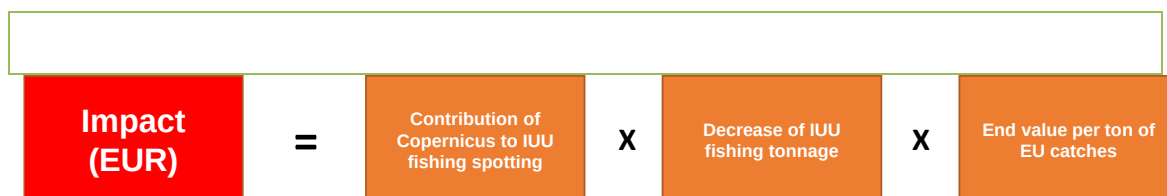
This impact has been extracted from the Copernicus ex-ante study (2017) without updating.

The value of this impact is calculated on a EU scale.

IUU fishing implies the harvesting of livestock resources which abundance directly affects the revenues accessible to anglers. In addition to depriving regular anglers from their source of revenues, illegal fishing often relies on minimal cost approaches (exploitation of forbidden but more attractive fishing areas, forbidden fishing methods etc.). Catches from IUU fishing can be sold at lower prices, generating unbalanced competition. The repression of IUU fishing activities dissuades illegal anglers, progressively leading to increased revenues for the industry. As it relies on a dissuasion effect rather than a direct mitigation (illegal catches seized cannot be saved and returned to sea when fishes are dead), the actual benefits for the industry materialize after few years, as the difference between the theoretical revenues with no IUU fishing fighting and the actual revenues. In the current exercise, it has been assumed that it takes 3 years for the dissuasion effect to materialize.

Figure 62: Methodological approach to increased revenues for the fishing industry

Methodological approach to increased revenues for the fishing industry
The valuation of increased revenues for the fishing industry assumes it is equal to the current shortfall due to IUU fishing. This shortfall relies on the valuation of the average ton of catches (meaning the revenues associated to the sale of the catches) and on the “dissuasion effect”, meaning the decrease of IUU fishing volumes due to IUU fishing repression.



The yearly volume of reported fishing activities (catches and aquaculture) in the EU varies around 6.2 million tons, which enables to estimate the total volume of IUU catches for the EU around 620.000 tons per year. When considering the evolution of the ratio of IUU catches versus overall catches, it can be estimated that since 1990 this ratio dropped from 21% down to 15%, representing an average decrease of 0.28 point per year (equivalent to 1.14% of the yearly IUU catches). Taking into account that the overall EU reported catches is constant over the past decade, this decrease in the share of IUU fishing with respect to the overall fishing activity represents the dissuasion effect attributed to IUU fishing repression. The model assumes that from 2015 to 2020 the rate of decrease of IUU fishing continues at this pace, leading to a yearly volume of fish stock saved from IUU fishing of about 17.700 tons. It should be noted that the 3 years delay between the repression actions and the actual IUU fishing reduction are taken into account in the distribution of the Copernicus contribution. The revenues for the fishing industry can then be derived based on the average value of the ton for catches landed. Over the past decade, IUU fishing stocks are valued around EUR 827 M per year, leading to a price of EUR 1.281 per ton.

Table 63: Size of Copernicus benefits for increased revenues for the fishing industry

IMPACT: Increased revenues for the fishing industry	Pessimistic scenario	Neutral scenario	Optimistic scenario
Cumulative: 2017-2022	277 553€	510 239€	815 269€
Cumulative: 2023-2035	2 362 474€	3 416 939€	4 558 570€
Cumulative: total	2 640 028€	3 927 179€	5 373 840€
Updated for this study	NO		

Preservation of fish stocks sustainability on the long term

This impact has been extracted from the Copernicus ex-ante study (2017) without updating.

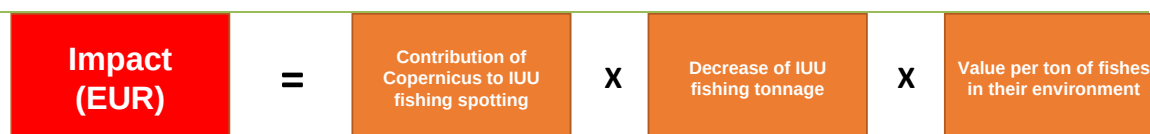
The value of this impact is calculated on a EU scale.

The logic to quantify this impact relies on the same principle of the IUU fishing dissuasion effect (with the same 3 years delay between repression and actual decrease of IUU fishing). Hence the same values are used: 620.000 IUU fishing volume per year, representing 10% of the EU catches. The dissuasion effect leads to a reduction of this share by 0.28 point per year up to 2020, and a slowdown of this effect by 0.05 point every 5 years up to 2035. The difference with the industry revenues impact lies in the valuation of the fish stock saved. Its value (per ton) is not the same as the commercial value used for the shortfall for the industry, but instead it takes into account the prospective value of the fish, as being alive, for the ecosystem and the future fishing activities. It is difficult to put an economic value on this, but 2 main factors enter into consideration: on one hand a fish alive is more valuable than landed catches as it still has the potential to grow, reproduce, and create more fishes; on the other hand, there are costs associated to its capture and to land it. In a past study this approach led to a valuation of the preserved livestock around 1.077 EUR per ton.

Figure 63: Methodological approach to preservation of fish stocks sustainability on the long term

Methodological approach to preservation of fish stocks sustainability on the long term

Fish stock sustainability is quantified based on the value of a fish when it is alive, as it is able to grow and reproduce. The reduction of IUU fishing saves fishes, which are able to renew the stock. The benefits materialize on medium to long term, as it takes into account the time of the reproduction cycle.



The projection of the baseline up to 2035 of the impact of Copernicus on the preservation of fish stock sustainability relies on the following assumptions.

- The volumes of reported catches within the EU remains constant (oscillating around 6 million tons per year), following the trend of the past decade.
- The ratio of volume of IUU fishing to the volume of reported catches will keep decreasing (dissuasion effect) up to 2035. For 2015-2020 the pace of decrease will be the same as the average of past 25 years (0,28 points per year) and will progressively slow down to 0,2 point for 2020-2025, 0,16 for 2025-2030 and 0,14 for 2030-2035. This attenuation of the pace of decrease aims at taking into account that it is not realistic to assume a total eradication of IUU fishing activities. By 2030 – 2035, the volume of fish stock saved from IUU fishing every year reaches 8.700 tons. It should be noted that the IUU fishing volumes considered represent a conservative position as the shares retained correspond to the values for Northeast Atlantic, which has the lowest shares of IUU fishing (worldwide) but does not necessarily include all the fishing areas for EU players.
- The valuation of landed catches remains constant, equal to EUR 1.077 per ton.

Table 64: Size of Copernicus benefits for preservation of fish stocks sustainability on the long term

IMPACT: Preservation of fish stocks sustainability on the long term	Pessimistic scenario	Neutral scenario	Optimistic scenario
Cumulative: 2017-2022	210 558€	387 078€	618 480€
Cumulative: 2023-2035	1 792 221€	2 592 161€	3 458 226€
Cumulative: total	2 002 780€	2 979 239€	4 076 706€
Updated for this study	NO		

Increased penalties perceived by Member States

This impact has been extracted from the Copernicus ex-ante study (2017) without updating.

The value of this impact is calculated on a EU scale.

The monitoring of IUU fishing leads to economic sanctions for the illegal fishers, inflicted and perceived by the MS. The contribution of Copernicus to IUU fishing monitoring leads to more opportunities to intercept fraudsters, therefore to additional sanctions. It should be noted that sanctions remain a point of heterogeneity between the MS which do not all have the same levels of penalties. The European Commission has identified some room for improvement in the rigor and harmonization of the practices in term of law enforcement.

Figure 64: Methodological approach to increased penalties perceived by MS

Methodological approach to increased penalties perceived by MS
The most immediate impact of the detection of IUU fishing activities is the penalty inflicted to the fraudsters, as it is not linked to the dissuasion effect. 4 categories of infringements are considered for this impact: unauthorized

fishing, fishing without a license, failure to comply with remote transmission of vessel movements and tampering of the satellite-based VMS. These infringements are selected for they have a more direct link with the use of satellite data.

$$\text{Impact (EUR)} = \text{Contribution of Copernicus to IUU fishing spotting} \times \text{Decrease of IUU fishing tonnage}$$

The number of fines perceived by MS related to the infringements is assumed to be constant in the future.

Table 65: Size of Copernicus benefits for increased penalties perceived by Member States

IMPACT: Increased penalties perceived by MS	Pessimistic scenario	Neutral scenario	Optimistic scenario
Cumulative: 2017-2022	162 703€	299 105€	477 916€
Cumulative: 2023-2035	1 384 898€	2 003 033€	2 672 265€
Cumulative: total	1 547 602€	2 302 139€	3 150 182€
Updated for this study	NO		

Reduction of casualties in maritime disasters – Regular maritime traffic

This impact has been extracted from the Copernicus ex-ante study (2017) without updating.

The value of this impact is calculated on a EU scale.

A better response in case of a maritime incident can materialize in different manners, the most impactful one being the reactivity to commission rescue teams on-site, so the gain in efficiency enabled by satellite images can be reflected in additional lives saved. The lives saved thanks to Copernicus are then monetized through an approach based on the statistical value of life (economic impact of an avoided fatality). This approach attributes a monetary value to each life, which should not be seen as the value of the person of course, but as the economic footprint of each person in the society, in the sense of the economic value generated by all day-to-day activities of this person (work, spending, taxes, social activities etc.).

Figure 65: Methodological approach to reduction of casualties in maritime disasters – Regular maritime traffic

Methodological approach to reduction of casualties in maritime disasters – Regular maritime traffic
The use of satellite images contributes, even if it remains to a limited extent, to more efficient S&R operations, which implies the saving of additional lives. The contribution of EO materializes through situational picture and support to vessel location, with a differentiation made between the incidents occurring close to coasts (with very limited contribution of EO as many complementary means are available) and incidents occurring in high seas where the large coverage of satellites enable more direct benefits. The number of lives is then monetized by using the notion of statistical value for life (economic impact of an avoided fatality).

$$\text{Impact (EUR)} = \text{Contribution of Copernicus to S\&R missions} \times \text{Number of lives saved from maritime incidents} \times \text{Statistical value of lives}$$

The report of EMSA on marine casualties and incidents reports that over 3.200 incidents are reported per year, involving different types of vessels (cargo ships, passengers' ships, service

ships, fishing ships etc.). During these events, over 115 persons perished in 2015, above the yearly average on 2011 – 2015 (476 casualties in total). The contribution of Copernicus to the S&R missions is quantified through the number of lives saved (that can be attributed to the availability of Copernicus data), that is to say the total number of lives at risk minus the actual casualties. For the current exercise, only the incidents categorized as “very serious” are considered, in accordance to the definition of EMSA: “A very serious marine casualty means a marine casualty involving the total loss of the ship or a fatality or severe damage to the environment.” These incidents represent 3% of the total incidents. In addition, it is estimated that the lives at risk are the total lives on-board vessels involved in the incidents categorized as “casualty with a ship”, which represent 68% of the incidents on average for the past 5 years. The remaining 32% of incidents, “occupational accidents”, potentially involve only one person and are much less representative of the total. By estimating the average number of people on the ships (per category of ship), the total number of lives at risk can be assessed around 4,500 per year. The statistical value of life (economic impact of an avoided fatality) used to attribute a monetary value to the lives saved is EUR 2.26 M per individual.

Table 66: Size of Copernicus benefits for Reduction of casualties in maritime disasters – Regular maritime traffic

IMPACT: Reduction of casualties in maritime disasters – Regular maritime traffic	Pessimistic scenario	Neutral scenario	Optimistic scenario
Cumulative: 2017-2022	5 622 341€	52 588 548€	157 077 098€
Cumulative: 2023-2035	309 793 120€	617 700 378€	1 021 243 349€
Cumulative: total	315 415 462€	670 288 927€	1 178 320 448€
<i>Updated for this study</i>	<i>NO</i>		

Reduction of casualties in maritime disasters – Refugees boats

This impact has been extracted from the Copernicus ex-ante study (2017) without updating.

The value of this impact is calculated on a EU scale.

The refugee’s crisis takes place in the Mediterranean Sea, mainly between Libya and the Italian and Greek coasts. Similarly, to regular traffic, several terrestrial means are commonly used to spot the vessels: satellite phones from refugees, patrols using radar or visual surveillance, aerial means such as drones (used by MRCCs and ONGs) etc. EO contributes to the efficiency of operations by helping on vessel identification (the appropriate rescue vessel varies as refugees’ boats can contain up to hundreds of people), by anticipating the migrant flows (surveillance of the Libyan coast, anticipation of peaks after long periods of hostile weather) and feeding drifting models to spot lost vessels (more efficient than spiral patrolling). If these levers are quite different from the regular vessel’s missions, the outcome remains the same, meaning an increase of lives saved. The lives saved thanks to Copernicus are then monetized through an approach based on the statistical value of life (economic impact of an avoided fatality).

Figure 66: Methodological approach to reduction of casualties in maritime disasters – Refugees boats

Methodological approach to reduction of casualties in maritime disasters – Refugees boats
The use of satellite images contributes, even if it remains to a limited extent, to more efficient S&R operations, which implies the saving of additional lives. The contribution of EO materializes through situational picture and support to vessel location. The contribution of Copernicus is evaluated through the extent of use of situational awareness data, drifting models and pre-frontier surveillance of North Africa countries in the S&R operations conducted by MRCCs, Frontex and ONGs. The number of lives saved is then monetized by using the notion of

statistical value for life (economic impact of a fatality).

$$\text{Impact (EUR)} = \text{Contribution of Copernicus to S\&R missions} \times \text{Number of refugees lives saved from maritime incidents} \times \text{Statistical value of lives}$$

The estimation of the number of refugees lives saved is challenging because of the very variable nature of the refugee's crisis, with figures potentially changing by a ratio of 3 or 5 from one year to another. Between 2015 and 2017, the number of refugees crossing the Mediterranean Sea varies between 200.000 to over 1 million. Although estimates vary considerably, it is estimated that about 30% of the refugees are rescued during the crossing. It can be noted that rescued refugees are not necessarily people with their life at risk at the moment of the S&R mission, but people who are rescued considering the high risk of the crossing in such conditions. Based on database from UNHCR, the rate of casualties among refugees crossing the Mediterranean Sea is about 1,1% (average from 2015 to 2017). Hence the estimate for the impact quantification considers that 1,1% of the refugees rescued would have perished without intervention. The statistical value of life (economic impact of an avoided fatality) for the refugees is the same as for regular traffic, equal to EUR 2.26 million.

Table 67: Size of Copernicus benefits for reduction of casualties in maritime disasters – Refugees boats

IMPACT: Reduction of casualties in maritime disasters – Refugees boats	Pessimistic scenario	Neutral scenario	Optimistic scenario
Cumulative: 2017-2022	2 555 268€	16 537 042€	40 953 638€
Cumulative: 2023-2035	67 322 996€	120 044 758€	187 828 213€
Cumulative: total	69 878 264€	136 581 801€	228 781 852€
Updated for this study	NO		

Reduced economic damage due to oil spills

*This impact has been extracted from the Copernicus ex-ante study (2017) without updating
The value of this impact is calculated on a EU scale.*

Following an oil spill, the consequences include several types of damages on the near-by areas, with economic consequences on commercial activities. Among the activities most directly impacted, fisheries can lose a part of their production in addition to a negative impact on their image leading to a reduced selling price. The tourism sector suffers from the reduced volume of tourists on the coast, and the maritime transport undergoes financial consequences as the routes may be disturbed, imposing longer paths and delays. In addition, the clean-up operations and compensations linked to oil slicks imply substantial expenses by public authorities. The economic damages also include the value of the oil lost that cannot be exploited by O&G companies. Based on the costs witnessed through past disasters, the economic damages are scaled to the size of the oil spills, leading to an estimate of the costs generated by the overall oil spills in Europe.

Figure 67: Methodological approach to reduced economic damage due to oil spills

Methodological approach to reduced economic damage due to oil spills
The oil spills in Europe from both ships (de-ballasting, accidents) and O&G platforms are associated to the average cost for each ton of oil for the local economy. The monitoring of oil spills (detection and response) by EO and

Copernicus contributes to mitigating these damages.

$$\text{Impact (EUR)} = \text{Contribution of Copernicus to oil pollution monitoring} \times \text{Economic damage per ton of oil spill at sea} \times (\text{Oil spills from ships} + \text{Oil spills from platforms})$$

The quantification of economic damages for each ton of oil spill is based on the costs assessed for the Prestige oil spill, which sank offshore of Galicia in Spain. During this disaster, the tanker leaked about 60.000 tons of heavy oil. A study on the extent of the socioeconomic consequences of this event shows that the total economic damages represented about EUR 2.5 billion for France and Spain, split across fisheries (22%), tourism (38%), maritime transport (1%) and costs for public administrations (39%). To these economic damages, the cost of oil lost in the disaster is added, based on the average price of the barrel of crude oil (155 liters) over the past decade, leading to EUR 510 per ton. This represents a total cost of about EUR 45.000 per ton of leaked oil as economic damages.

Table 68: Size of Copernicus benefits for reduced economic damage due to oil spills

IMPACT: Reduced economic damage due to oil spills	Pessimistic scenario	Neutral scenario	Optimistic scenario
Cumulative: 2017-2022	124 869 339€	166 598 150€	214 017 182€
Cumulative: 2023-2035	154 278 285€	203 226 984€	257 773 955€
Cumulative: total	279 147 625€	369 825 134€	471 791 138€
Updated for this study	NO		

Reduced environmental damage due to oil spills

*This impact has been extracted from the Copernicus ex-ante study (2017) without updating
The value of this impact is calculated on a EU scale.*

Following an oil spill, the consequences include several types of damages on the near-by areas, with environmental consequences, mostly on the ecosystem of the polluted area. The valuation of such impact is not straightforward and is achieved by the Contingent Valuation method (used for the Prestige disaster as well as for the Exxon Valdez disaster). Based the costs witnessed through these past disasters, the environmental damages are scaled to the size of the oil spills, leading to an estimate of the costs generated by the overall oil spills in Europe.

Figure 68: Methodological approach to reduced environmental damage due to oil spills

Methodological approach to reduced environmental damage due to oil spills
The oil spills in Europe from both ships (de-ballasting, accidents) and O&G platforms area associated to the average cost for each ton of oil on the environment. The monitoring of oil spills (detection and response) by EO and Copernicus contributes to mitigating these damages.

$$\text{Impact (EUR)} = \text{Contribution of Copernicus to oil pollution monitoring} \times \text{Environmental damage per ton of oil spill at sea} \times (\text{Oil spills from ships} + \text{Oil spills from platforms})$$

The quantification of environmental damages for each ton of oil spill is based on the costs assessed for the Prestige oil spill, which sank offshore of Galicia in Spain. The study on the extent of the socio-economic consequences of this event shows that the total environmental damages represented about EUR 1.2 billion. When scaled to the size of the oil spill (about 60,000 tons of heavy oil), this leads to an average cost about EUR 21,200 per ton. Another study on the consequences of the oil spill of Erika in 1999 estimates the total environmental prejudice around EUR 371 million. When scaling it to the size of the spill, about 18,000 tons, this leads to an average cost of about EUR 21,200 as well.

Table 69: Size of Copernicus benefits for reduced environmental damage due to oil spills

IMPACT: Reduced environmental damage due to oil spills	Pessimistic scenario	Neutral scenario	Optimistic scenario
Cumulative: 2017-2022	59 461 590€	79 332 452€	101 912 943€
Cumulative: 2023-2035	73 465 850€	96 774 754€	122 749 502€
Cumulative: total	132 927 440€	176 107 207€	224 662 446€
Updated for this study	NO		

Increased interception of illegal goods in law enforcement

This impact has been extracted from the Copernicus ex-ante study (2017) without updating. The value of this impact is calculated on a EU scale.

The amount of illegal goods intercepted at the border is an indicator of the law enforcement activities of MS. Illegal goods include Counterfeit goods, drugs and stolen vehicles. The impact from illegal weapons seizures remains very limited at EU borders. The majority of the weapons circulating in the EU come from former conflict zones such as the Western Balkans, and today very few weapons are intercepted at external borders, with hardly quantifiable impact from Copernicus (154 weapons reported by Frontex in 2016). Consequently, to less drugs being consumed in the EU, less addictions and acute health issues have to be treated by public healthcare structures in the Member States. The effect on healthcare systems is not immediate however, as many health issues are triggered by recurrent consumption or long-term exposure. The current approach assumes 5 years between the seizure of drugs at the borders and the materialization of the effect on health systems.

Figure 69: Methodological approach to increased interception of illegal goods

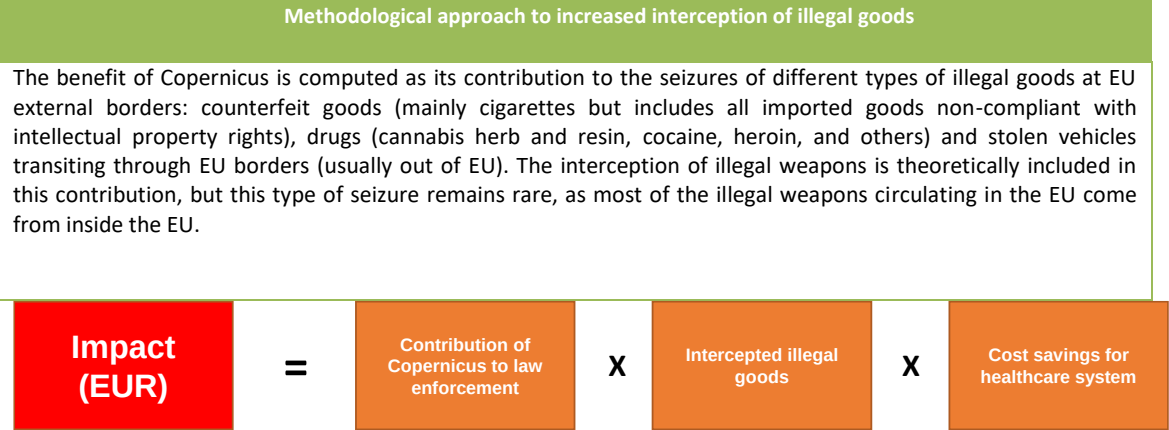


Table 70: Size of Copernicus benefits for increased interception of illegal goods

IMPACT: Increased interception	Pessimistic	Neutral scenario	Optimistic scenario

of illegal goods	scenario		
Cumulative: 2017-2022	645 597 309€	1 290 593 947€	2 080 055 867€
Cumulative: 2023-2035	4 322 528 021€	5 828 566 364€	7 501 434 274€
Cumulative: total	4 968 125 330€	7 119 160 310€	9 581 490 141€
Updated for this study	NO		

Increased interception of victims of THB

This impact has been extracted from the Copernicus ex-ante study (2017) without updating.

The value of this impact is calculated on a EU scale.

Over the past decades, human mobility around the world have continuously developed, as illustrated by the increase in the number of international migrants, of +40% since 2000 to reach 244 million in 2016. Although most of the migrants are not victims of trafficking of course, there is a correlation between the flows of migration and the amount of people victim of THB. The first category of exploitation for victims of THB is sexual exploitation, as it is the case for nearly 75% of women which represent about 70% of the victims (7% of men are also victim of sexual exploitation). The second main category of exploitation is forced labour, for 86% of men and 20% of women. The remaining categories include organ removal, child soldiers, forced marriage, forced begging or selling of children. The illicit activities performed by the victims of traffickers generate revenues, mainly for sexual exploitation and forced labour. By extracting the victims out of the networks, authorities prevent traffickers from accessing these revenues.

Figure 70: Methodological approach to increased interception of victims of THB

Methodological approach to increased interception of victims of THB
The valuation approach relies on the fact that victims of THB create value on the clandestine network by enabling traffickers to make revenues out of illegal activities. Each victim intercepted is withdrawn from the clandestine network and contributes to decreasing the value associated with illegal activities. This reduced value of the illicit market is then weighted by the contribution of Copernicus to interception operations.

$$\text{Impact (EUR)} = \text{Contribution of Copernicus to law enforcement} \times \text{Victims intercepted at EU borders} \times \text{Value of illicit market for traffickers}$$

Out of the 63,000 victims identified over 2012-2014 by the United Nations Office on Drugs and Crime (UNODC), about 4,000 were identified in the EU. Out of these victims, investigations show that about 35% come from non-EU countries, representing around 1,400 persons potentially identifiable at EU external borders when entering the EU (every year). Frontex estimates that people crossing the EU border at BCPs only represent a fraction of the overall border crossings (most people crossing between BCPs). Over 2009-2016, assuming the victims of THB intercepted fall in the categories “refusal of entry”, “person using fraudulent documents” and “illegal border crossing at BCPs”, we can estimate that about 25% of them are actually intercepted by the authorities. Past studies estimated the size of illicit markets linked to sexual exploitation and forced labor in the world. When scaling these revenues to the estimated number of victims, it can be estimated that each person exploited generates between EUR 15,000 and EUR 20,000 per year for the traffickers.

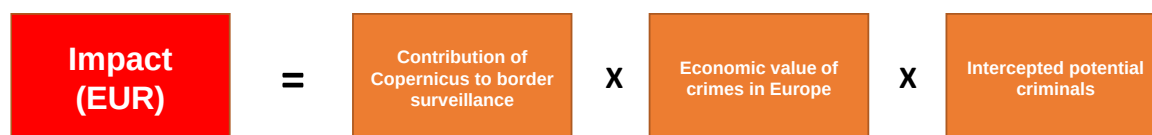
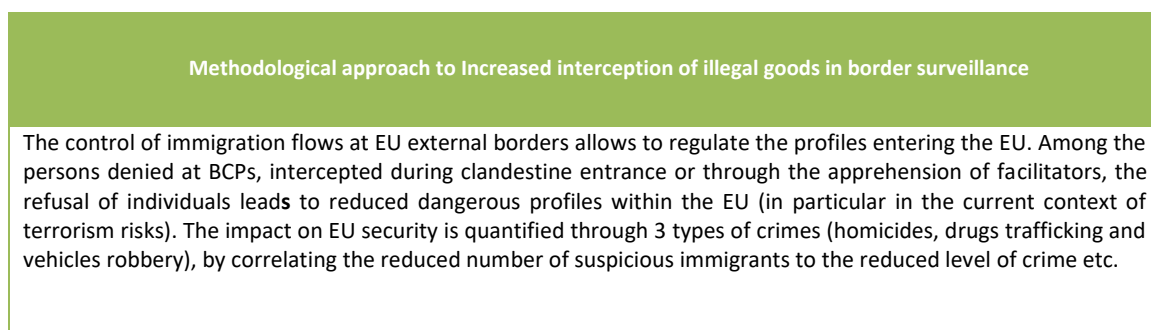
Table 71: Size of Copernicus benefits for increased interception of victims of THB

IMPACT: Increased interception of victims of THB	Pessimistic scenario	Neutral scenario	Optimistic scenario
Cumulative: 2017-2022	7 180 709€	14 047 653€	2 2200 019€
Cumulative: 2023-2035	135 232 101€	177 167 284€	202 197 953€
Cumulative: total	142 412 811€	191 214 938€	224 397 973€
Updated for this study	NO		

Increased interception of illegal goods in border surveillance

*This impact has been extracted from the Copernicus ex-ante study (2017) without updating
The value of this impact is calculated on a EU scale.*

If many immigrants at EU external borders are attempting to reach for EU for undisputable reasons (wars, political crisis, more favorable economic context etc.), many “noncompliant” profiles are intercepted by authorities during controls and are denied access to the EU. Among the reasons for denial, some are linked to regulatory and policy stances, while others are linked to the suspicions on the legitimacy of people, regarding their incentives for migration. In the current context of security concerns in EU Member States and growth of terrorist activities, borders become a more and more strategic point to mitigate EU crime and avoid external threats to reach Member States. The valuation of such control is achieved through the potential impact of suspicious profiles on EU criminality.

Figure 71: Methodological approach to Increased interception of illegal goods in border surveillance

The valuation of crimes is similar to the values used for previous drivers:

- The statistical value of life (economic impact of an avoided fatality) is estimated at EUR 2.26 M per person
- The average value of stolen vehicles is EUR 6,400
- The drugs unlawful acts are considered to be drugs seizures, with an average value of EUR 26,300 per seizure

Table 72: Size of Copernicus benefits for increased interception of illegal goods in border surveillance

IMPACT: Increased interception of illegal goods in	Pessimistic	Neutral	Optimistic

border surveillance	scenario	scenario	scenario
Cumulative: 2017-2022	2 255 210€	3 847 300€	5 737 184€
Cumulative: 2023-2035	11 223 203€	14 210 001€	17 488 151€
Cumulative: total	13 478 413€	18 057 301€	23 225 336€
<i>Updated for this study</i>	NO		

Summary table of benefits

The benefits of Copernicus and of the spending that has gone into its development and operations are summarized in the tables below. The first table summarized the GDP impacts expected due to the spending on Copernicus for 2014 – 2027 whereas the second table summarizes the end-user benefits incurred and expected due to the utilization of the Copernicus data and services (assessed for the period 2017 – 2035)

Table 73: GDP impacts due to 2015 - 2027 spending on Copernicus

Transactional Impact	Value
Total GVA (Gross Value Added)	12,9 B EUR
Type 2 Return multiplier	1,4 (taken from 2016 study)
Type 2 multiplier	2,49 (taken from 2016 study)
Direct Employment Supported (i.e. in space sector)	64 800 Person Years
Total Employment Supported	85 536 Person Years.

Table 74: End - user benefits due to the exploitation of Copernicus data and services

Copernicus Service	Impact Driver	Impact	Size in neutral scenario (2017 – 2035)	Updated for this study (Y/N)
Atmosphere Service	Air quality and pollution monitoring and forecasting	Decreased exposure to air pollution from air pollution alert services	10 406 047€	YES
Atmosphere Service	Air quality and pollution monitoring and forecasting	Increased ability to meet EU air pollution targets	13 158 470 599€	NO
Atmosphere Service	Solar energy monitoring and forecasting	Reduced CO2 emissions due to a decrease in reliance on fossil fuel energy sources	7 329 952€	NO
Atmosphere Service	Solar energy monitoring and forecasting	Reduced costs of energy (infrastructure management)	103 797 048€	NO
Land Service	Crops monitoring	Improved food security	9 378 658 108€	NO
Land Service	Crops monitoring	Improved agriculture profitability and cost efficiency	7 001 770 664€	YES
Land Service	Crops monitoring	Reduce the negative impact on environment	3 829 693 349€	NO
Land Service	Urban monitoring	Reduced traffic	143 325 191€	NO

Copernicus Service	Impact Driver	Impact	Size in neutral scenario (2017 – 2035)	Updated for this study (Y/N)
		accidents		
Land Service	Forestry management protection and	Cost reduction for forest agencies	28 881 114€	NO
Land Service	Forestry management protection and	Improve yields in forest industry thanks to sustainable management	725 603 642€	NO
Land Service	Forestry management protection and	Improve and restore forest ecosystems and green infrastructures	6 025 361 406€	NO
Land Service	Water resources management	Improve profitability in the Hydropower sector	732 296 638€	NO
Land Service	Water resources management	Improved agriculture productivity through better irrigation management	1 774 906 522€	NO
Land Service	Water resources management	Reduce groundwater depletion	244 790 650€	NO
Land Service	Wetlands monitoring	Improved restoration of wetlands ecosystems	6 017 268 860€	NO
Land Service	Ground elevation and ground motion monitoring	Reduced maintenance costs and improved safety thanks to efficient monitoring of subsidence	765 669 206€	NO
Land Service	Offshore infrastructure management (offshore wind)	Reduced toxic emissions and avoided waste of water	5 808 143 358€	YES
Land Service	Offshore infrastructure management	Increased revenues due improved offshore energy	2 584 380 132€	YES

Copernicus Service	Impact Driver	Impact	Size in neutral scenario (2017 – 2035)	Updated for this study (Y/N)
	(offshore wind)	production		
Land Service	O&G infrastructure management	Reduced cost and increased revenues for the European Oil and Gas industry	8 546 455 159€	NO
Climate Change Service	Climate modelling	Avoided economic losses from climate related extreme weather events	329 299 650€	YES
Climate Change Service	Urban monitoring	Reduced fatalities caused by urban heat islands	766 693 703€	YES
Marine Service	Coastal monitoring area	Reduced costs of land planning	1 610 693 065€	YES
Marine Service	Coastal monitoring area	Prevent loss of land	399 744 522€	NO
Marine Service	Coastal monitoring area	Protected population coastal against natural disasters	139 234 252€	YES
Marine Service	Coastal monitoring area	Protection of agriculture	180 429 695€	YES
Marine Service	Marine resources management	Increased productivity associated with reduced search time	476 296 539 €	NO
Marine Service	Water monitoring quality	Reduced plastics in the oceans	17 024 526 €	NO
Marine Service	Water monitoring quality	Increased productivity associated with harmful algal blooms	417 949 €	NO
Marine Service	Water monitoring quality	Reduced illnesses associated with harmful algal blooms	70 631 102 €	NO
Marine Service	Water monitoring quality	Reduced treatment costs associated with jellyfish sting	7 916 080 €	NO

Copernicus Service	Impact Driver	Impact	Size in neutral scenario (2017 – 2035)	Updated for this study (Y/N)
Marine Service	Ice monitoring to support navigation	Reduced costs of navigation	755 154 423 €	NO
Marine Service	Ice monitoring to support navigation	Avoided ecological impact/marine pollution	50 508 261 €	NO
Marine Service	Maritime navigation	Avoided loss of goods	174 511 990 €	YES
Marine Service	Maritime navigation	Fuel savings reached through optimized navigation routes	35 342 800€	NO
Emergency Service	Fire detection and monitoring	Reduced forest fire area	1 069 877 303 €	NO
Emergency Service	Fire detection and monitoring	Reduced toxic emissions to reduced forest fire area	1 333 960 421 €	NO
Emergency Service	Fire detection and monitoring	Reduced economic damages in forestry	5 504 015 399 €	NO
Emergency Service	Floods monitoring and forecasting	Reduced economic damages thanks to flood forecasting	17 033 389 273 €	NO
Emergency Service	Floods monitoring and forecasting	Reduced economic damages thanks to improved response	2 322 734 901 €	NO
Emergency Service	Floods monitoring and forecasting	Avoided fatalities and injuries thanks to flood forecasting	909 702 918 €	NO
Emergency Service	Floods monitoring and forecasting	Avoided fatalities and injuries thanks to improved response	76 246 776 €	NO
Security Service	Control of IUU fishing activities	Increase revenues for the fishing industry	3 927 179€	NO
Security Service	Control of IUU fishing activities	Preservation of fish stocks sustainability on the long term	2 979 239 €	NO

Copernicus Service	Impact Driver	Impact	Size in neutral scenario (2017 – 2035)	Updated for this study (Y/N)
Security Service	Control of IUU fishing activities	Increased penalties perceived by MS	2 302 139 €	NO
Security Service	Maritime safety - Search & rescue	Reduction of casualties in maritime disasters – Regular maritime traffic	670 288 927 €	NO
Security Service	Maritime safety - Search & rescue	Reduction of casualties in maritime disasters – Refugees boats	136 581 801 €	NO
Security Service	Oil monitoring Pollution	Reduced economic damage due to oil spills	369 825 134 €	NO
Security Service	Oil monitoring Pollution	Reduced environmental damage due to oil spills	176 107 207 €	NO
Security Service	Law enforcement	Increased interception of illegal goods in law enforcement	7 119 160 310 €	NO
Security Service	Law enforcement	Increased interception of victims of THB	191 214 938 €	NO
Security Service	Border control	Increased interception of illegal goods in border surveillance	18 057 301 €	NO

Table 75: Cumulative benefits value per scenario

Scenarios	Amounts
Total benefits (Pessimistic Scenario, 2017-2035)	72 536 081 758 €
Total benefits (Neutral Scenario, 2017-2035)	108 841 477 385€
Total benefits (Optimistic Scenario, 2017-2035)	156 989 031 699 €

In total, the utilization of the Copernicus data and services across the different downstream markets and sectors is expected to yield societal, economic and environmental benefits at end-user and EU citizen levels that can be monetized with a value of 108.8 B EUR for the timeframe of 2017 – 2035 (in a neutral scenario). In an optimistic scenario, these benefits were estimated to be valued at 156.9 B EUR and in a pessimistic scenario they were estimated at 72.5 B EUR

3.1.5. Efficiency and Cost Benefit Assessment of Copernicus

The following efficiency analysis takes as input the benefit assessment above and adds the costs of the Copernicus component's development and operations in order to provide a comparison of these two factors through a cost benefit analysis (CBA). The CBA aims to evaluate the extent to which the costs involved are justified and proportionate to the benefits achieved and aims at answering the question on the extent to which the intervention been cost effective.

Benefits of Copernicus

As mentioned in previous sections, the benefits of Copernicus were calculated at two levels. The first level of benefits includes the direct transactional impacts resulting from the investment and spending into the development and operations of the component. The second level of impacts includes the wider socio-economic benefits resulting from the utilization and exploitation of the infrastructure developed.

The direct transactional impacts (the GDP impact) evaluates the Gross Value Added and employment impacts that were assessed in the section above, and the table below summarizes them:

Table 76: GDP impact of Copernicus Component

Transactional Impact	Value
Total GVA (Gross Value Added)	12,9 B EUR
Direct Employment Supported (i.e. in space sector)	64 800 Person Years
Total Employment Supported	85 536 Person Years.

On the other hand, the wider socio-economic benefits, also calculated in the section above are summarized in the table below:

Table 77: wider socio-economic benefits due to the exploitation of Copernicus

Socio-economic impact	Pessimistic scenario	Neutral Scenario	Optimistic Scenario
Cumulative value of benefits (2017-2035)	72 536 081 758 €	108 841 477 385 €	156 989 031 699 €
Cumulative value of benefits (2017-2020)	7 497 199 937 €	11 253 881 833 €	15 839 687 799 €
Cumulative value of benefits (2021-2027)	25 168 384 180 €	37 970 514 312 €	55 251 697 329 €
Cumulative value of benefits (2028-2035)	39 870 497 641 €	59 617 081 241 €	85 897 646 571 €

Costs of Copernicus

The figures on the total spending on the Copernicus component were provided by the European Commission for the period 2014 – 2027, and the costs for the period 2008 – 2014 were extracted from the previous Copernicus Impact Assessment done by PwC. They are presented in the table below:

Table 78: Total spending on Copernicus per MFF

Spending type	Time Frame	Amount in M€
2008 – 2014		
Total spending	2008 – 2014	4055
Previous MFF: 2014 – 2020		

Total Spending	2014-2020	4145
Current MFF: 2021 - 2027		
Total Allocated budget (total expected spending)	2021 - 2027	5073
Total Spending (2014-2027)		9218

Cost-benefit assessment outcome

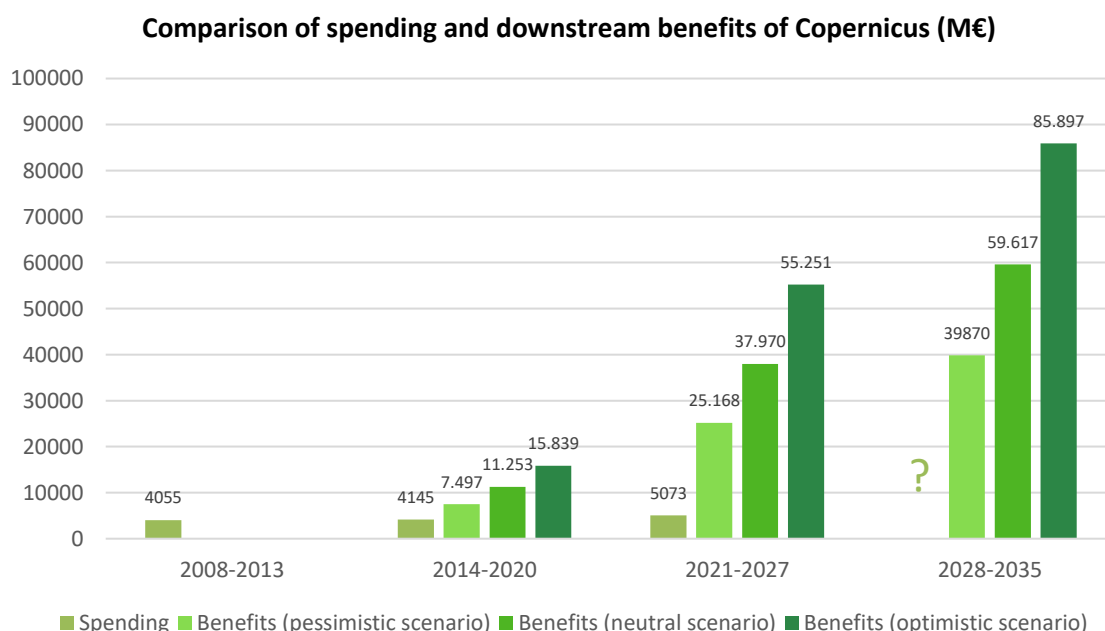
The Cost Benefit Assessment (CBA) of Copernicus looks at the ratio and the difference between the benefits generated by Copernicus, which provides open and free access to its data and services, and the costs it takes to develop and operate Copernicus.

Therefore, from the costs perspective the CBA will account for the costs that have accumulated from the beginning of the development of the Copernicus Component and that are expected until the end of this MFF. This is because the benefits from the exploitation of Copernicus are the consequence of the investment to develop the programme, including the investments made before the programme became completely operational.

From the benefits perspective, the CBA will account for also all the benefits accumulated since the beginning of the programme. In the previous ex-ante Impact assessment performed by PwC (from which the benefits were extracted and updated), Copernicus benefits were quantified starting from the year 2017, when the component (and its services) was at a mature stage of development.

The figure below presents the spending on Copernicus and the socio-economic benefits resulting from Copernicus in the time frames considered for this CBA. As shown in the chart, the budget allocated for Copernicus post 2027 is still not known.

Figure 72: Copernicus benefits and costs per timeframe



Over the timeframe 2008 – 2020:

Table 79: Cost Benefit ratio over the timeframe 2008 - 2020

Costs	Benefits			Benefit Cost Ratio (BCR)		
	Pessimistic	Neutral	Optimistic	Pessimistic	Neutral	Optimistic
8.2 B	7.5 B	11.2 B	15.8 B	0.9	1.36	1.92

EUR		

As shown in the table, the Benefit Cost Ratio (BCR) varies between the three different scenarios for the Copernicus benefits projection. In a neutral scenario the Cost Benefit Ratio of Copernicus is 1.36. This means that the downstream socio-economic benefits experienced by the Copernicus end-users and beneficiaries over the timeframe 2008-2020 outweigh the costs and spending that went into Copernicus over the same period by 36%.

In the optimistic scenario of the Copernicus downstream benefits quantification, the BCR in this period is 1.92 meaning that the benefits outweigh the costs by 92%. However, under the pessimistic scenario for benefits projection it would appear that over the period 2008 – 2020 the costs would still slightly outweigh the benefits by 10%. However, this is not alarming because this period of time was more focused on the development of the Copernicus infrastructure and the full operation started towards the end of this timeframe.

Over the timeframe 2008 – 2027:

It is not possible to perform a Cost Benefit Assessment for the period 2021 – 2027 independently as it would not be a fair comparison between costs and benefits. This is because the benefits expected in this period are not due to the costs incurred in that period alone, but also due to all the initial costs incurred in the beginning of the component development to put in place the infrastructure. Also, some of the benefits expected due to the spending during this period will be witnessed in the following timeframes however it is not possible to extract this portion of the benefits.

The table below outlines the Benefit Cost Ratios.

Table 80: Cost Benefit ratio over the timeframe 2008 - 2027

Costs	Benefits			Benefit Cost ratio		
	Pessimistic	Neutral	Optimistic	Pessimistic	Neutral	Optimistic
13.3 B EUR	32.6	49.1	71	2.5	3.7	5.3

As shown in the table, the benefit cost ratio (BCR) varies between the three different scenarios for the Copernicus benefits projection. In a neutral scenario the BCR of Copernicus is 3.7. This means that the downstream socio-economic benefits experienced by the Copernicus end-users and beneficiaries over the timeframe 2008-2020 largely outweigh the costs and spending that went into Copernicus over the same period by 270%.

In a pessimistic scenario the BCR goes to 2.5 and in an optimistic scenario it goes to 5.3 indicating the downstream benefits will outweigh the costs by 150% to 430%

Post 2027

Naturally, the benefits of the exploitation of Copernicus are expected to continue growing post 2027 due to the continuity and evolution of the service. Costs are also expected to continue being incurred for the same reason. However, as the budget for 2027 – 2035 has not been allocated yet, it will not be covered in the assessment. On the other hand, one caveat has to be made regarding the fact that a good portion of the benefits expected post 2027 are linked to the costs that have been incurred over 2008 – 2027, and not just due to the costs that will be incurred in 2027 – 2035. However, it is not possible to extract that portion of the benefits to incorporate it in the Benefit Cost Ratio.

It is possible to conclude that to-date the Copernicus societal, environmental and economic benefits witnessed by end users, beneficiaries and the EU society largely outweigh its costs and spending. Additionally, the initial investment and spending has a GDP multiplier of 1.4 indicating that each 1 euro spent on Copernicus would lead 1.4 euros of Gross Value added in the EU economy.

3.1.6. Relevance Assessment of Copernicus

Introduction

The relevance assessment evaluates the extent to which the Copernicus entrusted tasks are relevant to the end users. This is done by identifying the user needs in different domains and checking to what extent these user needs are met.

The user needs were extracted from the ‘Expression of User Needs for the Copernicus Programme’ document released in 2019. An extensive study led by the Commission was conducted to outline the needs of users across 15 segments, based on dedicated studies carried out between 2015-2018, user requirements workshops, task forces, expert groups, and several reports. Considering the vast efforts undertaken in the study and the fact that it typically served as a high-level input in the overall process of implementing user needs into the entrusted tasks, this document served as a basis for the relevance assessment.

To assess the relevance, the team aimed to determine to what extent the extracted user needs have been met since 2019 or are in the process of being met, as well as identified the existing gaps. This assessment was carried out through consultations with the various entrusted entities to understand how the Copernicus products and services have evolved since 2019 to meet user needs. Additionally, PwC also conducted interviews with relevant stakeholders, including Copernicus User Forum members to gather additional inputs on the user side.

Note: Since the assessment is based primarily on consultations, some applications may not be covered due to limitations in inputs from stakeholders. The assessment does not aim to replicate the previous user needs document but highlight the overall status in terms of user needs addressed and gaps identified. Additionally, some applications were excluded if the user needs were already addressed under another application to avoid repetition.

Relevance Assessment

This section outlines the results of the user needs assessment. The first sub-section provides an overview of the overall process of collection and implementation of user needs by the entrusted entities, as well as identification of any overall gaps in this process. This is followed by an assessment of each segment, further split into several applications. For each application, the introduction and the relevant user communities have been identified and extracted from the previous user needs document²⁶. The assessment is primarily focused on identifying the user needs addressed by Copernicus, gaps planned to be addressed by Copernicus, and gaps that are not being addressed. A summary of the key points related to the user needs and the results of the relevance assessment of the Copernicus component will be highlighted in the final sub-section.

3.1.6.1. Process of user needs collection and implementation

There are several forums through which user needs are gathered within the Copernicus Component. The Copernicus User Forum (CUF) aims to provide inputs to the Commission regarding the definition and validation of user requirements, and is responsible for the coordination of the Copernicus programme with its public sector users. The Framework Partnership Agreement on Copernicus User Uptake (FPCUP) is an EU-funded project, that was launched in July 2018. It aimed at increasing the number of Copernicus users and applications as part of the Commission’s User Uptake Strategy with Member States. The User Consultation Platform (UCP), led by EUSPA and extended to include Earth Observation since

²⁶ Expression of User Needs for the Copernicus Programme

2020, aims at bringing together the user community to share their experiences and needs, and discuss market trends in various domains.

Each entrusted entity has a separate process of translating user needs into the entrusted tasks. The user needs document¹⁶ that also takes inputs through the CUF, mentioned above, is one of several inputs that goes into the user needs process, which is continuously evolving. Therefore, while the document does not provide a detailed overview of needs, it has been identified as a key input and therefore a relevant basis to carry out the user needs assessment.

For CAMS, the user needs document¹⁶ is used as a first input in the process. Requirements are also gathered through the user support desk, workshops, and events, and set up by a contractor in a User Requirements Data Base (URDB) where requirements are evaluated based on importance, impact, and number of repetitions. It is regularly updated, taking into account user feedback and user statistics.

The C3S process is similar to that of CAMS, where requirements are gathered from various sources into a URDB. A User Requirements Analysis Document (URAD) is created to provide actionable recommendations to guide the evolution of the service. The CMEMS is also similar to the services above, with the user needs document as a high-level input, complemented with various fora to gather needs and requirements from the user community.

The CSS also has similar processes, however they typically serve a restricted set of users. The process includes gathering inputs from service feedback, as well as dedicated workshops with authorised users to directly collect feedback. For the CMS service particularly, needs are translated into operational requirements where requirements related to mature technologies are analysed and updated in the system. Additionally, as per the Strategic Research Agenda, the Commission is organising a workshop to address user needs related to security applications and to define objectives for the evolution of CSS with the entrusted entities FRONTEX, EMSA and SatCen.

The CEMS, like the security services, is also quite unique as access is primarily restricted to authorised users, including national, regional, and local authorities, with very specific needs for products. JRC has a close link with these users to derive needs.

Lastly, the process of ESA is aligned with all the ones listed above. ESA collects user needs and requirements on a continuous basis: from the user needs document issued by the EC, in addition to Copernicus Data Warehouse Requirements, Technical Specifications for the Copernicus Space Infrastructure, and Security Requirements for the Copernicus Programme. Additionally, ESA is often in contact with Copernicus Services, entrusted entities, users, and expert groups to adjust and align the needs. Satisfaction surveys are also carried out to support the process. An example is the collection of needs coming from the expert group, where their opinions are included in the Mission Requirement Documents (for example, for Sentinel Expansion Missions) and the users themselves are included in the Mission Advisory Groups (MAGs). The MAGs check that the development of the missions remain on track to fulfil the user needs, and explores ways of incorporating new needs in the mission if and when they arise.

3.1.6.2. Monitoring of the Land environment

Land cover, land use and changes

Copernicus services at the EU level include the development of CLC, CLC+, High Resolution Layers (HRL) and bio-geophysical parameters. At the global level, land cover mapping, and information on vegetation, energy, water, and cryosphere are available.

User Community

Commission services require the use of land use/cover statistical information at regional, urban and EU level. Additional users include national and local agencies such as planning services, geographical survey agencies, greenhouse gas inventory compilers, regions, and departments.

User Needs addressed by Copernicus

The need for improved spatial resolution has been addressed in CLC+ and HRLs, with a resolution of 10m currently available. Additionally, update cycles have been shortened from 6 years to 2 years in CLC+. For land use and change monitoring applications, user needs have been addressed with monitoring of bio-geophysical parameters available every 10 days.

Users are seeking the development of a land cover change alert system for change monitoring. While an alert system is currently not being developed, service providers are continuously aiming to update and improve automatic change detection to implement into products. As processing capabilities continue to grow, automation is being introduced across several aspects of the development of products and services.

Users at statistical institutes are seeking statistical products derived from Copernicus information. CLMS focuses on developing upstream products that downstream users can use to further develop application, therefore, in terms of statistical products, EEA is providing support with upstream products for users to then derive statistics from relevant products.

Gap Assessment

No unaddressed gaps were identified in consultations for this application.

Regional and urban policies

Copernicus services include data and information for pan-European purposes within the principles of subsidiarity and national sovereignty. However, several products are available at local scale to address regional and urban applications, including the urban atlas, riparian zones, and Natura2000 sites. It also includes climate data for climate change related planning.

User Community

Users are typically European regions, but also for regions as defined by Member States, and needs expressed for instance by the Committee of the Regions. Target communities also include regional planners, urban planners, city councils, the Covenant of Mayors' signatories, public utilities operators, and any agency or operator in charge of territorial management.

User Needs addressed by Copernicus

The spatial planning of large cities requires an in-depth understanding of land use / land change spatial patterns, including land cover maps and HRL at a resolution of less than 20m, which is available in the Copernicus offering. New layers of information such as building height, 3D mapping of buildings for energy consumption, building footprints and road width are also available. Additionally, outermost regions that are a part of the EU, but are remote are also being supported with the same level of products and applications available.

For European core data (e.g., cadastral parcels), users are seeking a reduction in time between observation and release of products, which is currently a work in progress by the CLMS.

For needs related to climate change adaptation planning and decision-making, past, current, and future climate datasets at the various levels of the nomenclature of territorial units for statistics have been made available in the climate data store.

Gap Assessment

No unaddressed gaps were identified in consultations for this application.

Soils

Copernicus delivers HRL products such as imperviousness at the European level. The Global Land Service provides products related to water and soil such as surface soil moisture and soil water index.

User Community

Includes regional planners, environmental agencies, agricultural departments, researchers in charge of climate change analysis or emergency services facing possible risks of droughts, landslides, floods, or fires. It also includes the community exploiting land and soil e.g., stone carry, mining industry, water extraction.

User Needs addressed by Copernicus

User needs related to the monitoring of ground motion for applications such as monitoring of landslides or subsidence are being addressed through the European Ground Motion Service developed by CLMS. The land service provides ground deformation maps to support these applications.

For climate change monitoring purposes, C3S is providing surface soil moisture products, including the development of long time series of data. Soil Moisture is also an Essential Climate Variable as stated by the GCOS, where inputs for the variable are provided by C3S. The land service also provides surface soil moisture data at the global level which can be integrated for applications such as mapping agricultural practices.

Gaps planned to be addressed by Copernicus

Currently, user requirements related to soil chemical content are not being addressed. This is because there are no inputs to develop products as data related to soil chemical content cannot be acquired by the current Sentinels. However, the Copernicus Hyperspectral Imaging Mission for the Environment (CHIME) planned to be launched in 2028, will provide inputs that could be used for development of products related to soil chemicals. At the same time, the LSTM expansion mission has as a secondary objective to support mapping and monitoring of soil composition, in terms of mineralogy and organic matter. Though it is conceived mainly for disaster & Geohazards and Build Environment, the expansion mission ROSE-L will provide additional information thanks to the L-band SAR as it is able to penetrate through many natural materials such as vegetation and soil.

Gap Assessment

Overall, there is a lack of clear user requirements based on policy therefore the development of some soil-related products has currently been placed on hold.

Inland Water

Water products from Copernicus include inland water, wetness, snow, and land ice products.

User Community

Includes river basin authorities and agencies, regional and local authorities in charge of drinkable water, wastewaters, agencies in charge of agriculture, emergency services and hydro-meteorological administrations. It also includes private actors of the hydro-energy

sector or the water transport. Communities working along the coastline where inland waters connect with the seas.

User Needs addressed by Copernicus

For an improved understanding of the hydrological cycle, future HR Water, Snow, and Ice products will continuously monitor surface liquid and solid water with the aim to provide inputs on the cycle. Users are also seeking evapotranspiration information, which is not directly produced by CLMS, but an input is provided for downstream users to derive this information.

To address needs related to the Water Framework Directive, the EU-Hydro product developed by CLMS will aim to address specific needs in the directive. To address user needs related to surface water, CLMS is moving towards continuous monitoring of liquid and solid terrestrial surface water, which was previously missing in the portfolio.

C3S provides water-related climate records based on hydrological modelling. Additionally, C3S provides a better understanding of the hydrological cycle, based on the evapotranspiration process and soil moisture information.

Gap Assessment

No unaddressed gaps were identified in consultations for this application.

Agriculture

The Copernicus component supports the agriculture sector through the existing land use / land change products portfolio, as well as assessing agricultural land use and trends, crop conditions and yield forecasts with high-resolution layers of information on grassland, wetness, or small woody features. Products include fraction of green vegetation cover, vegetation productivity, leaf area index, land dry matter and climate indicators on e.g., temperature, humidity, and precipitation.

User Community

Including European institutions, bodies in charge of agriculture planning and control, regional/national/local actors in ministries of agriculture and paying agencies.

User Needs addressed by Copernicus

Through CLMS, long-term archives consisting of vegetation biophysical parameters coupled with land cover information are in the process of being developed, and have been available since 2017.

Regarding crop classification and agricultural practices monitoring, first products covering the years 2017-2021 will be made available in 2024. Within the new contract for vegetation phenology and productivity monitoring, vegetation disturbances will be monitored, however without specifically assessing the cause of the disturbances.

Improvements in weather forecasting capacity are not under the mandate of Copernicus, however CAMS provides information based on the ECMWF weather system.

Gaps planned to be addressed by Copernicus

To support the CAP, users are seeking improvements in identifying landscape features. Currently, only small woody features are being monitored, but mapping of small landscape features other than woody features that would serve the needs flagged by DG AGRI are not in the pipeline. While some feasibility analyses have been carried out, results have not been very conclusive: small landscape features such as stone walls and small ponds cannot currently be

mapped since the resolution of current imagery is too low at 3m, and would require 0.5m resolution. Additionally, definitions of the landscape features are still ongoing.

New missions that have the objective of covering needs are CHIME, which will support with new and enhanced services for sustainable agricultural and biodiversity management; LSTM mission which aims at improving sustainable agriculture productivity at field scale and provide support to prevent water scarcity. The Copernicus Contributing Missions are supporting and will support the Agriculture sector by providing High resolution down to 1 m or less (VHR 1).

Gap Assessment

No unaddressed gaps were identified in consultations for this application.

Forestry

The Copernicus component has no dedicated services related to forest management. However, many products related to vegetation supports the forestry sector as also illustrated for agriculture.

User Community

Includes Member States representatives such as forest guards and ministries of resources or environment. Also includes the forest industry including timber, to furniture and paper industries for compliance.

User Needs addressed by Copernicus

One of the longest running products of CLMS is HRL Forest, including tree cover data, which is widely used for applications such as forest management.

CLMS monitors tree cover density, and while attempts have been made to monitor species, it is not currently possible to ensure operational species classification with at least 90% of overall accuracy.

The development of products related to tree height are dependent on the availability of ancillary data, and therefore will not be derived for an entire AOI unless data of similar quality would be available for the whole AOI.

Gap Assessment

Information related to health and damages (e.g., degradation, deforestation) are specific indicators or derived information that is not currently planned to be addressed by CLMS.

Biodiversity

The Copernicus portfolio did not yet address biodiversity with direct information products or data on live ecosystems until 2021. However, a few products are available to describe and monitor the environmental conditions and landscapes related to biotopes.

User Community

At the national and regional level by public administrations and agencies in charge of protected areas such as forest guards, park managers but also marine protected areas agencies. At the international level, the Group of Earth Observation (GEO)

User Needs addressed by Copernicus

The High-Resolution Vegetation Phenology and Productivity (HR-VPP) product developed by the CLMS will address key biodiversity applications, in particular, monitoring of vegetation phenology can support monitoring of the condition and degradation of ecosystems. CLC 2024 will be created to respond to additional biodiversity needs.

Based on data from the C3S, climate-biodiversity indicators can potentially support the assessment of habitat suitability, species distribution, species fitness and reproduction and ecosystem services.

Gaps planned to be addressed by Copernicus

Habitat types cannot be mapped by satellite imagery, although some applications may be supported.

Other needs for biodiversity from the community vary from new products to new indicators, mainly related to protected areas and ecosystems, land and forests. The mission ROSE-L will provide information for vegetation biomass data and allow gathering of information on volumetric targets in vegetation and forests areas. The CHIME mission will carry a Hyper Spectral Imager with the ability of studying biodiversity and ecosystem sustainability related features.

Gap Assessment

No unaddressed gaps were identified in consultations for this application.

Plant health

A few products are relevant to monitor plant health in Copernicus such as indexes on vegetation and information on water stress.

User Community

Plant health experts, national to local health and food services, ministries of agriculture, agriculture, and horticultural actors.

User Needs addressed by Copernicus

The next HRVPP developed for the land service is expected to address phenology and vegetation disturbances, which may help in identifying their influence the dynamics of plant disease epidemics. The cause of the vegetation disturbance, however, will not be provided.

Gap Assessment

Ultra-high-resolution with flexible acquisition time and frequencies required to detect pathogens at tree-level would not be feasible with current spatial resolution of satellites.

Cultural heritage

There are no specific products developed related to cultural heritage.

User Community

Include national institutes for environmental protection or natural science, ministries of education, weather and climate services, archaeological institutes, cultural foundations to regional organisations acting on the field, civil protection in charge of natural disaster management, or private companies involved in the maintenance or conservation of civil works.

User Needs addressed by Copernicus

The Urban Atlas from CLMS can support cultural heritage applications. Urban sprawl monitoring can be used to map surrounding infrastructure as well as determine the effects, such as environmental impact, of urban sprawl on cultural sites. The priority area monitoring component can support monitoring of hotspots for critical sites. Land cover, land use and land change maps on identified cultural hotspots can be used to monitor the evolution of sites. The European Ground Motion Service developed by the land service can also support these applications through monitoring of ground subsidence that enable identification of risks to sensitive sites.

The emergency management service can support disaster prevention at cultural sites through the early warning system.

The C3S service can address climate-related risks, including provision of long-term climate indicators, trends and forecasts that would affect cultural heritage sites.

Gap Assessment

No unaddressed gaps were identified in consultations for this application.

International and global dimension

Copernicus has a dedicated portfolio for land services outside the European territory and for the purpose of international policies with several reference products including water, cryosphere, vegetation, soil and land temperature products.

User Community

While users can be diverse in an international context, and no specific types of users are targeted, Copernicus can be used to support dedicated programs and developments in other countries.

User Needs addressed by Copernicus

The global service is providing basic variables (fAPAR, Land Surface Temperature, NDVI etc.), key generic products like analysis-ready-data (e.g., phenology) or composite products (e.g., water, urban, land cover) at global scale. A long-term time series of at least 10-15 years is available for all products, and there is a continuous evolution of components, algorithms, etc.

Users are seeking an evolution from static products (e.g., with fixed resolution, coverage, temporal frequency) to the possible provision of quality-controlled algorithms for generating on-demand products. This is currently under discussion, where the Copernicus Data Space Ecosystem will contain a repository with data and algorithms that can be used at a global scale.

The global land service provides timely and high-resolution information for dynamic monitoring of land features on pre-identified hot spots as an on-demand service, primarily focused on biodiversity protected areas. It includes identification of inter and intra-annual variability of specific environments like for example wetlands, grassland, forests, surface waters, urban areas.

Long-time series to identify and monitor changes, possibly achieved due to policy implementation, complemented with regular short-term monitoring is available through the global land service.

Users are seeking transparent, reliable, and repeatable methods for national forest inventories. While this can be tricky as countries are typically responsible for national inventories, new global land cover maps provide a dedicated component for deforestation.

Gaps planned to be addressed by Copernicus

Users are seeking improved resolution of 10-20m for existing global land products. The current resolution available is 100m, however, the next framework contract is expected to provide 10-20m spatial resolution.

Gap Assessment

In certain areas (e.g., Africa), intra annual variability is not available for dynamic monitoring

3.1.6.3. Marine environment, Maritime affairs, and fisheries

Marine environmental monitoring

Copernicus delivers daily real-time observation of the oceans, 10 days ocean forecasts and climate records describing ocean physics and ocean biogeochemistry. Products are delivered at the global level for oceans and EU regional sea basins.

User Community

Includes national hydrological, weather, or marine services, environmental agencies, ministries of transport, fisheries, operational maritime authorities for ports, coastguards and research communities involved in oceans, climate, Earth science or biology. Also includes private sector acting in blue economy especially interested in ocean physics: energy, shipping, tourism, fisheries, and aquaculture.

User Needs addressed by Copernicus

CMEMS is in the process of developing several products to improve the description of ocean physics. Horizontal resolution is being improved to reach $1/36^\circ$ for the global ocean, with a demo planned in 2024 and the product release in 2025. There are also developments underway to improve treatment of closed or marginal seas with high dynamics at sub-mesoscale, linked to interactions with the atmosphere, ice, waves and winds. CMEMS is also working on better addressing coastal areas and hydrological system, including efforts to improve river input models. New methodologies are being implemented to better address uncertainties and ensure high-quality datasets.

To better understand the biological component of the ocean in terms of flora and fauna, a Horizon Europe project, NECCTON is currently developing new modelling products of fisheries, pollution, and benthic habitats to predict and protect the biodiversity of marine ecosystems and determine effects caused by human pressures and climate change.

For monitoring of sea-ice conditions, CMEMS is working on improving models. While long-term projections are not yet available, a project, ACCIBERG, has been planned through Horizon Europe.

Overall, CMEMS is integrating the various components to provide a full consistent overview of the ocean dynamics to support daily applications through a one-stop shop.

Gap Assessment

No unaddressed gaps were identified in consultations for this application.

Coastal management

Copernicus already delivers a full suite of real time observation, forecasts and climate records scaled for the EU regional sea basins specific ocean features. However, the performances of such products are not representative enough of coastal phenomena.

User Community

Regions, department, town councils, community of communes - in charge of their coastline, bathing waters, drinkable waters and utilities such as ports, dams but also local mobility, urban planning, tourism development and nature protection. Also includes the private sector operating at coast for civil works, water operations, sanitation, energy, short sea shipping and tourism.

User Needs addressed by Copernicus

Information that is complementary and consistent from the land to the sea and vice-versa is under development through a Horizon Europe project. Improvement of coastal models with hi-res boundary conditions are being developed through a User Engagement Call for tender, where CMEMS launched 15 new projects working with 15 MS for a future coastal marine monitoring service.

For needs related to land-sea interactions, a DEM is currently not available for the coast either through CMEMS or CLMS. However, new products, such as hi-res bathymetry, are being developed and can provide some information on land-sea interactions such as erosion and sediment data.

Gaps planned to be addressed by Copernicus

While some coastal needs are not being addressed due to budget limitations to develop a coastal hub, new products under development are partially addressing a few needs. For example, DEMs are currently not being developed in coordination with the land service, however, other products being developed are partially addressing applications related to land-sea interactions.

As per consultations, it was noted that improved coastal information would require dedicated collaboration between the Land and Marine service as well as additional support for the Coastal hub.

Gap Assessment

No unaddressed gaps were identified in consultations for this application.

Fisheries and aquaculture

Copernicus operates a significant suite of real-time ocean observations and biogeochemical ocean forecasts to support activities related to fisheries, support to sustainable best practising, fisheries control, and fish stock planning.

User Community

The industrial fisheries and fish processing industry, public authorities and at European level by the European Fisheries Control Agency.

User Needs addressed by Copernicus

The development of ‘closer-to-shore products’ in real-time and at finer scale for small-scale fisheries and aquaculture activities taking place in the near shore and coastal areas are being addressed by CMEMS. More dynamic and fine scale information of physical and biogeochemical ocean variables are being addressed in the Horizon Europe NECCTON project.

Other variables covered in new products are either being developed or are planned to be developed including types of plankton and algae as well as environmental parameters such as bathymetry, river discharge, winds, and waves. Seabed habitats are not covered in Copernicus products, but MOI is collaborating with DG MARE EMODnet service on this topic.

Gap Assessment

No unaddressed gaps were identified in consultations for this application.

Pollution at sea

Under Copernicus, significant efforts have been made and to fight against intentional or accidental oil pollution. Fighting against plastics or chemical pollution is much more complex and this is not yet developed in Copernicus. Products are developed both through the CMEMS and CMS for this application.

Note: EMSA operates CleanSeaNet (CSN), the European satellite-based oil spill and vessel detection service. Copernicus Sentinel-1 mission is the primary provider SAR imagery for CleanSeaNet services. Since 2015, EMSA implements, on behalf of the Commission, the Copernicus Maritime Surveillance (CMS) service. This service offers an extension of the CleanSeaNet service to areas outside of European waters, providing global coverage in areas of European interest.

User Community

Public institutions in charge of the ocean good environmental status of their coasts and territorial waters, but also foundations and associations specially invested in fighting against plastics. To some extent land tenants such as farmers, cities identified as sources of pollution can also be potential users. The research institutes play an active role to support public knowledge-based decision-making.

User Needs addressed by Copernicus

EMSA provides, in near real time, detection of oil pollution on the sea surface and contributing to the identification of potential polluters, monitoring accidental pollution during emergencies, and providing support to oil spill surveillance operations and exercises. While the CleanSeaNet service is only available to national authorities from EU Member States and their overseas territories as well as EFTA countries, the CMS service is also accessible to national authorities from the European Neighbourhood Policy beneficiary countries

The CMEMS portfolio on the other hand provides data on oil spills, plastics, acidity, and eutrophication. While CMEMS has no specific products for pollution monitoring applications, the products available can be implemented for these applications.

Gaps planned to be addressed by Copernicus

For regulation tracking purposes, currently only oil spills are being monitored. Concerning the detection of plastics and/or chemical pollution in EU waters from space, these services are beyond the scope of CMS services. Nevertheless, by recognizing their significance and the challenges associated with leveraging existing technologies for precise detection, this matter has been proposed for inclusion in the forthcoming Strategic Research Agenda for Copernicus Security Services, that will provide guidance and recommendations for the Horizon Europe Framework Programme.

Additionally, due to the loss of Sentinel-1B, there has been an impact on CleanSeaNet, where approximately 45% of the services provided by CleanSeaNet were based on Sentinel-1B products. This loss has led to various consequences, including increased costs incurred due to the need to acquire additional commercial data to compensate for the data gaps ultimately

resulting in reduced coverage. Furthermore, delays in the launch of Sentinel-1C (that can mitigate the loss of Sentinel-1B) have further impacted the CleanSeaNet service. However, given the nature of the CMS, the usage of Copernicus Sentinel-1 data is very limited, thereupon the impact in the service caused by the Sentinel-1B anomaly is reduced.

Gap Assessment

No unaddressed gaps were identified in consultations for this application.

3.1.6.4. Arctic policy and polar areas

Copernicus addresses the poles with a dedicated Arctic Ocean monitoring and forecasting centre, cryosphere monitoring, climate forecasting and maritime surveillance applications.

User Community

All categories of users from the public to the private sector are considered in the frame of the Arctic policy up to the citizen and indigenous population.

User Needs addressed by Copernicus

To address user needs expressed by a polar expert group, the various services are developing relevant products.

The CMEMS provides data on floating ice variables including sea ice extent, concentration, thickness, type, drift, and iceberg detection, to support navigation and marine operations applications. The service also develops products related to sea level anomaly for marine forecasting applications and sea and ice surface temperature and sea-ice albedo for climate modelling applications. The CLMS provides information on snow cover extent and snow water equivalent which enable several applications including water management and climate modelling.

Most of the products needed are considered already available by the user community, but requests for improving them include resolution and time availability advancements, such as sub-daily resolution under 5 kms to support safe navigation.

The Arctic Hub, launched in November 2023, will provide products from the marine, land, atmosphere, climate, and emergency services that can address user needs in the Arctic region. This includes products that will support use cases such as shipping safety, changing ice conditions due to climate change, sustainability for navigation in polar waters, and several more.

Gaps planned to be addressed by Copernicus

For resolution needs, sea ice thickness (SIT) and sea-ice concentration (SIC) are almost fulfilled, but for SIT and thin ice < 0.5m data need complementary data to CRISTAL will be required such as CIMR. CIMR fulfils the SIC requirements of the oceanographic services <5 km and daily pan-polar coverage but will need complementary data with 20m resolution in order to fulfil the requirements of the Transport/Navigation services. This means that the horizontal resolution of the current Sentinel-1 constellation is not sufficient. Sentinel-1 is also not offering a daily pan-polar coverage.

To monitor climate change and sea level rise, there are currently gaps in caps and ice sheets parameters including extent, calving front, grounding line, surface elevation and surface elevation change, mass balance and mass change / melt extent. These parameters are expected to be covered by future missions including ROSE-L, CRISTAL and CIMR.

For transport activities and impact on ocean changes and climate modelling, there are gaps in monitoring surface fresh water which can also be covered by future missions such as CIMR,

Sentinel 3 and CRISTAL. Snow cover on sea ice is also a missing parameter that could be addressed through the CRISTAL and CIMR missions.

More refined data on permafrost is also currently unavailable but can be addressed by Sentinel-1 and ROSE-L and is expected to be addressed by CLMS in future evolutions of the service.

Gap Assessment

No unaddressed gaps were identified in consultations for this application.

3.1.6.5.Transport

Terrestrial transports

Terrestrial transport is currently not extensively addressed by Copernicus products.

User Community

Regional, local authorities and state in charge of the deployment of transport infrastructures and the private sector in charge of deploying and maintaining these civil works.

User Needs addressed by Copernicus

The mapping of terrestrial transports and infrastructures has been extended from the EU to EEA39, with the mapping of UK stopped due to Brexit.

To address needs for civil engineering applications such as network deployment, Digital Elevation Models and geophysical parameters are available through the land service.

Current, past, and future climate data is available at a 15km resolution, but has to be interpolated at the network level due to limitation of resolution of products.

Gap Assessment

There are still no specific products that are being developed directly to address needs for terrestrial transport applications.

Air transport

While limited, Copernicus delivers a few air quality products to support air traffic management and air safety as well as land products for civil engineering purposes as well as air quality and climate relate products for air traffic operations.

User Community

Includes pilots, airports, and the European Aviation Safety Agency.

User Needs addressed by Copernicus

Similar to terrestrial transport, Digital Elevation Models and geophysical parameters for civil engineering applications are available via the land service.

To support air transport and air traffic control needs, ECMWF provides real time volcanic ash information to mandated entities such as WMO and the Volcanic Ash Advisory Center. Data on pollutants affecting aircraft operations is also available via CAMS to support air traffic operations and identify risks.

Current, past. and future climate data is available at a 15km resolution, but has to be interpolated at the airport level due to limitation of resolution of products.

Gap Assessment

No specific gaps were identified in consultations for this application.

Maritime transport, navigation, and safety

Copernicus operates a comprehensive maritime surveillance service, as well as a marine service that provides ocean information to describe the marine environmental conditions for safe sea shipping.

User Community

Maritime authorities including coast guards and maritime rescue coordination centre, citizen sailors, and routing services operated by the private sector.

User Needs addressed by Copernicus

The marine service develops relevant products and services including sub-mesoscale ocean dynamics and met-ocean conditions that can be used to support transport operations.

Needs from maritime rescue coordination centres including detection of a missing target or oil spills are currently being addressed. While emergency support service is beyond the scope of the CMS service, EMSA provides technical and scientific assistance to MS and the Commission concerning accidental or deliberate pollution by ships. Moreover, upon request, EMSA extends support to EU Member States in search and rescue operations.

Gap Assessment

While a product is available for the detection of small icebergs through CMEMS, the reliability is currently not very high and would require new technologies or sensors to provide an improved product.

There are gaps in detection of 'dark' vessels that do not transmit data via vessel positioning systems, for example, vessels that could be in distress, illegal vessels or unregulated vessels. While optical and SAR sensors are already being used for this purpose, the use of satellite-based RF data would bring significant added value and would be an additional source of data, particularly if deployed in quasi real time (up to 15 minutes from acquisition) and with a high level of accuracy (up to 100m).

3.1.6.6.Energy

Energy transition and Public action

Many products from Copernicus such as fire radiative power, aerosols, ocean winds and waves, currents, are used for the development of solar and marine renewable energies solutions, and SAR Sentinel data and marine products are used by the oil and gas industry.

User Community

Public sector at European and national level in charge of energy regulation, traditional network utilities sector, potential end-users from the industrial renewable energies sector, climate, and research actors.

User Needs addressed by Copernicus

Seasonal forecasts are made available by ECMWF to perform studies and validate renewable energy choices. Additionally weather forecasts such as intra-day and day-ahead forecasts are available. The Copernicus thematic hub for energy is being developed to support the energy sector under the changing climate. For solar energy, solar radiation products are being developed to support across the value chain. For wind energy, wind data is provided at several heights by ECMWF.

To support regularly monitoring of global biomass changes in third countries to prevent possible adverse environmental impacts on EU biofuels procurement, products available through the global land service can be utilised. For example, through vegetation products, biomass changes in certain countries that are being monitored can potentially be linked to socio-economic data to carry out such assessments.

Gap Assessment

No specific gaps were identified in consultations for this application.

The energy markets

The energy private sector is active in using Copernicus products to develop renewable energies and for oil and gas operations.

User Community

Diverse private players across oil & gas and renewables sectors.

User Needs addressed by Copernicus

Oil and gas industry users are seeking dynamic information like ground motion to monitor changes in the terrestrial environment to support exploration and exploitation of infrastructure above and below ground. The European Ground Motion Service developed by EEA can support users through analysis of ground movements to protect their infrastructure and potentially support public interest by identifying seismic risk due to oil & gas activities.

For oil and gas applications, the marine service provides information on tides and waves, intrusion of unsalted waters, and sea ice. Products currently under development include seabed mapping and bathymetry.

For marine renewables, the target resolution is 1km for all regional seas as provided by the marine service and can go <1 km in collaboration with MS for required applications. Sub-mesoscale phenomenon like interferences between plant and waves, representation of tides into models, improved local wind and wave information, vertical and horizontal gradients in salinity/temperature, and improved boundary conditions for local ocean or hydrodynamic models are available.

Gaps planned to be addressed by Copernicus

Information related to density, plumes, and coastal resolution including interferences with watersheds, estuaries is currently not available. Improved coastal information requires dedicated collaboration with the Land service as well as additional funding for the Coastal hub.

Information on continental ice needed for most oil and gas extraction areas is currently not available, but could be supported by CRISTAL.

Gap Assessment

No specific gaps were identified in consultations for this application.

3.1.6.7.Raw materials

Copernicus does not deliver many products for raw material identification yet. However, environmental conditions of soils and land use are available.

User Community

Mining companies, waste management companies, manufacturers in the sector energy, electricity, composites, and battery, and in the public domain: geological survey institutes, geologists, geographical institutes, environmental agencies, marine and water management administrations.

User Needs addressed by Copernicus

For user needs related to mining exploration and exploitation activities, products related to surface water, soil wetness and vegetation, are currently available through the land service.

Users are seeking improved spatial resolution for mining prospection and exploitation activities on a local scale as well as global coverage targeting specific opportunities in third countries. While the services are currently not developing specific products for this application, the JRC has products that can be used, and the service can be activated by authorised users to monitor mining hotspots, for example, there are ongoing mining monitoring efforts in national parks in Africa led by the EU.

Gaps planned to be addressed by Copernicus

Detailed assessment or identification of raw materials is currently not possible as there is currently no input data from Sentinels to determine soil composition and chemical content. The Copernicus Hyperspectral Imaging Mission for the Environment (CHIME) planned to be launched in 2028, will provide inputs that could be used for development of products related to soil chemicals.

It is possible to monitor mining activities at a high resolution, however, it is not currently available at a global scale. The Copernicus Contributing Mission can provide support on this side, allowing higher resolution also for environmental products.

Gap Assessment

No specific gaps were identified in consultations for this application.

3.1.6.8. Air quality

Through CAMS, Copernicus provides hourly air pollution forecast bulletins with content in aerosols and dust, pollens, fine particle matters, ozone, carbon monoxide, sulphur dioxide, nitrogen dioxide and other gases or pollutants. It also includes the monitoring of the ozone layer and solar radiations. Data are also available as daily means and climate records to support trend analysis and planning.

User Community

Includes national to local level by public authorities such as institutes in charge of environment and industrial risk, agencies for sanitary security, universities, or cities. The private sector is beneficiary of air quality data to develop information services for citizen and health services. Industry is interested in air quality monitoring to develop industrial practices compliant of air quality standards, to monitor risk of pollution but also in the event of air pollution could affect their production.

User Needs addressed by Copernicus

CAMS is providing detection and forecast for six different types of pollen with plans to go up to 10 subject to further evaluation and quality control.

To support needs of local authorities, air quality values are available from multiple sources including electricity and heat production, petroleum refining and storage, fire smokes, agriculture. Specifically, the origin of pollution and breakdown of particulate matter is available for all European cities with a population greater than 500,000. Additionally, air quality is being monitored hourly at the sub-national scale. Additional parameters such as

ultrafine particles and CH₄ are being delivered. Several gases, aerosols, and pollutants at fine scale are being observed both in total column and all along the vertical profile, at sampling points and also covering larger geographical regions.

To aid the development of forecasts at a local scale, real time observations and short-term forecasts are available at a local scale across Europe, with point forecasts provided where observations are available from EEA.

Long-time series of air quality data is available for 20 years at the global level and 10 years at the European level based on availability for reporting, monitoring of benefits of policy implementation, and risk prevention planning.

To support trend analysis, decision making, and impact assessments, ozone and UV monitoring is provided through CAMS including quality-assured information about the state of the ozone layer.

Gap Assessment

Observations of trace metals in air quality is currently not being developed as it is currently difficult to do so. Future projections for air quality are currently not being developed due to budget limitations, however the need has been noted.

3.1.6.9. Health

Copernicus delivers products directly of benefit for health primarily in the area of air quality and pollens forecasts.

User Community

Cities, environmental agencies, urban planners, transport authorities and citizens.

User Needs addressed by Copernicus

While there are no specific products being developed for health currently through the land service, EEA is starting to collaborate with stakeholders in the sector.

As mentioned in the previous section, CAMS is providing detection and forecast for 6 different types of pollen with plans to go up to 10 subject to further evaluation and quality control.

The European Health Service, developed within C3S, has been very active, especially during COVID to determine the effect of particulate matter on COVID. The service also provides information on the impact of weather parameters, such as temperature, looking at the impact of heat waves on health.

The C3S Health Hub, launched in June 2023, aims to support user needs related to physical health, mental health, and well-being, with products from all Copernicus services. Products from the different services such the impacts of thermal stress, information on water pollution or ocean acidification, data on soil contamination or pesticide use, flooding data can support several use cases in the health segment.

Gap Assessment

No specific gaps were identified in consultations for this application.

3.1.6.10. Tourism

Copernicus does not target this sector of activity in particular, but it can provide some air quality, climate, and land use change information.

User Community

The supply chain (agriculture, civil engineering etc.), the tourism service providers (food and drink, accommodation, travel agents, transport, and logistics) and the support services (energy, waste, water supply), local administrations.

User Needs addressed by Copernicus

While there are no specific products being developed for tourism currently, EEA is starting to collaborate with stakeholders in the sector.

C3S provides information on climate change impacts on snow-covered surfaces and beaches for tourism applications, as well as identification of potential hazards. CAMS provides air quality information in areas of mass tourism.

Gap Assessment

No specific gaps were identified in consultations for this application.

3.1.6.11. Climate change

CO₂ and other long-lived GHG anthropogenic emissions monitoring

Copernicus already monitors some greenhouse gases with observation, daily and hourly forecasts but also climate records and long-term projections. Gases are monitored in total along the column at pan-European and global scale.

User Community

EU Member States are the primary users for this application.

User Needs addressed by Copernicus

CAMS will deliver CO₂ and CH₄ emissions information through the CO₂ Monitoring and Verification Support Capacity (CO₂MVS), including detection of emitting hotspots and monitoring of hotspots. The CO₂M mission, expected to be launched in 2026, will provide improved observations to support CO₂ monitoring applications. Countries, such as Germany, are already using CAMS information for UNFCCC reporting, and the addition of CO₂M along with the NCP programmes will increase uptake for CO₂ related applications.

Gaps planned to be addressed by Copernicus

While CO₂M is expected to be launched soon, only 2 satellites are currently in the pipeline with the 3rd satellite has been put on hold due to budget constraints. This is expected to impact revisit time and will not provide the optimal solution. However, ECMWF aims to adapt the solutions and is already making several developments to begin using CO₂M data as soon as it is available.

Gap Assessment

No specific gaps were identified in consultations for this application.

Adaptation to Climate Change, Member States needs and local level

Copernicus delivers relevant information on land use and land use change that can support the development of climate mitigation and climate adaptation strategies at European, national, regional level. Climate records of the past and seasonal forecasts are available for the atmosphere and the marine areas. Climate projections are available mainly for describing the behaviour of the Earth system (air, land, water).

User Community

Member States and local authorities are the key users.

User Needs addressed by Copernicus

The downscaling of products to meet needs at the local level will be carried out by C3S in ERA6, improving resolution by 2-4 times, with production starting in Q3 of 2024. Copernicus data and information services in the CDS are available to users through the Climate-ADAPT platform. ECMWF is providing climate data corresponding to the climate and weather variables that are relevant for the Eurocodes used for structural engineering. Additionally, the products are being developed further through the energy hub to provide information on energy efficiency of buildings.

Gap Assessment

No specific gaps were identified in consultations for this application.

Adaptation to Climate Change and the private sector

User Community

Sectors including building, energy, transport, agriculture and forestry sectors or cities planning.

User Needs addressed by Copernicus

Similar to the previous application, ERA6 will provide a better resolution to support entities at the local level to develop relevant climate adaptation and mitigation strategies. Additionally, ECMWF is also working on providing data at a decadal timescale. Additionally, in order to improve transparency efforts reference datasets are being provided with the available data.

Gap Assessment

No specific gaps were identified in consultations for this application.

Climate science and International cooperation

Copernicus provides a significant contribution to the international reporting in terms of climate change, including providing essential climate variables at the international level, publishing ocean monitoring indicators and participating in WGs from climate actions.

User Community

Research institutes, national meteorological and climate services organised in working groups and acting for the United Nations Framework Convention on Climate Change

User Needs addressed by Copernicus

C3S is providing the Essential Climate Variables that the users are seeking, including carbon dioxide partial pressure, ocean acidity, permafrost, above-ground biomass, CO₂, CH₄, and O₃ column and profile measurements. Constituents of the atmosphere such as the aerosol optical depth and cloud products are available. Needs from the European Space Agency Climate Modelling User Group related to temporal resolution, vertical resolution and accuracy are being met by the current products, with limitations only in horizontal resolution.

Gaps planned to be addressed by Copernicus

For aerosols, while short term forecasts are available, future projections are currently unavailable. With regards to improved resolution needs, required vertical resolution has been achieved, however, horizontal resolution of 10km is not available. While the ERA6 product mentioned in previous applications will reduce the resolution significantly by 2-4 times, it

will reach ~18km. This is limited primarily by cost, including computational costs and costs related to verification and quality control.

Gap Assessment

No specific gaps were identified in consultations for this application.

3.1.6.12. Humanitarian aid and civil protection in Europe

Support to natural and man-made disasters

Copernicus operates an emergency service to provide fast response to major disasters with two services: rapid mapping of the situation adapted to the type of disaster, in the following hours of occurrence, and recovery mapping after the event, to monitor in time how the situation is recovered by the local authorities and the population.

User Community

Authorised users are the civil protection, local authorities, and national administrations.

User Needs addressed by Copernicus

Services developed under CEMS rapid mapping include pre-event information, impact assessments (fast and detailed) and detailed damage assessments. The service covers several types of disasters including fires, floods, droughts, earthquakes, volcanic eruptions, storms, cyclones, landslides, and ground deformation.

CEMS provides a risk and recovery service which meet user needs for risk prevention preparedness, disaster risk reduction, and recovery phases across several applications.

CEMS has an early warning system in place which provides continuous monitoring and forecasting at a European level for fires, floods, and droughts.

A newer service made available through CEMS is exposure mapping, which provides highly accurate and continuously updated information on built up infrastructure and population mapping with 10m resolution.

Overall, the CEMS service is aiming to continually improve the service to provide better resolution and faster response as well as improvements in algorithms and forecasts to remain state of the art.

Gaps planned to be addressed by Copernicus

There is a gap in the flood awareness systems for coastal flood monitoring which CEMS is hoping to add to the early warning system.

Fast response of fire outbreak detection in less than 15 minutes is not possible as the limiting factor is the time taken to acquire the satellite imagery. While there are efforts to streamline efforts to acquire data from Sentinels and CCMs at a faster rate, the current response rate is between 8-24 hrs.

Gap Assessment

For users seeking hourly updates, this is not possible due to the temporal resolution of satellites and would require a GEO SAR satellite for hourly updates. For optical data from Sentinels, there is also the limitation of temporal resolution.

3.1.6.13. International development and cooperation

International cooperation with developing countries

Copernicus supports developing countries in cooperation with Commission services by providing products on vegetation, cryosphere, and water on pre-identified hotspots identified with the European public partners.

User Community

While users can be diverse in an international context, and no specific types of users are targeted, Copernicus can be used to support dedicated programs and developments in other countries.

User Needs addressed by Copernicus

Users are seeking monitoring of hotspots for economic and rural development and biodiversity conservation which is currently available through the global land service through projects such as Nature Africa. In addition to environmental protection, the service enabled economic benefit in surrounding areas.

Copernicus services are also addressing food and water security applications, including water related products such as water temperature and water quality, land cover mapping phenology and crop type mapping for food security related applications.

For user needs related to supporting national disaster risk reduction strategies and risk prevention in developing nations, there have been a lot of new developments within the emergency service. This includes drought early warning and monitoring system, which are very useful for areas within Asia and South America for drought risk prevention. The new exposure mapping component provides data which enables calculations on the impact of the disaster, in addition to creating prevention strategies. Risk and recovery mapping components, enable applications for risk prevention and assessment. Additional products include, but are not limited to, tsunami risk assessment, wildfires, and post-event analysis on floods.

The global land service is providing a 300m resolution for all global land products with an aim to further improve resolution up to 10m.

Gap Assessment

No specific gaps were identified in consultations for this application.

Rural development, Food and Water Security

User Community

While users can be diverse in an international context, and no specific types of users are targeted, Copernicus can be used to support dedicated programs and developments in other countries.

User Needs addressed by Copernicus

The Copernicus services provide relevant information to support land use and rural development mapping in the field of agriculture, forest management, water management. For early warning systems, the emergency service has developed a global flood forecasting system that provides an improved risk assessment. For prevention of food crises, the services provide relevant data such as rainfall and vegetation phenology that can be used to determine vegetation stress and consequently provide inputs. A global drought observatory was developed which provides information on food crises.

For land governance applications, while there are no specific products develop, hotspots monitoring provides information about protected areas, development of new roads, agriculture fields (land management). For natural resource monitoring, there are applications for vegetation mapping or land cover than can support use cases.

It is important to note that while the Copernicus services provide products that can support several applications, it would require further development or integration with other data to provide solutions to meet some of the user requirements.

Gap Assessment

No specific gaps were identified in consultations for this application.

Humanitarian aid and emergency management beyond EU

Emergency management as operated for the EU countries is accessible at global scale to authorised users in the event of major disasters that request international assistance.

User Community

Civil protections, operators on the field, local to national administrations from countries in distress.

User Needs addressed by Copernicus

ECMWF facilitates the use of data for services supporting the development of climate resilience policies and actions similar to the Europe in third countries affected by cyclones, sea level rise, major floods and desertification as all data is available at the global level.

Products developed by CEMS as described in the section above related to humanitarian aid within EU are also relevant in addressing user needs at an international scale in terms of in terms of risk prevention mapping, timely disaster response and recovery mapping. CEMS has an early warning system in place which provides continuous monitoring and forecasting at a global level for floods and droughts.

Gaps planned to be addressed by Copernicus

For the early warning and monitoring system, forest fires are only monitored at the European level. While there are plans to expand to a global level the service is limited by availability of data, as it would require the use of third country satellite data.

Gap Assessment

No specific gaps were identified in consultations for this application.

3.1.6.14. Migration and Home affairs

The Copernicus component already runs some services related to policies under migration and home affairs through the security service.

EU border surveillance

User Community

Security services are accessible only to authorised users in accordance with the Copernicus Regulation.

User Needs addressed by Copernicus

FRONTEX provides a guarantee of service for border surveillance applications.

To improve reactivity of the systems, users are seeking automation of ordering of several satellites over critical areas and/or during critical periods which is currently available through the service.

FRONTEX is coordinating the EUROSUR fusion services to cooperate with other agencies and benefit from other services for maritime surveillance, support to external action or monitoring of environment that can be provided by existing Copernicus services.

The European Border and Coast Guard Agency addresses several needs including provision of monitoring services for external borders of EU and third countries through agreements, including monitoring and tracking of illegal activities.

Gap Assessment

Users are seeking increased temporal and spatial resolution in services. Higher revisit frequency (~2 hours) is not available for VHR sensors ($\leq 50\text{cm}$) over an AOI due to a lack of several satellite constellations offering such capabilities. Higher resolution for electro-optical sensors ($< 30\text{cm}$) is not available from commercial satellite imagery providers. Constant monitoring of an AOI is also not possible as it would require geostationary satellites for surveillance purposes.

For night time optical satellite imagery, current available solutions do not meet the requirements for border surveillance. For video footage with optical sensors, current available solutions do not meet the requirements for border surveillance (e.g., maximum length of video etc.)

Police investigations

User Community

Security services are accessible only to authorised users in accordance with the Copernicus Regulation.

User Needs addressed by Copernicus

User needs for police investigations are currently not being addressed by the security service. While data and products may be available to support applications, there are no mandates or direct efforts to support law enforcement through the Copernicus services.

Gap Assessment

Currently no services are available for this application.

Critical infrastructures

User Community

Includes national and regional authorities in charge of territories hosting critical infrastructures.

User Needs addressed by Copernicus

Monitoring of critical infrastructures is currently limited to maritime and infrastructure around borders.

Gap Assessment

As per user needs, monitoring of critical infrastructures has currently not been extended to energy, water, health, information and communication technologies networks, communications.

3.1.6.15. Security policies

Support to EU external action

Typically managed by SatCen, however out of scope of assessment as CA has not been signed with SatCen and no consultations were carried out.

Maritime Security

The Copernicus CMEMS and CMS services currently supports the development of products and services for maritime security including protecting the EU strategic maritime interests such as overall security and peace, external border control, maritime infrastructures, and climate change.

User Community

Law enforcement, border control, customs and fisheries inspection, environmental authorities, maritime administration, research and innovation, navies or other maritime forces, coast guards, intelligence agencies, EU agencies and all relevant international partners and organisations, in particular the United Nations and the North Atlantic Treaty Organisation (NATO).

User Needs addressed by Copernicus

CMS provides in quasi-real time (20 to 30 minutes) high-quality satellite-based SAR and optical image products with a variety of resolutions and sensor types, as well as several products including oil spill detection, vessel detection, feature detection, activity detection, change detection and SAR wind and wave products.

CMS users also benefits from other datasets offered by EMSA, such as vessel detection traffic systems, Automated Behaviour Monitoring algorithms for the detection of specific or anomalous ship behaviour, and external data sources (e.g., intelligence data provided by users), to enrich the maritime awareness picture delivered to the end-users, optimizing surveillance efforts and deployment of on-scene assets.

An on-going project is developing an AI/ML-based tool capable of processing EMSA's vast database of EO satellite images to automatically generate value-added products for EMSA's EO operational services. The initial aim is the generation of vessel detection and vessel classification, and afterwards progress to more complex products (e.g., feature detection and oil spill detection).

Gap Assessment

Very high resolution (< 0.5m) and high resolution (1 to 10 meters) images are crucial for a wide range of use cases, benefiting all of CMS function areas, as well as availability in near real time. Moreover, the fast-tasking capability is also key, enabling quick responses to emergency situations.

In the scope of the space component, EMSA up to now has not identified a space-based solution with the required accuracy to monitor the emissions of individual ships. This would be a significant asset to support member states ship emission monitoring efforts and deployment of on-scene assets.

3.1.6.16. Cross-cutting functional needs

Cross-cutting needs are identified from all types of users and are typically agnostic to the type of applications or services. They are typically linked to the overall Copernicus component, and they are subdivided into data acquisition, data processing and quality control, data ordering and delivering, data archiving, and discovery, interoperability, and standards.

Data acquisition

User Needs

User needs include an increased flexibility and predictability in the acquisition of data: from 1 to 3 hours (Near Real Time) even if it implies prioritizing speed over image quality, in particular for security; improved coordination with users, improved combination of satellite imageries (thus compatibility), and finally the automation of selecting and planning acquisition of data in case of rapid mapping. Related to the Contributing Missions, users request transparent access conditions, user-friendly access, more certainty in data acquisition plans and a need for reference data.

User Needs addressed by Copernicus

The Sentinel instruments have been established as global references in terms of data quality, providing opportunities for users and at the same time allowing to collect new user needs in terms of resolution, revisit, or specific complementing measurements. Sentinel data acquisition and quasi-real-time production (local stations) can provide a regional (within the station coverage) quasi-real-time (10-15 min from sensing) data service via Sentinel collaborative (local) stations. ESA normally supports operations in terms of mission planning (acquisition scheduling including all auxiliary information) over the local geographical area of interest and provision of satellite-to-ground interface information. Examples of quick and effective acquisition of Sentinel data are many. The Municipality of Thessaloniki acquired a new Satellite data service that allowed to have access to near real time Sentinel 2 and 3 satellite data, supporting various needs such as Urban Environmental Management or the Civil Protection. In Italy, during the floods in Emilia Romagna (2017) and when a forest fire occurred on the sloped of Vesuvius (2017), satellite data from Sentinels 1 and 2 were acquired in few hours and the deployment of rescuers was optimised.

Additionally, the establishment of the Dynamic Purchasing System (DPS) improved the data acquisition process from CCMs. The DPS provides a new way to procure data from contributing missions by improving accessibility, streamlining the procurement process, and reducing administrative burdens for entities. This system has enabled an increase in the number of CCM data providers, particularly NewSpace players.

Data processing and quality control

User Needs

User needs include improved responsiveness between data acquisition and delivery, remote big data processing and cloud processing capabilities, improved processing with generic standardized algorithms, and automation of processing. Improvements in the quality documentation are required, and concepts of quality indicators should be generalised to all services.

User Needs addressed by Copernicus

As mentioned in the ESA Long Term Scenario document, a ground segment transformation process was triggered and completed in 2022 to respond to the challenged faced in the CSC ground segment operations. Challenges include evolution and optimization of the service, risk reduction, performance increase and new missions/satellites smooth integration. The transformation allowed to significantly reduce the relative operational costs, increase the flexibility and resilience. The CSC Production operations involve a series of tasks necessary for processing acquired Sentinel satellite data, which includes user level data, engineering data, and HKTM (L0 level). This ensures that the data meets quality standards and is accessible for archiving and user retrieval. Systematic production is responsible for generating a predetermined set of User Level Data tailored to each Sentinel satellite based on associated User Level Data and timeliness criteria. The outputs are specific to the mission and instrument. All Sentinel production services adhere to consistent interfaces, performance

criteria, and expected service outputs, ensuring transparency and interchangeability from a user's perspective. Each Sentinel production service functions independently for its mission, with production operation sharing coordinated by ESA. The performance of Production operations is monitored through a Service Level Agreement, with standardized indicators covering production completeness, timeliness, data processor anomaly reporting, and PRIP (pick-up points) availability. The operational processing of satellite data into Level-0 and Level-1 User Level Data for Sentinel satellites relies on well-defined processing algorithms. The operational implementation and maintenance are tailored to the specific operational environment and requirements, including processing performance, scalability, and optimization for particular computing environments.

Data ordering and delivery

User Needs

User needs include facilitate user-friendliness in terms of interfaces, transparency, and common open standards. Moreover, an improvement of the overall data delivery time for emergency specifically and an improvement in the accessibility as well as in the delivery format are specified as needs.

User Needs addressed by Copernicus

Data Access is a common service for all currently active Copernicus missions, presently offering data access for all ESA-operated Sentinel missions as part of operational service provision. This Data Access service offers customizable access options for various user categories (including Open Access, Copernicus service, Collaborative GS, International partners, etc.). On top of that, the Copernicus Data Space Ecosystem has been implemented, offering immediate access to large amounts of open and free Earth observation data and scalable interfaces, both for new and historical Sentinel images, commercial datasets, as well as Copernicus Contributing Missions. Regarding other aspects, the User registration follows user categories, featuring self-registration (web-based) for Open Access and operator-managed registration for other services. Access policies are adjusted accordingly, including parallel download quotas. User information is managed in compliance with relevant personal data regulations, aiming to collect and retain the minimum necessary information for data access and reporting. The Data Access function ensures the immediate availability of a configurable volume of data, ranging from one year to the entire mission duration. Data that is no longer immediately accessible remains available to users through the same data access interfaces by initiating retrieval from a data archive or on-demand processing. Data retrieved in this manner are stored in a cache for a configurable period. Among the use cases of Copernicus data friendliness there are many startups, the DIAS and now the CDSE.

Data archiving

User Needs

Data archives to extend to several years, available as 'hot' storage with data accessible in a matter of seconds to remain suitable of performances needed for large scale processing

User Needs addressed by Copernicus

The data preservation function, carried out through the Long-Term Archive (LTA) element as an operational service, is responsible for storing essential mission data. The LTA service's scope is uniform across all missions, designed to be Sentinel-generic and meet the archiving requirements of any Copernicus mission. Geographical redundancy and secure storage for all Sentinel missions are ensured by having multiple LTA service instances in the Ground Segment (GS) architecture. Depending on their capacity and cost efficiencies, the same LTA can serve a single Copernicus mission or multiple missions. As a general practice, each LTA manages an Archive Interface Point (AIP) in a cloud-based environment to provide access to requested data. LTA services operate autonomously and are governed by service providers

who adhere to ESA's service management requirements and service level agreements. ESA assigns LTA services to providers through standard procurement processes. Qualified services are managed through framework contracts, allowing providers to access sample data for operational preparations. Routine LTA service operations are monitored through reporting and monitoring interfaces, integrated into End-to-End (E2E) operations monitoring, and supported by dedicated dashboards for each service.

Discovery, interoperability, and standards

User Needs

Data and information products or functionalities covered by Copernicus, including metadata content, could be compliant with the implementing rules and technical guidelines of the INSPIRE Directive.

User Needs addressed by Copernicus

The INSPIRE Directive, establishing an infrastructure for spatial information in Europe to support Community environmental policies, and policies or activities which may have an impact on the environment entered into force in May 2007. All entities that manage Copernicus Contributing Missions are required to provide metadata that meet or exceed the requirements of the European Commission's INSPIRE Directive. The directive aims to create a common spatial data infrastructure for European Union policies and activities that impact the environment, making it easy for public sector organisations to share environmental spatial information and facilitating public access to this type of information across Europe.

Under the leadership of ESA, the Copernicus Contributing Mission Entities agreed on a common approach to data provision, using an XML format metadata file that complies with the INSPIRE Directive and ensures consistency and harmonisation across missions. The metadata are compliant with ISO (19115 and 19139) standards covering dataset language, reference, description, geographic location, temporal extent and date of revision, responsible party contact information, resource location and quality information including product lineage.

3.1.6.17. Takeaways on Relevance Assessment of Copernicus

This section will highlight the results of the relevance assessment of the Copernicus component.

At a high level, out of the ~40 applications that were assessed, around half the applications were identified to still have at least one gap in user needs. However, nearly 90% of these gaps are planned to be addressed or are under consideration. Therefore, it can be deduced **that over 90% of identified user needs are either being met or planned to be met** through the current and future Copernicus offerings.

Regarding the user needs collection and implementation, the **entire process is continuous and exhaustive, taking into account inputs from multiple sources**. However, users have raised concerns about the user needs collection taking a top-down approach, whereas a bottom-up approach could provide a more holistic view of user needs. For example, the user needs document from 2019 takes into consideration intermediate user needs, but **end user needs are not accounted for to the same extent**. Additionally, concerns were raised about the User Consultation Platform developed by EUSPA for Copernicus. The UCP was originally created for Galileo, and the same approach might not work for Copernicus as the components are structured very differently, and it would be difficult to get a complete picture with the current approach. As there are other activities already in place for user needs, the UCP can be redundant and may not be filling necessary gaps in terms of user needs collection or user uptake. Additionally, the UCP is not widely known among user communities.

In terms of gaps identified, overall, there are **no critical gaps identified in user needs** across the various segments, however there are a few **priority application areas** that were highlighted by entrusted entities and users during stakeholder consultations, including **soils, coastal, biodiversity, climate change, and arctic & polar areas**. For soils, needs related to soil composition and chemical content are expected to be met by planned missions such as CHIME, LSTM and ROSE-L. CHIME and ROSE-L will also support the development of enhanced biodiversity management applications. For coastal applications, increased collaboration between the land and marine services, and the Coastal hub are expected to address several needs. For climate change, the CO2M mission is critical to support monitoring applications. Planned missions, ROSE-L, CRISTAL and CIMR aim to support several applications for arctic and polar areas.

For the user needs that are currently not being addressed or are not planned on being addressed, the two key constraints are financial and technical. Where there are budgetary constraints, entities are expecting to address needs in future evolutions of the service. Where there are technical constraints, for example, limitations in sensor technology, spatial resolution or revisit, the requirements are noted to be potentially addressed by future missions or CCMs. Some needs however cannot be addressed by Copernicus, as they require revisit or resolution that cannot be achieved, at least in the near long-term, for example, revisit of <1 hour or <0.5m resolution.

Overall, the services are under continuous development, providing improved products, as user needs continue to evolve. The interventions carried out by the entrusted entities within the Copernicus component are therefore **highly relevant in addressing user needs**, with only a few minor gaps to be addressed.

3.1.7. EU Added Value

This assessment of the Copernicus component aims to primarily determine the added value achieved by the component as a whole, beyond what would have been achieved by Member States acting alone. It provides a qualitative outlook of the performance of the component compared to what could be achieved on a national scale from the perspective of users, Member States, and the overall perception on an international scale.

The **Copernicus Component has provided significant added value** on a European and global level. It is a **leader in providing free and open EO data of the highest quality**, and has put Europe on the map, with **increased visibility of the EU** that didn't exist a few years ago in key areas such as climate change and disaster management, among others. It is a one-stop shop portal, providing access to a wide array of data, products, and services.

In addition to the free and open data policy, Copernicus provides data and services at a global scale ensuring a **consistently high level of quality**. Additionally, the component can only be sustainable at the EU-level, through next-gen missions enabling continuity of service and expansion missions aiming to address high-priority challenges in the mid-long term. As noted by several MS, the development and management of a program at this scale would be very difficult to achieve on a national level, both fiscally and operationally. Additionally, as **continuity is guaranteed, the services are considered to be trustworthy and reliable**, and therefore are more widely adopted and integrated into operational services at the national level. The success of the Copernicus program at EU level can also be reinforced through the high user satisfaction seen across all the services.

There are several needs across the EU that require a common response, therefore it is key to **share resources and work together to serve the common needs**, which is what is enabled by the Copernicus component. A key benefit of Copernicus at the EU level is that it can impact policies and regulation at the EU level which consequently supports regulations at the national level. Additionally, on a strategic level for the EU, Copernicus serves as a joint tool to provide strategic insights at a global scale, for example through global monitoring of land

and oceans. This enables the EU MS to remain non-dependant on third countries, another benefit that cannot be fully realised independently at the MS level.

Copernicus is supporting several third countries with remote sensing information, particularly where in-situ data is unavailable, which is only made possible due to **efforts at the EU level to jointly support the global community**. Copernicus is also playing a critical role at the global level, including supporting efforts related to climate change adaptation and mitigation including the Paris Agreement and UN SDGs, and supported non-EU countries through disasters with the emergency service. These activities through Copernicus have played an increasingly important role in the EU's bilateral relations with international partners, **opening up diplomatic routes and strengthening the EU's diplomatic ambitions**.

Copernicus also enables **EU wide collaboration**, providing the opportunity for MS to collaborate on projects among each other as well as with third countries. This includes providing the European EO sector, that is developing products and services using Copernicus data, **access to international markets that leads to recognition and growth** of EU industry across the globe.

As seen above, Copernicus is a leading provider of quality EO products and services with **high EU added value**. It benefits users from a local to an international scale, stimulates the European industry, and helps strengthen diplomatic relations, all of which is achieved through the joint efforts of the Union.

3.1.8. Policy Coherence

The policy coherence assessment can be segmented into three areas of coherence:

- Between Copernicus and EU & international policies
- Between the various Copernicus Services
- Between Copernicus and the rest of the Union Space Programme

Coherence between the implementation of Copernicus and various EU and international policies

For coherence with EU and international policies, similar to the relevance assessment in the previous section, the team has extracted the relevant policies from the user needs report that are applicable to the various segments supported by the Copernicus offerings. In addition, the team updated some of the relevant policies based on consultations with the entrusted entities to provide a more relevant overview of the current context to carry out the policy coherence assessment. Copernicus plays a key role in several EU and global policies across all services. In addition to directly supporting various policies, Copernicus data and tools are widely used planning and decision making by policymakers from the local, regional, and national levels to EU-level across various segments.

Land Service

The land monitoring service supports several EU level policies, in addition to international initiatives supported by the global land service. Several products within the land cover and land use mapping component support the Regulation on the inclusion of greenhouse gas emissions and removals from land use, land use change and forestry (LULUCF) into the 2030 climate and energy framework. Within the agriculture sector, CLMS is coherent with the Common Agriculture Policy (CAP). It also provides inputs for the Nature Restoration Law which aims to enhance biodiversity in agricultural ecosystems. For regional and urban development applications, the service supports the EU urban agenda, seeking to improve the quality of life in urban areas, through priority area monitoring. Products related to lake water quality and temperature support the Water Framework Directive, aiming to reduce water pollution levels for inland waters. The service also plays a key role in the Forest Strategy with the HRL Forest product and Biodiversity Strategy with products such as HRL Leaf Type and

HRL Small Woody Features. At the global level, land products support several international initiatives including support to UNEP, FAO and World Bank as well as the UN-REDD Programme.

Marine Service

The marine service supports several EU and international policies through ocean physics and biogeochemical data, Ocean Monitoring Indicators, essential ocean variables for ocean health, and the Ocean State Report. The arctic sea ice service supports EU arctic policy aiming to help preserve the Arctic region. The EU Marine Strategy Framework Directive, the EU Biodiversity Strategy, and the EU Habitat Directive are all supported by products developed by the marine service, including monitoring of physical and biogeochemical parameters to provide a better understanding of marine biodiversity and track changes in the marine ecosystems. The EU Strategy on Adaptation to Climate Change, which includes adaptation in coastal regions as they are vulnerable to extreme weather events, is also supported by the marine service through the development of several coastal products. The EU Water Framework Directive commits Member States to achieving good qualitative and quantitative status of all water bodies. The service provides high-resolution water quality data, including ocean colour information, that supports national authorities for reporting purposes. The Common Fisheries Policy is supported by marine service products such as satellite ocean colour and hydrodynamic models to use as a decision tool for fisheries closure and improvement of fish stock estimates. The service is also involved in the EU Green Deal for applications related to marine renewable energy, marine food, biodiversity protection and climate change monitoring.

On the international level, the marine service plays a role in the 2030 Agenda for Sustainable Development, providing an ocean acidification indicator to understand climate change impact on the ocean, which is a relevant indicator to implement UN SDG 14. The service is also involved with EU4OceanObs, an action that directly support EU policies related to the international ocean governance, enabling global uptake of the products and services developed by the marine service.

Atmosphere and Climate Services

The atmosphere service provides inputs to EU and international policies, with a focus on air quality. The service supports the EU Ambient Air Quality Directive which sets legally binding limits for concentrations in outdoor air of major air pollutants, including PM10, PM2.5, NO2, all of which are monitored through the service. The data is used for forecasts, assessments, and evaluation of air quality plans. The EU Effort Sharing Regulation sets national targets for Member States to collectively contribute to an emission reduction at EU level, and the service provides data to measure pollutant levels and emissions at a national scale. The service also provides identification of sources and origin of pollution to support EU and national level legislation aimed at targeting industrial emissions. Both services are also providing key data aligned with the EU Green Deal. Data from the atmosphere service is supporting the H2020 Carbon Dioxide Human Emissions (CHE) project to monitor global to monitor global CO2 emissions. The climate service provides data that supports biodiversity, including datasets, tools and indicators on biodiversity and ecosystem services to understand climate change impact on biodiversity at local to global scales.

On the international scale, the atmosphere service is contributing to international coordination frameworks, such as the Integrated Global Greenhouse Gas Information System from WMO (WMO-IG3IS) and the Committee on Earth Observation Satellites (CEOS). Copernicus data is supporting national inventory reporting of GHG emissions under the United Nations Framework Convention on Climate Change (UNFCCC), Kyoto Protocol and Paris Agreement. The climate service produces Essential Climate Variables to report to the International Global Climate Observing System program (GCOS). Additionally, climate

projections scenarios developed by the climate service are included in Assessment Reports of the Intergovernmental Panel on Climate Change (IPCC).

Security Services

Border surveillance is regulated through the EUROSUR Regulation and the Regulation on the European Border and Coast Guard, supported by the border surveillance service which provides reports, digital products and map products aiming to provide a clear view of the EU external borders for internal security and EU strategic autonomy.

The maritime surveillance service supports the European Fisheries Control Agency, an EU agency mandated is to promote the highest common standards for control, inspection, and surveillance under the Common fisheries policy (CFP), through monitoring of fishing grounds, illegal fishing at sea and ports, and fish farms. The service also supports the EU's maritime security strategy, which promotes international peace and security, as well as respect for international rules and principles, while ensuring the sustainability of the oceans. This includes data to help detect, track, and potentially identify vessels in distress during search and rescue efforts, potential illegal activities, or pollution monitoring (e.g., tracking oil spills).

Emergency Service

The emergency service largely supports the EU Civil Protection Mechanism, aiming to improve prevention, preparedness, and response to disasters in EU and participating third countries. This is carried out through the rapid mapping, risk and recovery mapping and early warning components developed by the service. The service supports multiple policies addressing various disasters, including floods (Floods Directive), droughts (Water Framework Directive), fires (EU forest strategy).

Coherence between the Copernicus Services

The various segments and applications addressed by Copernicus are supported by data and products across all the different services, therefore it is important for the different services to be coherent. Copernicus has started to launch Copernicus Thematic Hubs with a focus on key applications areas. The purpose of the hub is to combine relevant information and products generated by the different Copernicus services or components (space & in-situ) for one thematic area, providing a single point of entry at the level of Copernicus. The hubs aim to facilitate access to a specific user community, improve internal coordination of relevant projects and initiatives, and promote collaboration and synergies between the entrusted entities and services to develop products aligned with the thematic area. The Coastal and Health Hubs have already been launched, the Energy Hub is expected to be launched in November 2023, and an Arctic Hub is also in the pipeline.

The Copernicus Coastal Hub, operated by CMEMS, provides coastal data and information from the Copernicus marine, land, climate, emergency, and security services to support evidence-based decision-making and sustainable management practices for coastal ecosystems. It aims to support implementation of relevant EU policies, and the EU Green Deal through sustainable use of marine resources and resilience to climate change in coastal zones. The arctic hub is also expected to be operated by CMEMS.

In addition to the hubs, the marine service develops products that are highly complementary to the maritime surveillance service. Various parameters such as sea surface temperature, wave height, ocean currents and sea surface height from the CMEMS ocean model help CMS in assessing a more complete maritime surface picture across several applications including fisheries control, law enforcement, maritime safety and security, customs, and marine pollution monitoring.

The Copernicus Health Hub is operated by CAMS but offers access to information products related to health and well-being from all Copernicus services. It supports the provision of

environmental information that are pertinent to health, including physical, mental and well-being. Applications range from heatwave and sun impacts, environmental quality conditions, and epidemiology.

The Copernicus Energy Hub, operated by C3S, is focused on supporting the EU Green Deal and the efforts to make Europe's energy supply more sustainable and secure, with data from all the Copernicus services. The applications will be related production & planning, transmission & distribution, efficiency & emissions, and consumption.

While there are several areas of coherence within the Component, there is also the possibility of an overlap of products being developed in the different services. Based on desk research and consultations, it was found that some similarities could occur within CLMS between activities carried out by EEA and JRC for the global land service, between CAMS and C3S implemented by ECMWF, and between CMEMS and CMS.

Within CLMS, EEA is focused on the pan-European level, whereas JRC provides global products, at varying temporal and spatial resolution. For example, JRC has developed a Dynamic Land Cover product and EEA has developed the CORINE Land Cover (CLC) and CLC+ products. While both of these are land cover products, the Dynamic Land Cover provides a global coverage annually at 100m resolution, whereas CLC+ provides pan-European coverage every 3 years at 10m resolution. Between CMEMS and CMS, while there might be some overlap in products across applications such as pollution monitoring, fisheries monitoring, and maritime safety, the target users widely vary for both services where CMS typically provides high-resolution, near-real time products for authorized users. CMEMS, on the other hand, provides data and products that are freely available to all users. Additionally, products such as iceberg detection developed by CMEMS can support maritime safety applications for CMS. Lastly, ECMWF implements both the C3S and CAMS services. While there is a possibility of some overlap, CAMS is primarily focused on products related to the atmosphere, including air quality, solar energy, and the role of the atmosphere in climate change. C3S on the other hand develops climate datasets and products not only from atmospheric data, but land and oceanic variables, focusing on climate change applications. Therefore, the two services can be considered more complementary than redundant. At a high level, while there might be some overlaps in the products, they are typically addressing different needs for different types of users, therefore the products may not be considered as redundant. Further analysis would be required to provide a more detailed view of potential overlaps in the service.

Coherence between Copernicus and the rest of the Union Space Programme

For coherence with the rest of the Union Space Programme, the team has gathered inputs primarily through consultations to determine current and future potential for coherence between Copernicus and other space programme components including EGNSS, SSA, and GOVSATCOM.

The Copernicus Component is coherent with the EGNSS Component at the downstream services level, across several segments. Sectors such as agriculture and urban planning are two of the key segments where combined applications are being developed, however there are several other segments such as environmental management and monitoring, border surveillance, maritime safety, transport, emergency/crisis management and many more that benefit from these synergies.

For agriculture, several applications can be supported through synergies between Copernicus and EGNSS including environmental management, variable-rate application, harvest monitoring, biomass monitoring, soil sampling, and risk management insurance. For example, crop health, soil moisture and NDVI derived by Copernicus coupled with highly accurate positioning data of the machinery from EGNSS enables more efficient use of resources and a reduction in environmental footprint. Additionally, in support of the Common Agricultural

Policy (CAP), specific tools such as the Farm Sustainability Tool (FaST) leverage Copernicus and Galileo data to provide EU farmers and MS with data to ensure compliance and sustainable farm management.

Copernicus data is largely used to develop layers of maps, and integrated with geo-referencing based on EGNSS to create geospatial products and maps that can be used in a wide array of sectors including urban planning, energy (including renewables), transportation, insurance, tourism, sports and many more. For example, in urban planning, Copernicus data can be used to monitor urban growth, as well as land use and land change over time, while EGNSS data can be used to understand mobility and geo-locate utilities and infrastructure. This combination of data would enable public authorities and urban planners to design smart cities, plan new infrastructure, and help track compliance with environmental legislation.

In the aviation sector, Copernicus data is used for emissions monitoring, and EGNSS positioning data from airplanes can better support predictive models to reduce environmental impacts. There are significant overlaps between the use of Copernicus and EGNSS in the marine sector, such as maritime surveillance, maritime spatial planning, and fish stock monitoring.

Within emergency management and humanitarian aid, Copernicus and Galileo provide joint support across several applications. For disaster preparedness, the monitoring of events such as landslides, tsunamis, earthquakes, or volcanic activities is heavily helped by both the components. For post-event recovery applications such as damage assessment, building inspection and restoration of the infrastructure service, coordination of Copernicus services and Galileo services is key. In the humanitarian aid field, health and medicine response and coordination in the case of a disaster is supported by EGNSS through geo-localization of people, and Copernicus through population monitoring.

A call was launched through Horizon Europe for the development of EGNSS and Copernicus applications fostering the European Green deal across several applications including clean energy, natural hazard mitigation, sustainability & smart mobility, biodiversity and overall, increasing the EU's climate ambition for 2030 and 2050. Such initiatives aim to stimulate the development of new downstream solutions based on synergies between the two EU space programme components.

Within the SSA component, the SST sub-component was created to ensure long-term availability of European and national space infrastructure, facilities and services which are essential for the safety and security of the economy, society, and citizens of Europe. SST aims to prevent damages to EU Space infrastructure, including Copernicus infrastructure, which is essential for the continuity of the services provided by the component. By safeguarding these assets, SSA plays a crucial role in ensuring that the essential services are delivered efficiently to the end users and can therefore be considered as highly coherent with the Copernicus component.

Copernicus is also coherent with GOVSATCOM, the component created to provide secure and reliable communication capabilities to EU and national actors engaged in critical missions that could be affected by a range of threats from natural disasters to cyber-attacks. These capabilities are crucial in situations where ground-based communication systems may be unavailable, for example if such systems are non-existent (in remote regions or high seas for example) or if they are disrupted or unreliable (in the wake of natural events such as earthquake or deliberate acts). In this perspective, GOVSATCOM will support public and governmental actors in events such as natural and man-made disasters, humanitarian crises or missions related to the Common Security and Defence Policy (CSDP) missions and will provide them with a portfolio of secure communication services. This aligns seamlessly with the Copernicus Emergency Management Service, as GOVSATCOM can augment the existing service by delivering secure communication solutions during disaster management activities.

In a similar way, GOVSATCOM can be used to support surveillance operations by providing surveillance actors with features such as transmission of high-resolution radar and optical images or secured access to specific information systems. These actors can include civilian security and military forces in charge of overseeing EU borders and conducting maritime surveillance. In this way, GOVSATCOM can serve various application within the Copernicus Security Services domain, including the provision of secure communications for border and maritime surveillance.

Takeaways on Policy Coherence

Across the three areas of coherence assessed, **Copernicus is highly coherent at all levels.** Between Copernicus and policies, each service provides data and products that are relevant to national, EU and international policies and supports decision-making for policymakers. Within Copernicus, the various services are coherent in terms of providing data and products for common applications, which is further emphasized through the development of thematic hubs. For coherence with other space programme components, Copernicus is strongly coherent with Galileo across several market segments, on the downstream applications side. SSA and GOVSATCOM are coherent with the overall Copernicus component with SST ensuring prevention of damages to space infrastructure and GOVSATCOM supporting with secure communication capabilities.

3.1.9. Additional insights to the Copernicus component

Pricing Policy of Copernicus

The current pricing policy of Copernicus is a free, full, and open data policy, as per the Copernicus Regulation of 2014 stating, *“The data and information produced in the framework of Copernicus should be made available on a full, open and free-of-charge basis subject to appropriate conditions and limitations, in order to promote their use and sharing, and to strengthen European Earth observation markets, in particular the downstream sector, thereby enabling growth and job creation.”*

The aim of this section is to provide an outlook on whether the current pricing policy for Copernicus should be maintained. The conclusions are drawn primarily based on the results of the CBA and stakeholder consultations. **Based on the analysis outlined below, the team has identified that the free, full, and open (FFO) data policy of Copernicus is the most suitable pricing policy.**

Firstly, based on the CBA carried out in the previous section, it was demonstrated that the **socio-economic benefits brought by Copernicus** to end users and beneficiaries of its data and services, when monetized, **largely outweigh the costs of the component by 3.7 times**, even with the data and services being open and freely available.

Copernicus provides the emergency service (CEMS) which provides support to users across EU and the world across several applications including crisis management, humanitarian aid, and disaster risk reduction, preparedness, and prevention. Due to the FFO data policy, Copernicus offers a unique advantage across these applications and provides numerous benefits including saved lives and reduced economic losses. The climate change service (C3S) also provides similar benefits, in addition to data that can help improve the quality of life for citizens. Overall, the services are widely used **to provide a public service to citizens and governments across the EU and globe** which is made possible due to the FFO policy.

As stated in the Regulation, Copernicus must enable the European industry to develop and grow, particularly in the downstream sector. While Copernicus in itself does not have commercial value, it **aims to stimulate the industry** to develop products and added value services that are commercially viable. Copernicus has led to a surge in the creation of new products and services and an exponential growth in the number of SMEs using Copernicus

data. For this reason, the FFO policy is expected to be maintained, to continue to provide relevant information **not to compete with the industry**, but to complement them. There is a common agreement among stakeholders regarding the benefits incurred by Copernicus.

While **all stakeholders agree that the FFO data policy should be maintained**, it is important to note a few key **points that have been raised about re-assessing the extent of the FFO data policy** under certain contexts in the future. For example, concerns have been raised about restricting access to third countries, due to geopolitical conflicts. Additionally, as the availability of higher resolution data increases, it would be important to discuss options for restricting access. It is also important to consider how competitors could be benefiting from certain products and re-evaluate access in such cases as well.

Lastly, based on a recent study²⁷ released by the EC in 2020, the Copernicus FFO data policy remains the most relevant option, primarily due to the vast socio-economic benefits it brings to the EU. Additionally, there could be potential contradictions with international commitments and agreements of EU by restricting access, and additional incurred costs to put new pricing policies in place.

The evolution of data and services offered by competitors

The Copernicus Component provides data, products and services based primarily on Earth Observation, accessible on a free, full, and open basis to users across the globe. It is a unique service, led by the European Union and is not directly comparable to most other EO services provided.

For example, the US does not have one comprehensive programme such as Copernicus, however, the Landsat Program, which provides land observations, and NOAA satellites, providing environmental observations could be jointly considered for comparison²⁸.

Landsat

The Landsat Program is run jointly by NASA and the USGS, and provides space-based data essential for making informed decisions about Earth's resources and environment. The program has been active since 1972, however, data has only been freely available to users since 2008 due to a policy change. The program has launched 9 satellites, Landsat-1 to -9, with only Landsat-8 and -9 currently active.

Landsat-1 and -2 carried a multispectral scanner with a ground resolution of 60m. Landsat-3 carried the same instruments with an improved resolution of 38m. All 3 satellites had a revisit time of 18 days. Landsat -4 and -5 carried sensors with improved spectral and spatial resolution, with a ground resolution of 30m and a revisit of 16 days. Landsat-6 failed to achieve orbit. These 6 satellites, launched between 1972-1993 are no longer active.

Landsat-7 launched with instruments similar to those on -4 and -5, with additional features that provided improved global change, land cover monitoring and mapping of larger areas. It provides a 30m ground resolution with a revisit of 16 days. While the nominal mission ended in 2022, an extended mission has begun at a lower orbit.

²⁷ Study on Copernicus data policy post-2020

²⁸ It is conceptually wrong to name Copernicus as a competitor to Landsat. Cooperation arrangements are in place to fully exchange the satellite data between the two for the benefits of the users. It is also very difficult to find a single constellation of satellites offering not just raw imagery but also services to users, like Copernicus does, therefore NOAA has been used for comparison.

Landsat-8 payload consists of two science instruments—the Operational Land Imager (OLI) and the Thermal Infrared Sensor, providing seasonal, global coverage at a resolution of 30m and revisit of 16 days. Landsat-9 was designed similarly to -8 to ensure data continuity and was launched most recently in 2021.

In terms of future missions, Landsat Next mission aims to measure up to 25 spectral bands, unlocking new applications for water quality, plant stress, snow cover, soil health and more. It is expected to be launched in 2029/2030.

Since 2008, Landsat Level-1 data, as well as Level-2 and Level-3 science products held in the USGS archive, have been available for download at no charge from a variety of data portals. Different data products coming from Landsat satellites can be accessed from 6 different systems: EarthExplorer, Commercial Cloud Access, GloVis, Landsat Look, ESPA and NASA AppEEARS.

NOAA

The National Oceanic and Atmospheric Administration is a scientific and regulatory agency based in Washington, D.C. The agency is charged with forecasting weather, monitoring oceanic and atmospheric conditions, charting the seas, protecting of marine mammals and managing fishing in the exclusive U.S. economic zone. As of today, NOAA owns or operates a total of 17 satellites.

In particular, they own and operate five geostationary satellite under the name of GOES (Geostationary Operational Environmental Satellites) mission, which provide advanced imagery and atmospheric measurement of Earth's Western Hemisphere, real-time mapping of lightning activity, and improved monitoring of solar activity and space weather. The GOES-R Series provides critical atmospheric, hydrologic, oceanic, climatic, solar and space data: from improved hurricane track, increased tornado warning lead time, better detection of rainfalls, monitoring of smoke and dust, better transportation safety data and route planning, etc.

Moreover, they own and operate five polar orbiter satellite called joint polar satellite system, which provides global observations that serve as the backbone of both short- and long-term forecasts. JPSS satellites circle the Earth from pole to pole and cross the equator about 14 times daily in the afternoon orbit to provide full global coverage twice a day. In doing so, they provide the majority of data that informs numerical weather forecasting in the U.S. and deliver critical observations during severe weather events like hurricanes and blizzards. Finally, NOAA owns and operates a deep space satellite (DSCOVR) launched in February of 2015, which maintains real-time solar wind monitoring capabilities, critical to the accuracy and lead time of NOAA's space weather alerts and forecasts. The DSCOVR mission succeeded NASA's Advanced Composition Explorer's (ACE) role in supporting solar wind alerts and warnings from the L1 orbit, which is the neutral gravity point between the Earth and Sun, approximately one million miles from Earth. L1 is a good position from which to monitor the Sun, because the constant stream of particles from the Sun (the solar wind) reaches L1 up to an hour before reaching Earth.

In terms of satellites which they do not own but operate, there are Suomi NPP in collaboration with NASA, Jason-3 which is owned by CNES, three defence meteorological satellites and the old goes-13 now called EWS-G1 in collaboration with U.S. Air Force.

Another important collaboration is Argos-4, an instrument of the Argos DCS (Data Collection System) family that flies on GAZELLE satellite. Developed with CNES, it collects a variety of data from both stationary and mobile transmitters around the world. This vital information helps provide a better understanding of Earth's physical and biological environment, including its weather and climate, biodiversity and ecosystems, as well as assist with maritime security, offshore pollution, and humanitarian assistance.

In terms of future missions, NOAA already plans NOAA's Geostationary Extended Observations (GeoXO) satellite system that will expand observations of Earth that the GOES-

R Series currently provides from geostationary orbit. The information GeoXO supplies will address emerging environmental issues and challenges regarding weather, the ocean, and the climate that threaten the security and well-being of everyone in the Western Hemisphere. Moreover, the NOAA's Near-Earth Orbit Network (NEON) Program will develop future low-Earth orbit (LEO) environmental satellites. Low and medium Earth observations are critical for weather forecasting, environmental observation, climate monitoring and public safety. NEON sets the stage for NOAA to manage future polar and other low Earth and medium Earth orbit satellite observations as loosely coupled projects.

NOAA currently provides two approaches to enable searching vast data holdings: the traditional NOAA Data Catalog for all data, and the new NOAA OneStop catalogue which initially includes only the archived datasets but will eventually replace the traditional catalogue. The environmental intelligence is managed by NESDIS. The National Environmental Satellite, Data, and Information Service (NESDIS) was created by the National Oceanic and Atmospheric Administration to operate and manage the United States environmental satellite programs, and manage the data gathered by the National Weather Service and other government agencies and departments.

Satellites high level comparison

Table 81: Satellites comparison

Satellite programme	Number of satellites	Type of sensors	Best spatial resolution	Coverage	Orbit
Landsat	2	Multispectral	15m-100m range	Global	LEO
Sentinels	7	Multispectra,SAR	Down to 5m with SAR Down to 10m with multispectral	Global	LEO
GOES & JPSS	10	Multispectral	JPSS down to 0.8km GOES down to 0.5km	Global (JPSS)	LEO & GEO

Service Comparison

The service layer of the three open EO data programs are similarly grouped. The main focus is, however, different: while NOAA is mainly related to weather, oceans, and atmosphere the Landsat is fully invested in covering the land segment. On the other hand, the Copernicus services started with Land and Emergency service, then extended to Marine, Atmosphere, Security and lastly in 2018 Climate Change.

Table 82: Service comparison

Copernicus services	Landsat	NOAA
Atmosphere	Agriculture and Food Security	Weather
Land	Climate and Carbon	Climate
Marine	Disaster Management	Ocean & Coasts
Climate Change	Ecosystem and Biodiversity	Fisheries

Security	Energy Resources	Marine and Aviation
Emergency	Forest Management	
	Human Health & Environmental Justice	
	Urban Development	
	Water Resources	
	Wildland fires	

KPI comparison

Copernicus

Copernicus budget at entrusted entity level equals to 5073 B EUR for the 2021-2027 timeframe. In 2022 Copernicus has achieved 161.6 million downloads. Even though this is slightly less than Y2021 which counted 185.7 million downloads, it still marks extremely significant numbers mostly coming from Sentinel-2 data (more than 50%). To understand the growth, the amount of data downloaded in PiB (one pebibyte equals 2^{50} or 1,125,899,906,842,624 bytes) grew from around 3.5 PiB in 2015 to almost 80 PiB in 2022.

Regarding the users, the open access hub counts 700.000+ users, out of which 15% (99,046) were active in 2022. In addition to that, the other four Hubs used for accessing the data have the following number of users: the International Hub has 10 Partners, the Collaborative Hub has 26 active users, and the Copernicus Services Hub has 358 users (21% active in 2022).²⁹

Landsat

The Biden-Harris administration submitted to Congress the President's budget for fiscal year 2022, including \$1.6 billion in proposed funding for the U.S. Geological Survey that manages the Landsat program. This budget includes \$116.9 million for the National Land Imaging Program, which includes \$32 million to support Landsat 9 satellite and continue developing sustainable land imaging with the subsequent Landsat Next project³⁰.

On the download side, in a study published by USGS to evaluate the economic valuation of Landsat Imagery it is explicated that the number of scenes downloaded in 2017 is around 22 million, with a cumulative amount since 2008 of 70 million. Considering that in March 2020 the number of cumulative scenes download hit 100 million, the Landsat download averaged around 15 million per year in 2018 and 2019.³¹

NOAA

NOAA's 2022 budget, given by the Consolidated Appropriations Act signed by President Biden, equals to \$6.1B. This includes \$4.42 billion for NOAA Operations, Research and Facilities (ORF) and \$1.69 billion in Procurement, Acquisition and Construction (PAC).

For what concerns the downloads, no data are publicly available on the exact number of downloads. NOAA' data are public and free, strongly used both for environmental application

²⁹ Copernicus Sentinel Data Access Annual Report 2022

³⁰ USGS.GOV, May 28 2021

³¹ Economic Valuation of Landsat Imagery, 2019, USGS

and weather forecasts in the U.S. As an estimate, NOAA satellites provide \$40 billion in household benefits per year for the American public from industries that rely on predicting US weather and environment.³²

Conclusions

Overall, Copernicus **provides a larger variety of data products and services**. It provides SAR data that is not available freely in any other service. When comparing various satellite programs, it is evident that Sentinels stand out for their SAR capabilities and versatility with a wide range of sensors and revisits. Landsat, with its historical data archive, focuses on environmental monitoring, while GOES and JPSS primarily emphasize weather and climate. Copernicus benefits from data from **Contributing Missions**, offering comprehensive information on climate change, air quality, land, marine ecosystems, emergency response, and security. In terms of services, Copernicus provides a broad spectrum of applications, including emergency and security services. Landsat offers Land-related services but with fewer spectral bands and no SAR capability, while NOAA excels in accurate weather predictions but lacks services related to emergency and security. All three programs share a commitment to open and free data policies, following the example set by Landsat in 2008, and have collectively demonstrated the societal benefits of such policies.

The three programs have worked well together in the past years, through created and exploited synergies. A clear example is the Harmonized Landsat and Sentinel-2 (HLS) project, a collaborative initiative between NASA and the US Geological Survey (USGS), aims to create a seamless and consistent surface reflectance dataset from the Landsat-8/9 and Sentinel-2A/B satellites. This project supports a range of Earth Observation applications and involves multiple agencies and centres, including NASA Goddard Space Flight Center, USGS Earth Resources Observation and Science (EROS) Center, NASA Marshall Space Flight Center, and USGS product archives. Another example is the fact that in 2018 The ECMWF-run Copernicus Climate Change Service (C3S) and the National Oceanic and Atmospheric Administration's National Centres for Environmental Information (NOAA NCEI) have embarked on a collaborative initiative to integrate meteorological records from NOAA's extensive data archives into the C3S Global Land dataset. This joint C3S-NOAA project's goal was to encompass all surface weather data gathered on land from meteorological stations and at sea from ships and buoys.

As a conclusion, it is possible to state that **the offerings from Landsat and NOAA are considered complementary to Copernicus** rather than competitors and help provide better insights for all user communities, when combined.

3.2. Galileo/EGNOS Components

3.2.1. Introduction to the Galileo / EGNOS Component

Galileo

Galileo is the world's first fully civilian GNSS owned by the European Union. It is an independent and advanced positioning system that provides accurate and reliable PNT worldwide without the need for foreign infrastructure, therein reducing European dependency on other satellite navigation systems like GPS, GLONASS, and BeiDou. It became operational with the Initial Service Declaration in December 2016

Galileo consists of a constellation of satellites in medium Earth orbit, working in conjunction with a global network of ground-based stations and user receivers. The constellation is

³² Nesdis.noaa.gov

designed to offer worldwide coverage with high precision and availability, even in challenging environments such as urban areas or dense forests. It operates on multiple frequency bands, which enhances its resistance to signal interference and increases the accuracy of location data.

One of Galileo's key objectives is to ensure the security and integrity of the navigation signals it provides. It offers a Navigation Message Authentication service that reduces the likelihood of spoofing for Open Service users. Galileo's Public Regulated Service (PRS) for governmental and authorized entities, provides an encrypted and robust signal, resistant to jamming or spoofing attempts, making it suitable for critical governmental applications requiring the highest level of availability and continuity including in the domain of defence.

Galileo has wide ranging civil applications, ranging from personal navigation devices to applications in transportation, agriculture, surveying, and scientific research. By having its own satellite navigation system, Europe gains strategic autonomy, economic benefits, and improved emergency response capabilities.

Galileo also serves an important role supporting European industry as an infrastructure upon which numerous end user applications can be built.

Galileo itself offers four services:

- Open Service: the standard, freely available and free of charge service offered through the L1, E5a and E5b frequencies. This can be picked up by affordable mass market receivers such as those in consumer electronics or private vehicles. The OS does not have integrity signals and is not precise enough (with DF, can go to 4m vertical and 8m horizontal in 95% of cases) for professional applications, but GNSS augmentation can push the OS signal to professional levels
 - OS-NMA: the authentication differentiator offered through the Galileo Open Service which enables receivers to authenticate the Galileo signal, vastly reducing the systems vulnerability to spoofing.
- High Accuracy Service: also free of charge service but aimed toward professional users. The HAS results from a re-scoping of the former "Commercial Service." The service is offered through provision of PPP corrections over the E6 frequency, and thus naturally requires an appropriate receiver. There are two service levels, SL1 is a global service offering orbit, clock, biases (code and phase) corrections with global coverage, and SL2 providing additional atmospheric corrections over Europe.
- Public Regulated Service: a public regulated service ('PRS') restricted to government-authorized users, for sensitive applications which require effective access control and a high level of service continuity.
- Search and Rescue Service: a service representing the European component of the COSPAS SARSAT effort. The service aims at relaying distress signals from PLB/ELT to the relevant authorities.
 - Galileo Return Link Service is a specific Galileo differentiator that enables people in distress to receive an acknowledgement of their distress call, allowing them to know that help is on the way.

EGNOS

The earliest element of the Union Space Programme, EGNOS (European Geostationary Navigation Overlay Service) is a satellite based augmentation system (SBAS) developed by the European Union (EU) to enhance the accuracy, reliability, and integrity of global navigation satellite systems (GNSS) in Europe. Launched in 2009, EGNOS acts as an overlay

to existing satellite navigation constellations like GPS and Galileo, providing users in Europe with improved positioning information.

Currently, EGNOS is comprised of a constellation of at least three geostationary telecommunication satellites and a ground infrastructure comprised of two Mission Control Centres (MCC) for data processing, two Navigational Land Earth Stations (NLES) per GEO for the space segment uplink, and a network of 40 Ranging Integrity Monitoring Stations (RIMS) distributed over Europe and North Africa.

The primary purpose of EGNOS is to improve GNSS signals in real-time. It achieves this by referencing PNT solutions derived from the GNSS satellites with known positions on ground (RIMS). The RIMS receive signals from GNSS satellites, and the PNT data is sent to the master control center, where it undergoes extensive processing to generate corrections to the position. The correction data is then uplinked to geostationary satellites, which are then broadcast back to Earth.

The corrected signals supported by EGNOS provide users in Europe with increased positioning accuracy, typically within three meters, as opposed to the standard GPS accuracy of up to 17 meters³³. This improvement is especially beneficial for applications that require high precision, such as aviation, maritime navigation, agriculture, surveying, and emergency services.

EGNOS has played a crucial role in enhancing safety and efficiency in various sectors. In aviation, it assists in precision approaches, helping pilots during critical landing phases, and enabling safer landings in adverse weather conditions. For maritime applications, it can aid in accurate positioning and route planning. In agriculture, EGNOS enables farmers to optimize their operations by precisely guiding machinery for planting, fertilizing, and harvesting, leading to cost savings and reduced environmental impact.

EGNOS currently offers three services:

- Open Service: the free and open service that can be used by mass market receivers and most applications
- EDAS: EGNOS Data Access Service offers ground-based access to EGNOS over the internet. Unlike the open service, access to EDAS is controlled.
- Safety of Life Service: designed for safety critical transport applications such as aviation, which require enhanced and guaranteed performance and an integrity warning system.

The system continues to evolve, with ongoing efforts to improve its performance and expand its coverage. EGNOS has become an essential component of Europe's satellite navigation infrastructure, complementing Galileo and strengthening Europe's position in the global GNSS landscape.

3.2.2. The Galileo / EGNOS component entrusted tasks and entrusted entities

For the purpose of this assessment, PwC and EC have opted to perform an assessment of the Galileo and EGNOS exploitation. Therefore, the entrusted entities involved are EUSPA and ESA. The tasks entrusted to ESA, however, are delegated via the contribution agreement between EUSPA and ESA, and thus those tasks are implicitly included through EUSPA's own entrusted tasks.

³³ EUSPA. EGNOS Performance Overview. <https://www.euspa.europa.eu/european-space/egnos/services/performance-overview>

3.2.2.1. Entrusted tasks

Galileo

Table 83: List of Galileo Interventions

Intervention Group	Intervention
1 Ensure Galileo Service Provision	1.1 Ensure that the Galileo services perform as per the published Service Definition Documents (open service (OS), Public Regulated Service (PRS) and Search and Rescue service (SAR))
1 Ensure Galileo Service Provision	1.2 Deliver quality assistance to users of the Galileo services through the distribution of relevant information, timely notification of events affecting the service, and providing support through the GNSS Service Centre (GSC) Helpdesk
1 Ensure Galileo Service Provision	1.3 Ensure smooth transition when deploying new versions of the ground segment or integrating new satellites in the constellation with no impact on the users (in terms of service interruption or degradation).
1 Ensure Galileo Service Provision	1.4 Develop, implement, and manage the Galileo incident detection and reaction chain of command from minor incidents to major crises/CD496, including the development of concept (addressing incident reaction chain), procedures, tools and exercises
2 Ensure Security of the Galileo Programme	2.1 Prepare and maintain the necessary accreditation dossiers to be submitted to the SAB in accordance with Programme roadmap and milestones related to system and service evolutions with the objective to obtain the relevant authorization by the SAB in a timely fashion
2 Ensure Security of the Galileo Programme	2.2 Ensure the PRS user uptake in accordance with the PRS uptake and technological roadmap approved by the Commission
2 Ensure Security of the Galileo Programme	2.3 Support the elaboration and implement the security baseline of the infrastructure and services of G2G, in accordance with the approved G2G Roadmap (document still to be produced and endorsed at PCCB) and the related service implementation plans
3 Roll out new services or features anticipated in the space programme regulation	3.1 Prepare and ensure the timely implementation of PRS service towards the PRS IOC and FOC in accordance with the approved Galileo FOC Programme Roadmap and the regulatory framework
3 Roll out new services or features anticipated in the space programme regulation	3.2 Prepare and ensure the timely roll out of Galileo OS, including OSNMA, HAS, CAS and SAR services as per the approved Galileo FOC Programme Roadmap
3 Roll out new services or features anticipated in the space programme regulation	3.3 Finalize service definition and manage implementation and declaration of new services or features anticipated in the Space Programme Regulation as follows (Ref. to Figure 1 below): Signal Authentication Service (SAS) Emergency Service (ES) Timing Service (TS) Contribution to Integrity Monitoring Service Contribution to Space Weather Information Service
3 Roll out new services or features anticipated in the space programme regulation	3.4 Prepare service definition leading to declaration of evolutions of the Galileo OS, including OS-NMA, PRS, HAS and SAR services as per the indicative service roll-out plan for Galileo 2nd Generation (Ref to Figure 1 below for what concerns activities within the MFF 2021-2027 boundary – the part beyond the MFF boundary will be further consolidated with the objective to improvement services delivery dates) and to be consolidated in the G2G roadmap (document still to be produced and endorsed at PCCB), as part of the Galileo Exploitation Plan
4 Ensure development and deployment of Galileo infrastructure evolutions	4.1 G1G Space Segment: completion of the deployment of the Galileo 1st Generation satellites (Batch#3 satellites), including the acceptance of the Batch#3 satellites and associated launch services until 2025. This also includes the upgrade of the satellites software (ASW, NSGU) in accordance with the planned service milestones defined in the Programme FOC Roadmap
4 Ensure development and deployment of Galileo infrastructure evolutions	4.2 G1G Ground Segment: development and deployment of the ground segment and associated system release (SB1.7, SB2.0, SB2.1) to support the FOC Programme Roadmap, taking into consideration the lessons learned of previous incidents and implementing recommendations to further improve the robustness of the system

Intervention Group	Intervention
4 Ensure development and deployment of Galileo infrastructure evolutions	4.3 G2G Space Segment Batch-1: Deploy the first Batch of the second-generation satellites through the two parallel contracts for the development and the manufacturing of the first 12 G2G Galileo satellites with a first launch targeted by the end of 2024 and according to the G2G roadmap. Ensure the preparation of the associated operational activities for Launch, LEOP, orbit raising phase and routing operations of those satellites. Perform the G2G Batch#1 in-orbit test campaign completion
4 Ensure development and deployment of Galileo infrastructure evolutions	4.4 G2G Space Segment Batch-2: Prepare the procurement of the G2G Batch2 in view of placing a new contract for up to 20 satellites before the end of the MFF
4 Ensure development and deployment of Galileo infrastructure evolutions	4.5 G2G Ground Segment: Develop and Deploy the G2G Ground Segment in view of supporting the Galileo G2G Roadmap as illustrated in the figure above for what concerns activities within the MFF 2021-2027 boundary – the part beyond the MFF boundary will be further consolidated with the objective to improvement services delivery dates (to be reflected in a programme roadmap to be endorsed at PCCB): Supporting the launch of the first G2G satellites by end of 2024; Supporting Galileo legacy service of the first G2G Satellites by 2025, including the associated enhancements of Galileo Legacy Services through early G2 capabilities; Ensuring continuity of operational constellation; Supporting the new features of the G2G: by 2027 system (including G2G Satellites and Ground Segment features) to ensure the testing and validation of G2G functionalities
4 Ensure development and deployment of Galileo infrastructure evolutions	Service facilities evolutions development and deployment GSMC: Upgrade of the GSMC as per GMS evolutions (GMS3.0.1 and GMS3.1) to support PRS IOC and PRS FOC milestones in line with the Programme FOC Roadmap; GRC: Upgrade of GRC to ensure near real-time performances monitoring capability; GSC: Upgrade of GSC to support future G1G and G2G services and deploy the appropriate redundant infrastructure in accordance with the schedule established in the FOC Programme Roadmap (G1G and G2G); SAR SC: Upgrade of the SGSC to support future SAR G2G services and deploy the appropriate redundant infrastructure .Upgrade the RLSP monitoring capability to ensure worldwide performances monitoring; SAR Ground Segment: Ensure the evolution of the SAR Ground Segment in relation to the evolutions agreed in Cospas-Sarsat, including the 2nd Generation of Beacons.
4 Ensure development and deployment of Galileo infrastructure evolutions	4.7 Develop an implementing plan for longer term evolutions of Galileo aligned with high requirements defined by the Commission, consistent with the related Galileo/EGNOS upstream R&D actions undertaken in the context of Horizon Europe and taking into account secured communication capabilities envisaged to be deployed in the context of GOVSATCOM and future initiatives of the EU in the area of Connectivity
5 Support Commission international activities	5.1 This objective requires to support the Commission in international activities (e.g. technical support, implementation roadmaps, other information) for the implementation of the Commission international activities and agreements, in particular: Negotiations with third countries and international organisations; Standardisation activities linked to services and the relevant user segment.

EGNOS

Table 84: List of EGNOS interventions

Intervention Group	Intervention
1 Ensure EGNOS Service Provision	1.1 Ensure that the EGNOS services perform as per the published Service Definition Documents (open service (OS), safety-of-life (SoL) and EDAS). This includes to avoid regression of performance upon updated Service Definition Documents over the EU Member States' territories geographically located in Europe. To meet this objective and in addition to the nominal service provision processes, the effective and timely implementation of maintenance processes are required: Preventive maintenance: develop, qualify and deploy correction of anomalies and refreshed

Intervention Group	Intervention
	technology before impact on services. Corrective maintenance: deploy fast corrections to recover major underperformance in the services
1 Ensure EGNOS Service Provision	1.2 Ensure smooth transition from EGNOS V2 to EGNOS V3 with no impact on the users (in terms of service interruption or degradation).
1 Ensure EGNOS Service Provision	1.3 Ensure that the services provided by EGNOS defined in Article 46 of the Space Programme Regulation cover, as a priority, the EU Member States' territories geographically located in Europe, including for this purpose Cyprus, the Azores, the Canary Islands and Madeira, by the end of 2026
2 Ensure Security of the EGNOS Programme	2.1 EGNOS V2: Propose an EGNOS V2 security accreditation baseline; Update EGNOS V2 risk assessment in compliance with the approved EGNOS V2 accreditation baseline; Establish risk profile based on security audits covering cyber domain; Establish updated EGNOS V2 risk treatment plan.. EGNOS V2 security accreditation baseline
2 Ensure Security of the EGNOS Programme	2.2 EGNOS V2: build and maintain, not later than 2024, an up-to-date accreditation dossier based on the EGNOS V2 security accreditation baseline which will allow timely provision of secured and accredited services
2 Ensure Security of the EGNOS Programme	2.3 EGNOS V3: build and maintain an up-to-date accreditation dossier according to the Security Accreditation Strategy which will allow timely provision of secured and accredited services..
2 Ensure Security of the EGNOS Programme	2.4 timely implement EGNOS Security risks treatment plans both for EGNOS V2 and EGNOS V3 as far as budget allows.
3 Develop new EGNOS services enabling new application	3.1 Start delivering the new DFMC services, as a priority, over the EU Member States' territories geographically located in Europe, including for this purpose Cyprus, the Azores, the Canary Islands and Madeira.
3 Develop new EGNOS services enabling new application	3.2 Enable new applications for EGNOS services: Aviation: in compliance with ICAO standards, support the development of new applications (e.g. in Navigation or Surveillance). Maritime: in compliance with IMO standards, both for services including integrity commitments in the range domain by 2023 and also for DFMC services including integrity in the position domain by 2027 in accordance with the EGNOS V3 Implementing Act⁸. Rail: within ERTMS, by 2024 for services including integrity commitments in the range domain and by 2027 a preliminary design of services enabling the continuous train localisation based on GNSS + EGNOS signals and other sensors. EDAS: new services including the distribution of Galileo data and other products. Other domains where EGNOS services could be used as a result of the service analyses done by the Programme, for instance liability-critical applications for road applications or integrity for High Accuracy services
4 Ensure EGNOS evolution	4.1 EGNOS V2.4.2B to solve RIMS-C obsolescence issues, improve performance under severe ionospheric conditions and deploy additional RIMS by end 2023
4 Ensure EGNOS evolution	4.2 EGNOS V2.4.3 to solve NLES obsolescence issues and integrate GEO 3 into services by end 2024
4 Ensure EGNOS evolution	4.3 EGNOS V3.1 to ensure service continuity and security accredited services beyond EGNOS V2 end-of-life.
4 Ensure EGNOS evolution	4.4 EGNOS V3.2 to deliver, in accordance with the EGNOS V3 Implementing Act: LPV-200 Single Frequency services in all EU-MS (+ NO/CH) territories + ENP-South and ENP-East extensions by end 2027. LPV-200 DFMC services in all EU-MS (+ NO/CH) territories + ENP-South and ENP-East extensions by end 2027 (including capability to deliver improved performance down to Vertical Alert Limits of 10 m. in all EU-MS (+ NO/CH) territories excluding Azores, Madeira and Canary Islands).
4 Ensure EGNOS	4.5 To qualify and put into operations an EGNOS V3 release taking into account the

Intervention Group	Intervention
evolution	evolutions of ICAO standards for DFMC SBAS by their applicability date in Nov 2024
4 Ensure EGNOS evolution	4.6 To successfully integrate the processing of GPS IIIF satellites by EGNOS V3 in time for their planned entry into service in 2026 without impacting the EGNOS services
4 Ensure EGNOS evolution	4.7 To successfully integrate the processing of backward compatible Galileo 2nd Generation Batch 1 satellites by EGNOS V3 in time for their planned entry into service in 2025 without impacting the EGNOS services.
4 Ensure EGNOS evolution	4.8 To complete by end 2027, as a minimum, the preliminary design of an EGNOS V3 release including SBAS Authentication and a “Dual-Frequency Single-Constellation” (either Galileo or GPS) mode.
4 Ensure EGNOS evolution	4.9 To take initial steps towards the procurement of GEO 5 services, taking credit for capacities to be deployed in the context of GOVSATCOM and future initiatives of the EU in the area of Connectivity.
4 Ensure EGNOS evolution	4.10 To procure SDAF to support the delivery of evolved EDAS services by 2024.
4 Ensure EGNOS evolution	4.11 Develop an implementing plan for longer term evolutions of EGNOS within 1 year of the adoption by the Commission of the corresponding implementing act (expected in the 2023-2024 timeframe). This plan will be aligned with the related Galileo/EGNOS upstream R&D actions undertaken in the context of Horizon Europe and take into account secured communication capabilities envisaged to be deployed in the context of the future EU Connectivity Programme.
5.1 Support Commission International Activities	Pending confirmation of relevant additional budget sources, the following EGNOS extension activities are envisaged: Extension to Iceland; Extension to Middle-East / Africa.

3.2.2.2. Galileo/EGNOS budget

In the case of Galileo and EGNOS, the budget granularity does not extend to the level of the intervention group due to the way that the interventions are organised. Therefore, the budget is organised only at the level of component as below:

Table 85: EGNSS Budget (current prices)³⁴

	2021-2027	2021	2022	2023	2024
Direct					
Direct Galileo	€ 50 M	€ 12.9 M	€ 4.80 M	€ 4.20 M	€ 4.50 M
Direct EGNOS					
Total Direct	€ 50 M	€ 12.9 M	€ 4.80 M	€ 4.20 M	€ 4.50 M
Indirect EUSPA					
Galileo Exp	€ 7,437.00 M	€ 3,386.9 M	€ 480.0 M	€ 1,677.1 M	€ 1,006.7 M
EGNOS Exp	€ 1,402.00 M	€ 475.3 M	€ 74.3 M	€ 154.3 M	€ 337.8 M
Total EUSPA	€8,839.00 M	€ 3,862.1 M	€ 554.2 M	€ 1,831.4 M	€ 1,344.4 M
Sum EGNSS					
Sum Galileo	€ 7,487.0 M	€ 3,399.8 M	€ 484.8 M	€ 1,681.3 M	€ 1,011.2 M
Sum EGNOS	€ 1402.5 M	€ 475.3 M	€ 74.3 M	€ 154.3 M	€ 337.8 M
Total EGNSS	€ 8,889.5 M	€ 3,875.0 M	€ 599.1 M	€ 1,835.6 M	€ 1,348.9 M

³⁴ Data provided by EC

3.2.3. Effectiveness of the Implementation of Galileo / EGNOS

The assessment of the effectiveness of implementation is divided into two interrelated sections.

- First, the extent to which the interventions outlined above were completed within the allocated time and budget, and the outcomes or severity of any delay or budget overrun that may have occurred.
- The second, the performance based on several KPIs as outlined in the contribution agreement

3.2.3.1. Assessment of the implementation of the entrusted tasks by entrusted entities

EUSPA was the only entity addressed since – for the purpose of the exploitation tasks and the MFF budget – EUSPA is the entity directly reporting to the Commission. While ESA has several tasks, these tasks are subdelegated to ESA by EUSPA and are thus implicit within the interventions below.

Each of the interventions outlined in the previous section comprises several activities. These activities were extracted directly from the EC EUSPA contribution agreement. As described in the results assessment methodology section, the specific outcome of each activity was determined based on the status, timeline, and budget, that mapped to a numerical outcome on a scale of 1-6. As shown in the figure below, each number defines a different outcome within this scale.

Figure 73: Definition of scale to assess implementation of entrusted tasks

1	Implemented as per Contribution Agreement	2	One deviation from Contribution Agreement with no consequences	3	Two deviations from Contribution Agreement with no consequences
4	One deviation from Contribution Agreement with one consequence	5	Two deviations from Contribution Agreement with one consequence	6	Two deviations from Contribution Agreement with two consequences
NA Non Applicable / Out of scope of assessment					

It is important to note that while the assessment was carried out at the activity level, the results shown below have been consolidated at the intervention level.

Galileo

1. Ensure Galileo Service Provision

Intervention 1.1: Ensure that the Galileo services perform as per the published Service Definition Documents (open service (OS), Public Regulated Service (PRS) and Search and Rescue service (SAR)).

This includes to avoid regression of performance upon updated Service Definition Documents.

To meet this objective and in addition to the nominal service provision processes, the effective and timely implementation of maintenance processes are required:

- Preventive maintenance: develop, qualify and deploy correction of anomalies and of refreshed technology before impact on services.
- Correction maintenance: deploy fast corrections and permanent correction to recover major underperformance in the services.

Description of Activities

The Service Definition Documents (SDD) define the targets for each of the services, and they are updated as required in accordance with the EC FOC Programme Roadmap. Currently, there are SDDs published for the OS, HAS, PRS and SAR.

Overview of Results

Galileo is performing in accordance with all the latest SDDs at the time of writing. The latest SDDs are from Dec 2021 for OS, Jan 2023 for HAS, Oct 21 for PRS, although the OS will receive an updated SDD in Q4 2023. **EUSPA confirms that all activities are on track for this update.**

For the SAR service, the existing three European MEOLUT facilities have been complemented by a fourth facility in Reunion extending the Forward Link Service Coverage Area over the Indian Ocean

Preventative maintenance activities are being conducted, there are no outstanding tasks, everything is reported as planned adequately.

For corrective maintenance, all identified patches were implemented (e.g. OSPF extended mode) without incident.

Intervention 1.1 Qualification	Implemented as per Contribution Agreement
At current status, this intervention is implemented as per the contribution agreement with no delay. It is nevertheless worth noting that the continual achievement of this objective (especially with regards to service continuity) relies not only on service performances but also on a specific system configuration (notably a specific number of satellites). Galileo satellites currently cannot be launched due to absence of EU launch service compatible with Galileo orbit. A contract has been signed with a non-EU launch service provider as risk mitigation but the actual use of such launch service depends on the availability of a signed international agreement between the EU and US. This is an external dependency as EUSPA and ESA does not have any control over deciding how launches should happen but is working closely in support of the Commission to identify a solution. In this regard, there is a potential risk to the service commitment, as if some satellites fail (dropping the # of satellites below the number that can provide the service) there is currently no way to replace them. This is compounded by the fact that some satellites are reaching design life. While they are expected to function beyond design life, there's still a chance they can fail. As this is an assessment of the implementation of EUSPAs interventions, the absence of suitable launch options remains an external dependency over which EUSPA has no control. Intervention 1.2: Deliver quality assistance to users of the Galileo services through the distribution of relevant information, timely notification of events affecting the service, and providing support through the GNSS Service Centre (GSC) Helpdesk.	

Description of Activities

This objective aims at ensuring that users who require it have adequate assistance, notably through the GSC Helpdesk.

Overview of Results

The GSC helpdesk is operational. Regular (annual) user satisfaction surveys are held, informing EUSPA that **users are generally satisfied with the GSC helpdesk**. The surveys also allow EUSPA to understand user needs better.

There are metrics available and reported such as response time that inform the effectiveness of the helpdesk, and the **helpdesk is within the acceptable margins for these metrics**. These metrics are discussed in the performance assessment in Section 0.

Intervention 1.2 Qualification	Implemented as per Contribution Agreement

Intervention 1.3: *Ensure smooth transition when deploying new versions of the ground segment or integrating new satellites in the constellation with no impact on the users (in terms of service interruption or degradation).*

Description of Activities

Aims at ensuring that there are no or minimal impact on users when new versions of the ground segment or space segment enter into operation.

Overview of Results

A large transition will occur with the roll out of system build 2.0 (SB2.0). While this is a major transition, there have been smaller transitions in the past – such as for Galileo-GPS time offset coordination or for in orbit testing of satellites). **These transitions have not resulted in any service degradations.**

Intervention 1.3 Qualification	Implemented as per Contribution Agreement

Intervention 1.4: *Develop, implement, and manage the Galileo incident detection and reaction chain of command from minor incidents to major crises/CD496, including the development of concept (addressing incident reaction chain), procedures, tools and exercises*

Description of Activities

This intervention is related to the Security Operations and Monitoring activities (SOM). There is a chain of command from GSMC going forward depending on the risk.

Overview of Results

Incidents have been well managed through the chain of command.

To manage key operational continuity risks, the two GSMC facilities often practice switches between the prime site near Paris and the backup site near Madrid. Such an exercise is ongoing currently.

It is noted that CD496 has been superseded by CD698, but the differences between the two are not relevant for the purpose of the study.

Intervention 1.4 Qualification	Implemented as per Contribution Agreement

Intervention Group 1 Summary

Intervention group 1 deals with provision of Galileo services. Meaning it aims to ensure that users of Galileo have access to the service as described, and that any interruptions or incidents are minimised or otherwise dealt with quickly.

In terms of this objective, EUSPA is fully aligned with this objective as service provision has been perfectly in line with the SDD. The only caveat to this is regarding the long term sustainability of this objective, which is contingent on launch procurement. This, however, is outside the mandate of EUSPA and is thus considered an external dependency. The impact of the launch crisis is further discussed under intervention group 4.

2. Ensure Security of the Galileo Programme

Intervention 2.1: *Prepare and maintain the necessary accreditation dossiers to be submitted to the SAB in accordance with Programme roadmap and milestones related to system and service evolutions with the objective to obtain the relevant authorization by the SAB in a timely fashion.*

Description of Activities

This intervention is an ongoing recurrent process wherein EUSPA needs prepare and submit dossiers to the SAB, including the integration of ESA dossiers for the system under development activities.

Overview of Results

All accreditation dossiers are submitted to the SAB in accordance with the programme roadmap. From a governance perspective, EUSPA is present in the SAB as Component Manager of Galileo, while EC is present as the Space Programme Manager and ESA as Design Authority. There remain some risks with this objective going forward as implementation of this task yet has some deficiencies such as with ESA-EUSPA-COM coordination of inputs to SAB/SAP which can affect sustainable achievement of programme objectives. Additionally, the SAB audit #2 has identified important findings in the implementation of cyber requirements by the agency.

The programme has experienced schedule impact due to security accreditation milestones (M5 and M6) not granted according to plan by the SAB. This has resulted also in a schedule and financial impact to realign Ground Mission Segment (WP2X Contract) to the SB2.0 migration Program Schedule.

Intervention 2.1 Qualification

One deviation from contribution agreement with no consequences

Intervention 2.2: *Ensure the PRS user uptake in accordance with the PRS uptake and technological roadmap approved by the Commission.*

Description of Activities

Aims at ensuring uptake of the PRS.

Overview of Results

PRS uptake is based on the initiative of member states. EUSPA is **participating actively to various working groups** for the exchange of technology implementation and capabilities, which are defined in the Galileo exploitation management plan. In addition, EUSPA have their own contracts with industry to **develop PRS receivers and other Users Segment tools**.

Under the leadership of the Commission, EUSPA also **participated in meetings with MS to demonstrate the status of the tools developed and to exchange with stakeholders**.

EUSPA noted that it is the member states which determine the number of PRS users that they have, and that by design EUSPA is to respect the confidentiality of member states with respect to this. That said, the Commission has requested that EUSPA take further action to improve user uptake of PRS where this is possible.

Intervention 2.3: Support the elaboration and implement the security baseline of the infrastructure and services of G2G, in accordance with the approved G2G Roadmap (document still to be produced and endorsed at PCCB) and the related service implementation plans

Description of Activities

Aims at ensuring the development of a security baseline for G2G.

Overview of Results

Following all relevant procurement processes executed at ESA level, all G2G contracts implement the latest security mission and services baseline as defined in the Programme CBCS.

In addition to the security baseline for G2G, EUSPA and ESA are collaborating with EC in the completion of G2G Roadmap document.

All G2G activities are aligned with the G1G Roadmap so far, and completion of G2G Programme Roadmap expected early 2024.

As of writing, the intervention is on schedule as per the contribution agreement. EUSPA notes that the development of a security baseline is business as usual, as this a common task required for all new products. Everything is aligned with the existing G1G Roadmap, and EUSPA internally has all details needed for the G2G and so can complete the security baseline when the G2G roadmap is developed and validated.

Intervention Group 2 Summary

Intervention group 2 deals with ensuring that Galileo is secure. There are no processes here that have specific milestones as these are generally ongoing recurring processes. While these are being done adequately and there do not appear to be any indication of delays going forward according to EUSPA, there remain some areas of improvement such as in the implementation of cyber requirements of the agency, coordination in preparation of accreditation inputs, and in defining planning and implementing PRS downstream activities.

3. Roll out new services or features anticipated in the space programme regulation

Intervention 3.1: Prepare and ensure the timely implementation of PRS service towards the PRS IOC and FOC in accordance with the approved Galileo FOC Programme Roadmap and the regulatory framework.

Description of Activities

Aims at ensuring the PRS service roll out and functionality.

Overview of Results

The PRS implementation is currently in progress and is proceeding according to the established schedule. The introduction of the new PRS Signal In Space (SIS) is anticipated to occur by the end of 2023, with the declaration of PRS Initial Operational Capability (IOC) service expected in 2024. The completion of SCR steps 1 and 2 has already been achieved, and the system qualification review is currently underway.

Regarding service-related aspects, various components necessary for IOC and FOC (Full Operational Capability) have been initiated, including the procurement of various elements (POCP, TVG, and the Key Transfer Device.)

Although the project is presently on track and within budget according to EUSPA, it should also be noted that there were some schedule deviations incurred on PRS and that necessitated a realignment of the FOC roadmap.

It is also essential to acknowledge that, given its significance and size, there are inherent risks that must be actively managed. To address this, EUSPA, under the guidance of the EC, is jointly leading a risk management task force. This task force conducts weekly progress monitoring and is prepared to implement corrective actions as required.

Looking ahead, the successful attainment of PRS IOC is contingent on the Member States (MS) as well. It is possible that MS may identify new requirements, which could potentially extend the implementation timeline. This external influence has the potential to impact not only the project's scope but also its schedule and budget. As of now, however, EUSPA is still on schedule or budget respect to the realigned roadmap and has the risk management task force to mitigate some risks. Some areas of improvement have been identified by external audits and implementation of mitigation actions are due by 2027.

Intervention 3.1 Qualification

One deviation from the contribution agreement with no consequences

Intervention 3.2: Prepare and ensure the timely roll out of Galileo OS, including OSNMA, HAS, CAS and SAR services as per the approved Galileo FOC Programme Roadmap.

Description of Activities

Aims at ensuring OS roll out and functionality – including all services.

Overview of Results

Galileo OS FOC is not only associated with a certain service milestone, but also with an infrastructure milestone (e.g. number of satellites in orbit). The ongoing launch crisis thus is a hurdle towards achievement of Galileo OS FOC.

To achieve the service commitment, Galileo doesn't need all the satellites (the actual minimal number of satellites needed for the system to function at service commitment is classified). But by definition, the roadmap requires all satellites to be in orbit before OS FOC. This is out of the hands of EUSPA as its dependent on the Commission to handle the launch crisis, although EUSPA is actively supporting the identification and implementation of other launch options.

This being said, there are some severe delays with the CAS, while the OS NMA is also delayed which notably has implications for the Commissions commitments to address user needs in the transport domains, notably in road and rail domains.

There are also ground segment updates ongoing, but this is **on schedule**.

All the **other services are on schedule**, bearing in mind the risks of the launch crisis.

Intervention 3.2 Qualification

One deviation from the Contribution Agreement with one consequence

It is important to note that the Commission has performed a **re-assessment of the programmatic definition of the OS FOC Programme objectives**, in particular in relation to the constellation sustainability analysis and the steps to reach the FOC constellation operational configuration given the impact on the launch calendar. A new FOC Programme roadmap document has been approved by the Programme Board.

The risk is in satellites that are nearing the end of life. While the satellites are expected to function beyond design life, there is some risk to service provision if the satellites fail before launch services for replacement can be procured.

Intervention 3.3: Finalize service definition and manage implementation and declaration of new services or features anticipated in the Space Programme Regulation as follows:

- Signal Authentication Service (SAS)
- Emergency Service (ES)
- Timing Service (TS)
- Contribution to Integrity Monitoring Service
- Contribution to Space Weather Information Service

Description of Activities

Aims at finalising the service definition and implementing new Galileo services.

Overview of Results

The SAS is on track for implementation with the G2G infrastructure. Work on this is currently ongoing and there are no issues thus far.

The early warning is on track, although the schedule had to be revised in the past due to authentication needs.

The new SAR Services provided through the Return Link are on track (e.g. remote beacon activation and two way communication).

The timing service, contribution to integrity monitoring service and to space weather information service (ionospheric monitoring service) are all on schedule.

Overall, there is **no expectation of risk on this objective**, accounting for G2G coming into operation. For the roll out of these services, there is some external dependency on industrial contracts. For now, there is no reason identified that would lead to delay. EUSPA has developed a risk management strategy with ESA and the EC to mitigate any industrial risk that may arise.

Intervention 3.3 Qualification	Implemented as per Contribution Agreement

Intervention 3.4: Prepare service definition leading to declaration of evolutions of the Galileo OS, including OS-NMA, PRS, HAS and SAR services as per the indicative service roll-out plan for Galileo 2nd Generation (Ref to Figure 1 below for what concerns activities within the MFF 2021-2027 boundary – the part beyond the MFF boundary will be further consolidated with the objective to improvement services delivery dates) and to be consolidated in the G2G roadmap (document still to be produced and endorsed at PCCB), as part of the Galileo Exploitation Plan.

The objective is limited to milestones occurring in the timeframe MFF 2021-2027.

Description of Activities

Aims at defining the future services of Galileo.

Overview of Results

No indication of any deviation from the plan. **Everything is on schedule for G1**, including those capabilities expected to be implemented in G2G In Orbit Validation contracts as per applicable Mission baseline. Long term implementation of G2G Programme Roadmap (MFF 2028-2035) is not part of this objectives.

.

Intervention 3.4 Qualification	Implemented as per Contribution Agreement

Intervention Group 3 Summary

Intervention Group 3 deals with ensuring that the upcoming services for Galileo are rolled out as planned. For service provision, there are no expected delays for the elements in the contribution agreement. Indeed, while infrastructure FOC cannot be achieved within the timeframe, EUSPA can nevertheless still provide the services at the expected level without having all the satellites for FOC operational.

EUSPA is currently on track and on schedule for their own elements, although they still need to demonstrate maturity of their cyber processes. There are external dependencies that can induce risks, but for this EUSPA has implemented risk management strategies (including a risk management task force) as far as possible within its scope of activities.

4. Ensure development and deployment of Galileo infrastructure evolutions

Intervention 4.1

G1G Space Segment: completion of the deployment of the Galileo 1st Generation satellites (Batch#3 satellites), including the acceptance of the Batch#3 satellites and associated launch services until 2025. This also includes the upgrade of the satellites software (ASW, NSGU) in accordance with the planned service milestones defined in the Programme FOC Roadmap

Description of Activities

Aims at deploying the last batch of Galileo 1st Generation spacecraft. This intervention involved activities delegated from EUSPA to ESA.

Overview of Results

There are three parts to this objective:

First, Building and Acceptance. ESA has successfully completed the acceptance of all satellites in accordance to schedule and budget, with the last satellites accepted in July 2023. Some Passive Hydrogen Masers (PHM) and Clock Monitoring and Control Units (CMCU) are still pending final integration: 4 CMCU units have been sent to manufacturer for replacement of components with potentially low reliability and 7 PHM's are planned to be delivered with last unit arriving in 2024. In both cases the delivery is in line with launch schedule. ESA reports regularly the status of all the topics in the quarterly implementation reports/annual implementation reports, risk register and the 3PM/2PM which is the project managers coordination meetings as per applicable FFPA/CA.

This task is delegated to ESA by design as ESA is the contracting authority. Second, the launch of these satellites is **subject to launch service availability**. Due to the Russian invasion of Ukraine, **launch services with Soyuz from Kourou have been suspended and Ariane-6 launcher development is delayed**. This is an external delay outside of EUSPA's control. As a risk mitigation, ESA acting on behalf of the Commission as launchers contracting authority has signed a contract with SpaceX for the use of two Falcon 9 launch services in 2024 allowing the deployment of 4 Galileo satellites. An EU-US security agreement is also needed to perform the launches and is under negotiation under the lead of the Commission.

As a temporary measure, the satellites were shipped back to the EU for storage until the new launchers are available.

Intervention 4.1 Qualification

One deviation from Contribution Agreement with one consequence

There is a timeline deviation from the contribution agreement as the final batch of G1G are not yet completed, and even if they were, they would not be launched due as the EU currently has no access to a suitable launcher (but can be considered as an external dependency).

As mentioned in objective 3.2, OS FOC cannot be achieved due to the launch commitment, but this has no bearing on service provision since the constellation can function without all the satellites in operation.

There are consequences of this. While the service component of G1G should be operational, there is increased risk on service availability. Additionally, it affects the timeline for G2G as well, as G2G cannot be put into operation until the G1G constellation is complete.

Intervention 4.2

G1G Ground Segment: development and deployment of the ground segment and associated system release (SB1.7, SB2.0, SB2.1) to support the FOC Programme Roadmap, taking into consideration the lessons learned of previous incidents and implementing recommendations to further improve the robustness of the system.

Description of Activities

Aims at deploying the next system build (versions) of the Galileo 1st Gen Ground Segment.

Overview of Results

Regarding the three system builds mentioned, EUSPA and ESA work complementarily to roll out the system builds, where ESA is subdelegated responsibility to develop and qualify the product.

SB1.7 was qualified by ESA and put into operation on schedule by EUSPA

SB2.0 is currently in the qualification stage. There was a 9-month delay caused by two factors.

First the change in the SAB of the conditions to connect the pre-OPE to VAL chain.

Second, a qualification issue caused because the contractor has had difficulty to develop the new product which has delayed the qualification review. The contribution agreement objective does not measure a date, rather mentioning the FOC roadmap which is updated based on conditions. Currently the entry in operation is expected for Dec 2023 which is consistent with the newly approved FOC Programme Roadmap approved by the Commission.

SB2.1 is in development. System qualification was planned for end of March but was shifted by six months. The reason for the delay was explained to be due to the delay in 2.0, as 2.0 is needed for 2.1.

Intervention 4.2 Qualification	Implemented as per Contribution Agreement
This objective is rated as implemented per the contribution agreement as the contribution agreement states that the deployment of the ground segment should be in support of the FOC roadmap. As the FOC roadmap itself is delayed, from a technical standpoint, this objective is not delayed since EUSPA is on track to the December 2023 date for SB2.0. To ensure that delays do not happen again, EUSPA has requested the creation of a task force to encourage transparency such that problems can be anticipated more easily in the future. Intervention 4.3: <i>G2G Space Segment Batch-1: Deploy the first Batch of the second-generation satellites through the two parallel contracts for the development and the manufacturing of the first 12 G2G Galileo satellites with a first launch targeted by the end of 2024 and according to the G2G roadmap. Ensure the preparation of the associated operational activities for Launch, LEOP, orbit raising phase and routing operations of those satellites. Perform the G2G Batch#1 in-orbit test campaign completion.</i> Description of Activities Aims at deployment of the 1st batch of Galileo Second Generation satellites.	

Overview of Results

In view of the launch situation, the 2024 launch objective cannot be met and was modified by the Commission in late 2022 through the release of Change Requests to EUSPA/ESA, in order to:

- Implement the latest state of the art cryptography as requested by Member States.
- Ensure dual launch capabilities in the contracts.

Following approval of these changes and the agreement with Launch Service provider, the target readiness for first G2G launch is mid-2026.

In addition, it is important to note that the G1G spacecraft need first to be launched for FOC, and the ground segment needs to be fully developed otherwise the G2G satellites cannot function fully. This is linked to the first reason, as they cannot launch due to launch availability.

The G2G Ground Segment activities are under development on schedule under the execution of ESA. Operational G2G preparatory activities managed by EUSPA are expected to start in early 2024.

Intervention 4.3 Qualification	One deviation from Contribution Agreement with one consequence (not attributable to EUSPA)
As the 2024 target in the CA cannot be met, this objective is rated as above. This is, however, based on an external dependency. As mentioned above, there is a new launch date that has been updated by the Commission. G2G first launch has been pushed back to Q2 2026, but as Galileo 2nd Generation is a completely novel spacecraft, there is always some risk of further delay. The budget for this objective has already been paid, so it is balanced. There are consequences of this since it means that services associated with G2G FOC will be delayed. Nevertheless, the Programme foresees to start provision of G2G Services with initial performance – as done with the G1G initial Services declaration. This deviation stems from a change of programme roadmap and is thus not attributed to EUSPA.	

Intervention 4.4: *G2G Space Segment Batch-2: Prepare the procurement of the G2G Batch 2 in view of placing a new contract for up to 20 satellites before the end of the MFF.*

Description of Activities

Aims at starting procurement of the 2nd batch of Galileo Second Generation satellites.

Overview of Results

Activity is not started yet which is normal.

This objective is still on track to start in the second half of the MFF, in line with the Financial Long Term Plan agreed between EC/EUSPA/ESA. At the time of writing, it was considered that this **objective may be scrapped** as there may be no budget for it as decided with Commission due to other priorities. This is to be assessed at a budget review with EC.

However, ESA notified the Commission during the Contribution Agreement Amendment process late 2023 that this objective is expected to be executed early 2026, provided no additional risks are incurred by the Programme.

Intervention 4.4 Qualification	One deviation from the contribution agreement with no consequences

We rate this objective as “one deviation from the contribution agreement with no consequences” as the objective is deprioritized due to the non-achievement of 4.3. It in itself will have no consequence within the MFF as there is no purpose to prepare G2G batch 2 when batch 1 cannot be launched.

Intervention 4.5: *G2G Ground Segment: Develop and Deploy the G2G Ground Segment in view of supporting the Galileo G2G Roadmap as illustrated in the figure above for what concerns activities within the MFF 2021-2027 boundary – the part beyond the MFF boundary will be further consolidated with the objective to improvement services delivery dates (to be reflected in a programme roadmap to be endorsed at PCCB):*

1. *Supporting the launch of the first G2G satellites by end of 2024.*
2. *Supporting Galileo legacy service of the first G2G Satellites by 2025, including the associated enhancements of Galileo Legacy Services through early G2 capabilities.*
3. *Ensuring continuity of operational constellation.*
4. *Supporting the new features of the G2G: by 2027 system (including G2G Satellites and Ground Segment features) to ensure the testing and validation of G2G functionalities.*

Description of Activities

Aims at deployment Galileo Second Generation ground segment.

Overview of Results

Regarding (1), as mentioned in intervention 4.4, the objective cannot be met due to external factors.

All relevant dates following the launch have been updated in common agreement by EC/EUSPA/ESA as part of the Contribution Agreement Amendment, inside the updated Technical Annex.

The evolution of the GCC is ongoing and is on schedule.

Intervention 4.5 Qualification

Not Applicable

It is difficult to characterize this objective, as there are significant deviations from the contribution agreement in terms of timeline, but the consequences of these delays are already covered in intervention 4.1 and 4.3.

Indeed, these delays do not have further consequences since there is no reason to prioritize G2G elements when the spacecraft themselves cannot be launched. Nevertheless, the objective is characterized as being consequential to reflect the cascading nature of delays.

It should be noted that all relevant dates following the launch have been updated as part of the Contribution Agreement Amendment, inside the updated Technical Annex.

Intervention 4.6

Service facilities evolutions development and deployment

- *GSMC: Upgrade of the GSMC as per GMS evolutions (GMS3.0.1 and GMS3.1) to support PRS IOC and PRS FOC milestones in line with the Programme FOC Roadmap;*
- *GRC: Upgrade of GRC to ensure near real-time performances monitoring capability;*

- *GSC: Upgrade of GSC to support future G1G and G2G services and deploy the appropriate redundant infrastructure in accordance with the schedule established in the FOC Programme Roadmap (G1G and G2G);*
- *SAR SC: Upgrade of the SGSC to support future SAR G2G services and deploy the appropriate redundant infrastructure .Upgrade the RLSP monitoring capability to ensure worldwide performances monitoring;*
- *SAR Ground Segment: Ensure the evolution of the SAR Ground Segment in relation to the evolutions agreed in Cospas-Sarsat, including the 2nd Generation of Beacons.*

Description of Activities

Aims at deployment of Galileo facilities.

Overview of Results

GSMC has functioned normally from both sites in Spain and France with routine handover tests between the two (handover of primary vs backup). The GMS3.0.1 and GMS3.1 are linked to the system builds 2.0 and 2.1 respectively and so are linked to those interventions.

The GRC has continually functioned normally, acting as the main source of KPI reporting for Galileo. Monitoring capabilities for HAS, OSNMA, and the ionospheric monitoring service are being deployed.

The GSC v1.3 is operational (for the HAS) while the 1.4 (for OS NMA IOC) was validated and authorization to connect to the operational system was recently requested to the Security Accreditation Board (SAB). Aimed at IOC in the first semester of 2023 (non risk adjusted schedule), and an OSNMA initial service (1.4.1) at the end of the second semester (non risk adjusted schedule). The 1.4.1 has passed CDR and has a QR planned in June 2023. EUSPA has launched the ITT for the GSC V2.0 and V2.1. and will be issuing the BAFO technical specification in the Q3 2023.

SAR SC and SAR GS are both linked. They deployed the 4th MEOLUT in Reunion (Indian Ocean Area) and it provides operational data to COSPAS SARSAT. There are two planned evolution for the EWS and remote beacon activation service respectively. SAR does not follow the G1 G2 scheme. The RLS service is fully operational and providing service beyond committed performances.

The GCC (more linked to objective 4.5) is being evolved to accommodate G2G schedule need as well. Extensions for PRS IOC are ongoing. There were some authorisations for the connection of the pre-operational chains between GCCs and GSMCs and the pre-operational chains to the validation chains that were not granted by the SAB, and so the situation was reassessed, but it is still on schedule according to the FOC Programme Roadmap 1.6.1.

Intervention 4.6 Qualification

Implemented as per Contribution Agreement

Overall, there are no issues with this intervention.

Intervention 4.7: Develop an implementing plan for longer term evolutions of Galileo aligned with high requirements defined by the Commission, consistent with the related Galileo/EGNOS upstream R&D actions undertaken in the context of Horizon Europe and taking into account secured communication capabilities envisaged to be deployed in the context of GOVSATCOM and future initiatives of the EU in the area of Connectivity.

Description of Activities

Aims at development of ideas for future Galileo services.

Overview of Results

There are several actions taking place under Horizon Europe and Fundamental Elements taking account of advancing user needs and improved capabilities of Galileo – especially that of the Galileo differentiators.

Intervention 4.7 Qualification	Implemented as per Contribution Agreement

As there is no specific objectives, this intervention is in progress as there are actions taken.

Intervention Group 4 Summary

Intervention group 4 deals with the hard infrastructure, such as the space segment and the ground segment. It is here where there are some delays in the component, most notably in the space segment. At the time of writing, for G1G, the main cause of delay is the launch crisis. It cascaded into delaying G2G batch 1, which also will not be launched per the initial schedule.

As this issue is handled externally to EUSPA, they have limited visibility or control to mitigate these kinds of delays.

Overall, the rollout of evolutions of Galileo G1G OS FOC and the evolutions are delayed, due to a range of external factors such as industry contractor delays and political delays pertaining to the Russian invasion of Ukraine. Ground segment activities related to G2G are also similarly delayed but of lower priority with no additional impact. Terrestrial activities related to the service component are on schedule.

Therefore, EUSPA can be considered to have conducted their tasks successfully, as non-completion is due to external causes.

5. Support Commission international activities

Intervention 5.1: *This objective requires to support the Commission in international activities (e.g. technical support, implementation roadmaps, other information) for the implementation of the Commission international activities and agreements, in particular:*

- *Negotiations with third countries and international organisations*
- *Standardisation activities linked to services and the relevant user segment*

Description of Activities

Ad hoc objective pertaining to supporting the Commission in international activities.

Overview of Results

There is no way to monitor this objective, as it is an ad hoc objective. Currently EUSPA is supporting the commission in forums like EUROCAE, COSPAR SASAT, ICAO and other organisations and their working groups. EC has highlighted however, that there is room for increased involvement by EUSPA on the ICG.

Intervention 5.1 Qualification	Implemented as per Contribution Agreement

EGNOS

The EGNOS interventions are listed below, followed by an assessment based on the EUSPA consultation, supported with EC inputs, and finally a qualification of the impact based on the approach outlined above.

1 EGNOS service provision

Intervention 1.1: *Ensure that the EGNOS services perform as per the published Service Definition Documents (open service (OS), safety-of-life (SoL) and EDAS).*

This includes to avoid regression of performance upon updated Service Definition Documents over the EU Member States' territories geographically located in Europe.

To meet this objective and in addition to the nominal service provision processes, the effective and timely implementation of maintenance processes are required:

- *Preventive maintenance: develop, qualify and deploy correction of anomalies and refreshed technology before impact on services.*
- *Corrective maintenance: deploy fast corrections to recover major underperformance in the services*

Description of Activities

Aims ensuring EGNOS performs as per the SDD.

Overview of Results

As they stand, EUSPA is on track to targets from the current SDDs, although some targets are not met for peripheral areas or due to limitations in EGNOS V2 – to be fixed by EGNOS V3. More details can be found in the performance assessment.

For maintenance, there are several examples of preventive and corrective maintenance that have been done, so EUSPA is completing its objective in this regard. An example is when EUSPA identified a dormant anomaly in the system and corrected it on air, they communicated the issue to the users and the service was not impacted.

It has been highlighted, however, that there is currently no EGNOS Service Provision plan in place, encompassing the service provision procedures, including Preventive and Corrective maintenance processes. This action was initially identified through a Lessons Learned exercise conducted two years ago, and it remains pending completion by EUSPA.

Intervention 1.1 Qualification

One deviation from Contribution Agreement with no consequence

Intervention 1.2: *Ensure smooth transition from EGNOS V2 to EGNOS V3 with no impact on the users (in terms of service interruption or degradation).*

Description of Activities

Aims at ensuring that there are no interruptions during the transition to ENGOS V3.

Overview of Results

EGNOS v3 is not ready for deployment and is not expected to be ready until 2027. Currently, there are a full set of activities underway which will ensure that this objective (smooth transition) will be achieved with no service interruption during the transition and that v3 will perform at least at the same level as v2. ESA is regularly assessing and comparing the planned V3 performance with the actual and planned V2 performance in order to mitigate this risk and these elements are provided to EUSPA.

In particular, there are some actions taken to prepare for the maintenance and extension of the service, such as procuring new versions of V2 to ensure continuity of service. It is the same space segment for V2 and V3, so they are already using some parts of V3 for V2 (GEO 3).

Intervention 1.2 Qualification

Implemented as per Contribution Agreement

Intervention 1.3: *Ensure that the services provided by EGNOS defined in Article 46 of the Space Programme Regulation cover, as a priority, the EU Member States' territories geographically located in Europe, including for this purpose Cyprus, the Azores, the Canary Islands and Madeira, by the end of 2026.*

Description of Activities

Aims at ensuring EGNOS service coverage over all EU MS territories in Europe, incl. Cyprus, Azores, Canary Islands and Madeira.

Overview of Results

There is a 1-year delay, at current. This was originally part of the EGNOS v3 contract, which entry in service is being postponed to end-2027, but actions to partially reach this objective will be done under EGNOS v2.4.2B.

EGNOS V3 is technically complicated and this complexity was underestimated by the industry, due to new activities introduced by the Program and also due to COVID.

There are three main reasons preventing the full achievement of the objective with EGNOS 242B:

1. There is a peak of solar activity in this period, which complicated matters and degrades the service performance
2. There are physical limitations (e.g. it is not possible to locate RIMS stations in the surroundings of Azores islands or Madeira which are oceanic)
3. To achieve coverage in these locations, EGNOS relies on sites outside the EU (Israel, Ukraine, Turkey, Egypt, Morocco, Tunisia). But to reduce the dependency on non-EU sites (for resilience purposes), alternative sites will be deployed, which will cause delays in the achievement of this objective.

Neither of these are under EUSPA control, as the decision to reduce dependence on non-EU sites comes from the Commission for non-dependency and resilience reasons.

That said, in the matter of relocating the RIMS and addressing the associated delays, the Commission holds the perspective that there exist several viable possibilities in this regard, and subsequently progress could be made in a more expeditious manner.

Realistically, the delay may further increase in particular due to the need for new sites for EGNOS V2 and due to industrial difficulties in the development and delivery of EGNOS V3 either directly due to Industry or due to the additional dependencies with external (outside Industry control) undertakings.

Intervention 1.3 Qualification

One deviation from Contribution Agreement with one consequence

This is rated as a deviation in terms of timeline that has a consequence. In this case, the consequence is the inability to provide EGNOS cover of the mentioned states by the end of 2026.

Intervention Group 1 Summary

Intervention group 1 deals with provision of EGNOS services. Meaning it aims to ensure that users of Galileo have access to the service as described, and that any interruptions or incidents are minimised or otherwise dealt with quickly.

Unlike Galileo, EGNOS (an SBAS) is not inherently global. It relies on a network of ground sites, meaning that service provision can be different based on proximity to the ground infrastructure. Task 1.3 which aims at provision of service across EU territories in Europe is delayed due to external factors, notably that there is a simultaneous need to expand coverage and close sites, making achievement of the objective complicated. Additionally, due to the solar peak and loss of stations, SDD commitments are also not fully met at this stage.

2 Ensure security of the EGNOS Programme

Intervention 2.1: EGNOS V2:

1. Propose an EGNOS V2 security accreditation baseline;

2. Update EGNOS V2 risk assessment in compliance with the approved EGNOS V2 accreditation baseline;
3. Establish risk profile based on security audits covering cyber domain;
4. Establish updated EGNOS V2 risk treatment plan..

Description of Activities

Aims at ensuring that EGNOS V2 is secure.

Overview of Results

Regarding (1), the security accreditation and certification plan (SACP) V2 was expected in Sept 2022, but this was delayed by 6 months. The SACP is part of the baseline, but what is important is the accreditation and reference requirements for V2. This is already done for EGNOS 243, it is just not detailed and scheduled officially in the SACP. The accreditation was already defined and validated by the SAB.

Because of this, on a macro level there is no delay.

For (2) the risk assessment has been completed

For (3) the audits are ongoing as planned

For (4) the first element is done and the second should be done by the end of 2023.

Overall, there are no risks with this objective.

Intervention 2.1 Qualification	One deviation from the contribution agreement with no consequence

Intervention 2.2: EGNOS V2: build and maintain, not later than 2024, an up-to-date accreditation dossier based on the EGNOS V2 security accreditation baseline which will allow timely provision of secured and accredited services

Description of Activities

Aims at ensuring that there is an updated EGNOS V2 security accreditation dossier.

Overview of Results

On schedule for 2024.

Intervention 2.2 Qualification	Implemented as per Contribution Agreement

Intervention 2.3: EGNOS V3: build and maintain an up-to-date accreditation dossier according to the Security Accreditation Strategy which will allow timely provision of secured and accredited services

Description of Activities

Aims at ensuring that there is an updated EGNOS V3 security accreditation dossier.

Overview of Results

The milestones are the SACP v3 which is delayed by 9 months and the v3 accreditation dossier. The first version of the SACP has been done, the first elements of an accreditation dossier have been produced, but an **update of the accreditation strategy has been decided by SAB**. EUSPA has acknowledged the changes to the accreditation strategy and worked with ESA to understand how these updates can be implemented.

It is under consideration. It **will have impacts in terms of schedule and budget**, which will necessitate direct negotiations with industry.

The changes from the SAB are the main cause of the delay. Therefore this is an external dependency rather than an issue inherent to EUSPA exploitation, however, it has led to difficulties with industry.

Intervention 2.4: *Timely implement EGNOS Security risks treatment plans both for EGNOS V2 and EGNOS V3 as far as budget allows.*

Description of Activities

It is a recurrent objective for when accreditation has been granted.

Overview of Results

Currently there is no accreditation for v2 or v3 yet as it is under preparation, but EUSPA can present risks and treatment plans to the SAB. While these plans are established, it is worth noting that they sometimes take longer than planned to implement.

This is therefore a minor deviation as there are no plans currently presented and approved by the SAB. Should be plan be approved and subsequently implemented by end of 2023, this intervention can be reassessed.

Intervention Group 2 Summary

Intervention group 2 deals with ensuring that EGNOS is secure. This is highly linked to aligning with the baselines set by the SAB. Regarding EGNOS V2, there have been delays in the production of EUSPA documentation both for EGNOS V2 and V3. For EGNOS V3, these delays will cause budget increase.

In addition, there have been changes within the SAB that have led to delays, although this is an external dependency.

3 Develop new EGNOS services enabling new application

Intervention 3.1: *Start delivering the new DFMC services, as a priority, over the EU Member States' territories geographically located in Europe, including for this purpose Cyprus, the Azores, the Canary Islands and Madeira.*

Description of Activities

Aims at delivering the new DFMC services over EU MS European territories.

Overview of Results

The DFMC service is planned to be delivered with EGNOS v3.2. The milestone is the SDD for the v3.2 which was expected in 2027, **this is currently at risk.**

EGNOS v3.2 is developed by industry under contract from ESA. Today, the aim is for end 2028, no longer 2027 but it is not yet officially contracted for 2028 which is why the delay is not officially down as until 2028.

This delay was caused partly by external factors to EUSPA, notably by industry underestimation of their work to derive and flow down (from system down to sub-system) the applicable requirements, by COVID and also by additional necessary activities introduced by the Program. EUSPA has not the full visibility and control on industry contracts. It should be noted that these contracts were awarded under the previous MFF, and since then there have been some changes. ESA confirmed that since the beginning of this development contract, as

per FFPA, ESA is managing the industrial contract and is providing visibility and involving EUSPA in their domain of responsibility in the different industrial milestones.

Since 2021, EUSPA has become the contracting authority and ESA is the procurement and design authority, and single interface to Industry (as per FFPA). This model is only 18 months old, so the benefits of the new model are yet to fully materialize.

Intervention 3.1 Qualification

Two deviations from Contribution Agreement with one consequence

The intervention is rated as a deviation with a consequence, as the delay directly affects the roll out of DFMC services over EU MS.

Intervention 3.2: *Enable new applications for EGNOS services:*

1. *Aviation: in compliance with ICAO standards, support the development of new applications (e.g. in Navigation or Surveillance).*
2. *Maritime: in compliance with IMO standards, both for services including integrity commitments in the range domain by 2023 and also for DFMC services including integrity in the position domain by 2027 in accordance with the EGNOS V3 Implementing Act⁸.*
3. *Rail: within ERTMS, by 2024 for services including integrity commitments in the range domain and by 2027 a preliminary design of services enabling the continuous train localisation based on GNSS + EGNOS signals and other sensors.*
4. *EDAS: new services including the distribution of Galileo data and other products.*
5. *Other domains where EGNOS services could be used as a result of the service analyses done by the Programme, for instance liability-critical applications for road applications or integrity for High Accuracy services.*

Description of Activities

Aims at updating EGNOS services in various domains.

Overview of Results

Regarding (1) there is **nothing to track** since it is the core activity of EGNOS. EUSPA is exploring new applications in areas like ADS-B or drones, and is further implementing conventional activities like airport approach procedures. EUSPA also supports the commission in defining authentication standards with ICAO.

For (2) there are two objectives to track. The SF service and the DFMC L5 service. The plan is to have the SF service & integrity in the ranging domain by end of 2023. There is a **risk that this date will not be achieved**.

For the DFMC objective, its linked to EGNOS v3.2 which is pushed back to 2028 and is **not going to be achieved within the MFF**. As discussed under objective 3.1, there are significant delays to v3.2 roll out.

The objective of integrating in the positioning domain **may be technically not possible** even beyond 2028 for maritime as it depends on standardization of the local environment of the receiver (position of the receiver, area around it, its ability to handle interference, multipath). While there are standards in aviation, there are no such standards developed by the IMO.

For (3) all is ongoing. The first part of the objective deals with SF service declaration including ranging integrity which is similar to and can leverage the maritime objective. For the DFMC part, the objective is also only the preliminary design. However, as it is “design” it is not linked only to exploitation but also to R&D, which means that there is some dependence on Horizon Europe which handles the R&D. Overall it would have to be re-assessed in 2024.

With (4) the introduction of Galileo data in EDAS relies on EGNOS v3, therefore it can only happen with the delivery of v3.

For (5) several FE and Horizon Europe projects aim at leveraging EGNOS advanced services for new domains, such as drones. There are no specific objectives, so no milestones to track yet.

Intervention 3.2 Qualification	3 of 5 (i.e. 60 %) tasks implemented as per Contribution Agreement
	2 of 5 (i.e. 40%) tasks have one deviation from Contribution Agreement with no consequence

There are delays to the maritime service, but these are related to the delay from the roll out of v3.2 and therefore the consequences are already covered under that objective. Additionally, as mentioned above it may be impossible to achieve the second part of the maritime objective due to a lack of industry standardisation.

Intervention Group 3 Summary

Intervention group 3 deals with provision of EGNOS services. As some EGNOS ground sites are being closed (Egypt), and because there are delays associated with EGNOS V3, certain elements of the service associated with complete geographical coverage and associated with the advanced features of EGNOS V3 (notable V3.2) will not be possible. Therefore the DFMC services will not be rolled out in the MFF.

That being said, these are due to external dependencies. For services related to EGNOS V2 development is ongoing based on experience in the maritime domain. The DFMC part will have to be reassessed in 2024.

4 Ensure EGNOS evolution

Intervention 4.1: EGNOS V2.4.2B to solve RIMS-C obsolescence issues, improve performance under severe ionospheric conditions and deploy additional RIMS by end 2023.

Description of Activities

This intervention aims at V242-B entry into operation by end of 2023.

Overview of Results

It is “at risk” officially but this is because its aimed for October or September, meaning that there are several months of margin before end 2023 to achieve the objective. Thus far there is no reason to believe the objective should not be met.

Intervention 4.1 Qualification	Implemented as per Contribution Agreement

Intervention 4.2: EGNOS V2.4.3 to solve NLES obsolescence issues and integrate GEO 3 into services by end 2024.

Description of Activities

This objective aims at V243 entry into operation by end of 2024.

Overview of Results

There is some risk of a 2 – 3 month delay due to prioritisation of 242-B, but 243 is based on the same platform, it is the same industry that built 242-B so the latter was prioritised. As of writing, there is no deviation.

Intervention 4.3: EGNOS V3.1 to ensure service continuity and security accredited services beyond EGNOS V2 end-of-life.

Description of Activities

This intervention deals with a smooth transition between v2 and v3.

Overview of Results

V2 is being extended to absorb the consequences of v3 delay. This means that there is no milestone to track and no issue.

Intervention 4.4: EGNOS V3.2 to deliver, in accordance with the EGNOS V3 Implementing Act:

- LPV-200 Single Frequency services in all EU-MS (+ NO/CH) territories + ENP-South and ENP-East extensions by end 2027.
- LPV-200 DFMC services in all EU-MS (+ NO/CH) territories + ENP-South and ENP-East extensions by end 2027 (including capability to deliver improved performance down to Vertical Alert Limits of 10 m. in all EU-MS (+ NO/CH) territories excluding Azores, Madeira and Canary Islands).

Description of Activities

Objective aims at SDD for both v3.2 SF and DFMC by end of 2027.

Overview of Results

For the SF of EGNOS V3.2, there should be coverage of the EU MS by 2027 (at risk) but not for all of ENP South or East. This will be delayed until 2028 as a minimum as there is still the need for additional stations. For the DFMC and improved performance down to VAL 10 in ENPS and ENPE, there are delays linked to EGNOS V3.2 services which are not expected by end 2027.

The DFMC will not be ready anywhere until 2028 at earliest due to the reasons mentioned in 3.1.

As mentioned in 3.1, the service will not be ready meaning that all territories cannot benefit from LPV-200 by the expected date. It should be noted that this is due to the same reason as for 1.3 – the need to deploy EU sites as alternative to some non-EU sites.

Intervention 4.5: To qualify and put into operations an EGNOS V3 release taking into account the evolutions of ICAO standards for DFMC SBAS by their applicability date in Nov 2024.

Description of Activities

Aims at qualification and operation of an EGNOS V3 release considering the ICAO standards for DFMC SBAS.

Overview of Results

EUSPA is on track. As EUSPA is part of the ICAO working group, they have excellent visibility on future regulations so they can introduce anticipations into industry contracts. ESA anticipated largely the implementation of these evolutions in the first years of the industrial contracts which allowed to mitigate drastically this risk.

Intervention 4.5 Qualification**Implemented as per Contribution Agreement**

Intervention 4.6: *To successfully integrate the processing of GPS IIF satellites by EGNOS V3 in time for their planned entry into service in 2026 without impacting the EGNOS services*

Description of Activities

Integrate GPS III processing by EGNOS V3.

Overview of Results

On track. This is work that is done with previous evolutions and requires no significant additional work.

Intervention 4.6 Qualification**Implemented as per Contribution Agreement**

Intervention 4.7: *To successfully integrate the processing of backward compatible Galileo 2nd Generation Batch 1 satellites by EGNOS V3 in time for their planned entry into service in 2025 without impacting the EGNOS services.*

Description of Activities

Ensure that G2G batch 1 satellites are compatible for EGNOS V3.

Overview of Results

Most likely there is no risk. As long as G2G is backward compatible with G1G, there is no reason why there should be any additional work to avoid impacting EGNOS services. That being said, EUSPA cannot be 100% sure that G2G will be fully backward compatible, so they manage it as a potential risk.

Intervention 4.7 Qualification**Implemented as per Contribution Agreement****Intervention 4.8**

To complete by end 2027, as a minimum, the preliminary design of an EGNOS V3 release including SBAS Authentication and a “Dual-Frequency Single-Constellation” (either Galileo or GPS) mode.

Description of Activities

Complete preliminary design of EGNOS V3 release incl. SBAS authentication and DFMC.

Overview of Results

This objective is within reach by end 2027. The study is planned under the contribution agreement with ESA, but there is a risk of budget availability depending on whether industry requires higher budgets. In the event of this, the study activity will be deprioritised.

This objective is low priority as there is no need for a study on EGNOS v3 if the v3 system is not yet ready.

Intervention 4.8 Qualification**Implemented as per Contribution Agreement**

For now, it is rated as implemented as per the contribution agreement, but as mentioned above, going forward there may be some budget risk leading to this activity being deprioritised. This would not lead to consequences for the programme.

Intervention 4.9

To take initial steps towards the procurement of GEO 5 services, taking credit for capacities to be deployed in the context of GOVSATCOM and future initiatives of the EU in the area of Connectivity.

Description of Activities

Begin procurement of next GEO satellite.

Overview of Results

Currently there is uncertainty. In the ideal case, GEO 5 would be a payload aboard the IRIS² constellation under the Union Secure Connectivity Programme, but this is dependent on the Commissions requirement for IRIS² – such as whether it will have a GEO component and whether it will carry an EGNOS payload.

If hosting the payload on IRIS² is infeasible, EUSPA plans industry consultations later in 2023 or early 2024 to host it aboard a commercial GEO satellite.

GEO 5 itself is a lower priority since it is needed only to replace GEO1. But there is a large margin of time since GEO1 is still operational and may be for well beyond its design life. Also GEO1 is not needed for EGNOS v3, meaning that GEO 5 is more likely to be a replacement for GEO 2 which is expected to operate for a very long time.

Intervention 4.9 Qualification	Implemented as per Contribution Agreement

Intervention 4.10

To procure SDAF to support the delivery of evolved EDAS services by 2024

Description of Activities

The intervention aims at EDAS SF/L1 using SDAF V2 by 2024.

Overview of Results

There is already a delay of 16 months. SDAF is a subsystem, mainly network equipment. Procurement is ongoing for this, but EUSPA has postponed this objective, which is why its delayed 16 months. In addition, the cyber security risks continue increasing and SDAF will be a much more robust solution to the EGNOS interface to internet.

Intervention 4.10 Qualification	One deviation from the Contribution Agreement with no consequences

The reason for postponing this objective is that EDAS server already provided this service, and SDAF is only aimed at EGNOS v3. The service itself can still be delivered, meaning that prioritising doesn't affect the service provision. However, due to the increased cyber security risks, it is possible that the SDAF delay could leave EGNOS vulnerable.

As of now, however, this risk has not yet materialised and therefore will need to be reassessed in 2024.

Intervention 4.11

Develop an implementing plan for longer term evolutions of EGNOS within 1 year of the adoption by the Commission of the corresponding implementing act (expected in the 2023-2024 timeframe). This plan will be aligned with the related Galileo/EGNOS upstream R&D actions undertaken in the context of Horizon Europe and take into account secured communication capabilities envisaged to be deployed in the context of the future EU Connectivity Programme.

Description of Activities

The intervention aims developing a plan for future evolutions of EGNOS.

Overview of Results

The “Long Term Evolutions Implementing Plan” is not started since the “Implementing Act” has not been delivered by the Commission. This is the plan for long term evolution of EGNOS, including authentication, integrity over Galileo HAS, new services. To feed this implementing act, EUSPA need to be fed by Horizon Europe upstream and mission analysis.

In terms of target, the goal is “within one year” which is feasible provided they receive the act on time.

Intervention 4.11 Qualification

Implemented as per Contribution Agreement

Intervention Group 4 Summary

Intervention Group 4 deals with ensuring the evolutions of the hardware of EGNOS. For the most part, this is on schedule as the objectives are often highly specific asking for EUSPA to deliver releases, designs or to begin procurement, which are possible within the timeframe. Where there are expected to be delays is regarding EGNOS V3 (notably V3.2) and its associated services.

The delay is based on issues like site procurement and industry delays. There have been steps taken to mitigate this, but it will take time to see the results of mitigation.

EUSPA often has to reprioritize objectives since the agency has had to assume more responsibility in 2021 under the FFPA, but the ramp up of resources (hiring and training) is gradual, meaning that over the period they need to juggle priorities.

It can be said that the objectives were optimistic and ambitious, as EUSPA also chooses to be ambitious and optimistic with evolution targets. Going forward, EUSPA plans to be more conservative with target setting.

5 Support Commission international activities

Intervention 5.1: Pending confirmation of relevant additional budget sources, the following EGNOS extension activities are envisaged:

- Extension to Iceland;
- Extension to *Middle-East / Africa*

Description of Activities

Extend EGNOS to Iceland and Middle East Africa.

Overview of Results

The Iceland site is already being prepared, and the budget is planned. The site is aimed for 2029.

The MEA sites are planned for v3.2, but it will be slowed because of the EU level policy (not attributable to EUSPA) to close sites in Egypt and put on hold sites in Kyiv. Budget was already provided.

Intervention 5.1 Qualification

1 of 2 tasks implemented as per Contribution Agreement

1 of 2 tasks have one deviation from Contribution Agreement with one consequence (not attributable to EUSPA)

3.2.3.2. Assessment of the performance of the Galileo/EGNOS components

Both Galileo and EGNOS are measured against several KPIs on a quarterly basis to ensure they are performing as per the target. The notes column is coloured according to the achievement of the target in the following manner:

- GREEN – Target achieved, or no target but performance indicator is increasing based on previous year
- RED – Non achievement of target
- WHITE – No target to track.

Galileo

Table 86: Galileo KPI Assessment (red – target unmet, green – target met, white – no target)

#	KPI	Target	Outcome (Q4 2022)	Notes
1	Total # of satellites (ratio of satellite successfully launched vs planned)	100%	93%	Linked to launch availability as mentioned above
2	Total # of fully operational satellites (ratio of fully operational satellites vs commissioned satellites)	100%	Sep – 87.6% Oct – 86.0% Nov 85.0%	The low value is due to several reasons: GSAT104 is commissioned but not fully operational. There are ongoing discussions for decommissioning During the upgrade to ASW3.1, one satellite was out for upgrade every fortnight with each update taking one week. Additional issues like clock jumps, failures and ground segment issues.
3	Navigation Service Performance (as per MPL in SDDs for all declared services)	100%	Sep - 100% Oct – 100% Nov – 100%	Data only for OS No data for PRS in 2022
4	Timely achievement of Service milestones vs. FOC Service roadmap non-risk adjusted and risk adjusted objectives (covers G1G and G2G) – SB2.0 S-DQR4 Jul 2022, SB2.1 S-DQR5	As close as possible from the non-risk adjusted schedule	SIP: Jul 2022 Working schedule: SB2.0 S-DQR4 Step1 19/12/22 SB2.0 S-DQR4 Step2 31/03/23 Working schedule: 29/03/24	SB2.0 delayed due to change in SAB conditions and ESA development activities. See Intervention 4.2
5	Timely achievement of Infrastructure milestones vs. FOC Service roadmap non-risk adjusted and risk adjusted objectives (covers G1G and G2G1)	As close as possible from the non-risk adjusted schedule	Relative to non-risk adjusted, FOC is delayed, SB2.0 is delayed, G2G is delayed	See intervention 4.1, 4.2, 4.3.

#	KPI	Target	Outcome (Q4 2022)	Notes
6	Timely achievement of accreditation milestones vs FOC Service roadmap non-risk adjusted, and risk adjusted (covers G1G and G2G1) (M4B & M5 delay)	As close as possible from the non-risk adjusted schedule	3 month at least	Linked to intervention 2, and caused by the delay in SB2.0
7	Timely achievement of PRS uptake and technological roadmap versus approved PRS uptake and technological roadmap	As close as possible from the non-risk adjusted schedule	NA	Not a metric that is tracked publicly, so not available.
8	Timely delivery of GSMC Security Monthly Report (delay)	0 days	OK	
9	Timely GSMC reaction to incident reported (delay vs. nominal value for 95% of cases)	0 day	OK	
10	Mean time between CAT-1 service incidents (avg. time between 2 CAT-1 consecutive incidents)	As long as possible	NA	There have not been two CAT-1 incidents yet.
11	Timely completion of preliminary analysis of security incident by GSMC (delay vs. nominal value for 95% of cases)	0 day	OK	
12	Mean time to mitigate CAT-1 service incidents (time between incident observation and recovery)	< a few hours	OK	
13	Timely delivery of GRC Monthly Performance Reports (delay vs nominal delivery date)	0 day	OK	
14	GSC Portal statistics (Sessions page views registered users subscribed users to NAGU notifications user requests)	For information	Sessions – 16063 Page Views – 40532 Registered Users – 143 Subscribed users – 25 User requests - 47	
15	GSC web portal availability (monthly availability)	> 97%	100%	
16	GSC Reaction Time for NAGU (avg. reaction time in days)	As per SSD	0.37 days	
17	GSC Reaction Time for User queries (avg time to answer user queries that don't require escalation)	< 3 days	1.28 days	
18	Timely delivery of Quarterly Performance Reports (delay vs nominal delivery date)	0 day	One quarterly report delayed by 1 day	No impact of this delay

#	KPI	Target	Outcome (Q4 2022)	Notes
19	Market (2027) (ratio of Galileo EGNOS enabled receivers to total receivers)	EGNOS 65% Galileo 70%	EGNOS 62% Galileo 65%	Target is for 2027.

EGNOS

Table 87: ENGOS KPI Assessment (red – target unmet, green – target met, orange – target unmet but difficult to realistically achieve, white – no target)

#	KPI	Target	Outcome Q4 2022	Notes
1A	# of airports with EGNOS APV-I procedures	For Info	286	Continual increase in 2022
1B	# of airports with EGNOS LPV-200 procedures	For Info	204	Continual increase in 2022
2A	# of airports with EGNOS procedures implementing APV-I service level and with APV-I available	For Info	284	Continual increase in 2022
2B	# of airports with EGNOS procedures implementing LPV-200 service level and with LPV-200 available	For Info	203	Continual increase in 2022
N A	# of EGNOS procedures	For Info	837	Continual increase in 2022
N A	# of EGNOS Procedures with an availability ≥ 99%	For Info	833	Continual increase in 2022
3A	EGNOS APV-I service availability %	>99%	98.24%	Target not met in Q4 due to underperformance in some peripheral areas caused by higher solar and ionospheric activity
3B	EGNOS LPV-200 service availability %	>99%	99.5%	Target met every quarter
4A	APV-I EGNOS SOL coverage area over EU-MS+NO+CH (+IS*) land masses	100%	97.03% (incl. IS)	Caused by a design limitation of V2, performance should be increased by V3
4B	LPV-200 EGNOS SOL coverage area over EU-MS+NO+CH (+IS*) land masses	100%	89.73% (incl. IS)	Caused by a design limitation of V2, performance should be increased by V3
4C	NPA EGNOS SOL coverage over EU-MS+NO+CH (+IS*) Flight Information Regions	100%	100% (incl. IS)	
5	EDAS users monitoring	For Info	445 (EU) 1 (non EU) 70 (actual)	EU increasing over 2022, others decreasing over 2022
6A	APV-I SoL availability service area vs SDD	100%	92.7%	Underperformance in some peripheral areas due to solar and ionospheric activity higher than expected and GPS maintenance impacts on

#	KPI	Target	Outcome Q4 2022	Notes
				performance
6B	LPV-200 SoL availability service area vs SDD	100%	90.41%	Same as above
6C	NPA SoL availability service area vs SDD	100%	100%	
7A	APV-I SoL continuity service area vs SDD	100%	95.75%	Same as above
7B	LPV-200 SoL continuity service area vs SDD	100%	82.08%	Same as above
7C	NPA SoL continuity service area vs SDD	100%	99.63%	Same as above
8	OS performance and availability (RIMS sites above 99% availability)	100%	88.88%	Same as above
9	EDAS performance and availability	100%	99.99%	Considered compliant
10	EU user satisfaction with respect to EGNOS services	80%	85.6% (Q3 value)	Q4 value not available yet
11	Share of EGNOS enabled receivers in the worldwide (1) and the EU (2) GNSS / SBAS receiver market	For Info	(1) 62% (2) 62%	65% is a proposed target for 2027
12	EGNOS Service helpdesk Reaction Time	< 3 day	2.95 day	
13	Timely achievement of Service milestones vs. objectives (a) Delay per service milestone (b) Average delay versus objective) (As per EGNOS objective 3 service milestones)	(a) < 3m (b) 0m	(a) 16m (EDAS) (b) 3.7m	Due to a change in priority with no impact on users.
14	Timely achievement of EGNOS V2 developments (e.g. V242B and 243) qualification milestones vs. objectives (a) Delay per System milestone (b) Average delay) (As per EGNOS objective 4 milestones related to EV2 developments)	(a) < 3m (b) 0m	(a) target achieved for all milestones (b) positive margin in average	
15	Timely achievement of EGNOS V3 development and Phase B studies milestones vs. objectives (a) Delay per System milestone (b) average delay) (As per EGNOS objective 4 milestones related to EV3 development and Phase B studies)	(a) < 3m (b) 0m	a) Not achieved for V3.1 (7m delay), positive margin for V3.2 b) average delay = 1m	Caused by industrial delays

#	KPI	Target	Outcome Q4 2022	Notes
16	Timely achievement of accreditation milestones (Delay per accreditation milestone versus approved Exploitation Roadmap) (As per objectives 2)	< 1 m	Data unavailable (milestones TBD EEXP 2023)	
17	Mean time between important/severe/critical service incidents	For info	14 days	
18	Mean time to mitigate important/severe/critical service incidents	< few hours	1 day	It has been agreed with EC that the time to mitigate a service incident for SOL service will be reported with a granularity of 1 day. Given that the criteria to raise the service incident is based on a degraded coverage computed over 24 hours, the minimum recovery time is 1 day.
19	EGNOS Portal statistics (Sessions (1), Page views (2), Registered users (3), Subscribed users to notifications (4), User requests (5))	For info	(1) 26013, (2) 33627, (3) 4266, (4) 2929 (new doc)/ 2070 (perfo alerts), (5) 11	
20	EGNOS web portal availability (Monthly availability)	>97%	99.33%	

3.2.3.3. Takeaways on the effectiveness of the implementation of Galileo and EGNOS

GALILEO

For Galileo, the implementation of entrusted tasks was evaluated across interventions extracted from the Galileo objectives in the contribution agreement. EUSPA has effectively performed their tasks and has achieved most of their objectives. The system performs as per the SDD from a service perspective as of 2023, but future features and services (as well as the declaration of FOC) are delayed. The main sources of delays are industry delays with delivering the infrastructure, and the launch crisis. As both of these are external delays, it cannot be said that EUSPA has responsibility to anticipate these delays.

In terms of the service, the performance of the service is well aligned with where it is meant to be as of 2023. Elements like the support services from the help desk and security monitoring are also generally aligned with where they should be. That being said, going forward there are some service delays to be anticipated.

Based on the results of this, it can be established that the implementation of Galileo under the 2021-2027 contribution agreement has been effective between 2021 and 2023 considering the global economic and political situation.

EGNOS

For EGNOS, the implementation of entrusted tasks was evaluated across interventions extracted from the EGNOS objectives in the contribution agreement. EUSPA has performed their tasks and has achieved many of their objectives. In general, some of the objectives were ambitious, considering the political and economic situation following the COVID pandemic.

There are some delays regarding the expansion of the EGNOS coverage area, notable because these delays are caused by EUSPA needing to close several sites outside of Europe for strategic reasons beyond the control of EUSPA. While acknowledging that it is difficult to identify new sites and deploy infrastructure, the Commission has highlighted that there are several options for EUSPA to explore, and EUSPA could be more responsive in exploring these sites rapidly and securely.

The other source of delay is with the roll out of EGNOS V3. There are numerous causes of this delay, notably changes from the SAB, the COVID crisis, and industrial delays all outside the control of EUSPA.

A final source of issues is on space weather, which has had an impact on many of the tracked indicators. This has caused some service outage issues on the periphery (Canary Islands, Northern Scandinavia) but the system release v242B is expected to mitigate this when it enters into operation in Q4 2023.

The performance of the service in terms of coverage is gradually improving, notably in the core domain of aviation, as an increasing number of airports leverage EGNOS. Service performance, however, has sometimes been slightly sub optimal for two reasons (mentioned just above), first, space weather, and second, that V3 is delayed. Both these two elements are currently being mitigated.

Therefore, it can be said that most of the tasks assigned to EUSPA were achieved successfully, outside some tasks that are due to external incidents. EUSPA has also taken steps to mitigate these issues as they form to reduce risk in the future, so we can state that EUSPA's implementation of EGNOS under the 2021-2027 contribution agreement has been effective between 2021 and 2023 considering the global economic and political situation.

3.2.4. Benefits assessment of the Galileo / EGNOS Components

Galileo and EGNOS are two critical programmes for the EU. GNSS has become an indispensable technology to the 21st century economy and society as it is relied on by almost all people on the planet to some degree. This can be direct, such as through supporting personal navigation, or indirect, such as through ensuring the security, health, environmental protection of citizens across covered areas.

Despite the costs of GNSS, the benefits they bring are also extremely large as modern society likely would not function the same without GNSS. Much like national defence or environmental protection, GNSS is a public good, meaning that it is both non excludable and non-rivalrous. Non excludable means that the publicly available signal is available to all and cannot be limited only to certain groups without fundamentally changing the service - such as through selective availability or specialised services such as the PRS. Non rivalrous means that the use of GNSS by one user does not prevent/degrade the use by other consumers – as in the signal is no less effective if used by a billion people as if used by one person.

These qualities enable GNSS to have immense public benefits to all users, but because to these qualities it is also difficult for a free market to produce these goods due to the “free rider problem.” Indeed, when selective availability was lifted from GPS in 2000, everyone on the planet with a receiver could benefit from the good regardless of whether or not they pay for it through taxation. The same applies to Galileo today.

Because of this capability, it's difficult to track exact causality of benefits – as the benefit does not always link directly to service provision. In this case, GNSS services are generally interchangeable between the four operational constellations for most use cases, therefore it is

difficult to quantify the added value of one constellation over another constellation. Therefore, the method to assess the benefits of Galileo/EGNOS is variable.

Overall, the value of GNSS technology can be addressed independent of any constellation, and the value of certain incremental improvements (or differentiator services) can also be calculated. This study aims to leverage past studies to build a high-level picture of the benefits of Galileo.

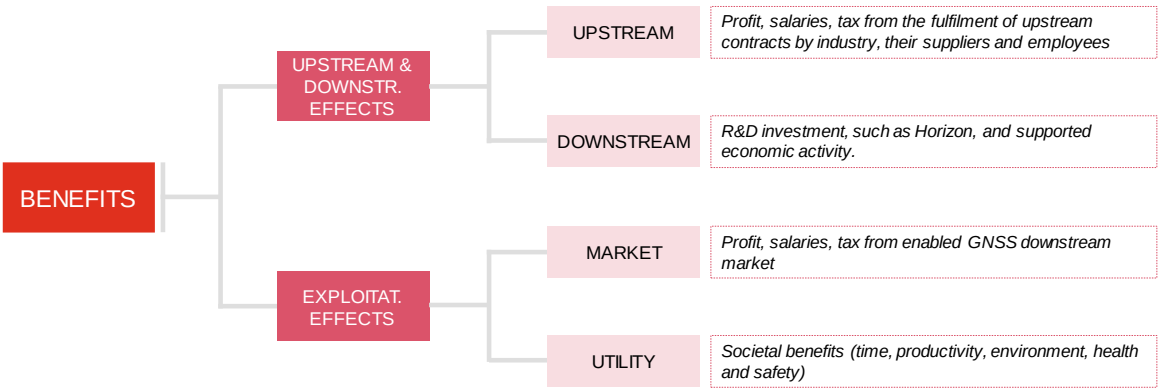
London Economics (2018) has assessed the impact of the GNSS in Europe as a whole as part of their Cost Benefit Analysis of Galileo Second Generation. PwC will build on this study to illustrate the impacts of Galileo for the assessed period of 2017 to 2035.

These benefits would link mainly to those of the OS and HAS, the PRS and SAR would be assessed separately as they are linked to very specific verticals.

In the case of EGNOS, Oxera (2022) has assessed the benefits of a reinstatement EGNOS to the UK. PwC will extrapolate the results of that study to align with the temporal and geographic scope of this study. Note that this study only covers the utility benefits of EGNOS, and deals only with the most critical vertical – aviation.

The study identifies benefits as either the benefits of activity in the upstream & downstream, or benefits from the exploitation of the services. This can be shown as below:

Figure 74: Benefit categories (Source: adapted from LE 2018)



3.2.4.1.Upstream

Upstream benefits refer to the multiplier effects of the initial upstream investment. This is measured as gross value added (GVA). Total GVA is composed of the direct, indirect and induced GVA. Direct GVA is the sum of the profit and labour (salaries) of the entities directly contracted, indirect is that of the entities that supply the space upstream, induced is that generated by consumer spending where the consumers are the employees paid by the firms contracted in the direct and indirect entities.

The LE study takes the following assumptions for the quantification of upstream benefits:

Table 88: EGNSS upstream benefits assumptions

Upstream profit margin	8% ³⁵
Upstream share of turnover spent on labour input	27.6%
Upstream Type II Multiplier	2.4
<i>(all prime contractors obtain EU VAT exemption)</i>	

³⁵ Profit margin stipulated on ESA contracts

PwC adds the additional assumption that the above **assumptions apply both to Galileo and to EGNOS**. Note that the values mentioned here are assumed as current prices.

Table 89: EGNSS spending assumptions

EGNSS Total Spending (spending) (2014-2020)	EUR 5,765 M ³⁶
EGNSS Total Spending (commitment) (2021-2027)	EUR 7,437 M ³⁷
Total EGNSS Value (2014-2027)	EUR 13,202 M

The total upstream impact can be calculated by following the formula:

$$Total\ GVA = Type\ II\ Multiplier \times Direct\ GVA$$

$$Direct\ GVA = Total\ Contract\ Value \times (profit\ margin + labour\ input)$$

$$Total\ GVA_{Upstream} = 2.4 \times (8\% + 27.6\%) \times Contract\ Value_{Upstream}$$

$$Total\ GVA_{Upstream} = 85.44\% \times Contract\ Value_{Upstream}$$

In this case, the upstream impact can be estimated based on the total contract value for Galileo and EGNOS. This results in a **value of EUR 11,279.79 M in total GVA** in current prices.

3.2.4.2.Downstream Spending

As downstream spending (H2020 and Fundamental Elements) is part of the spending envelope assessed, **these benefits are not added to this assessment**. Based on a literature review, London Economics estimated the multiplier for downstream spending (which would include spillover benefits) at 2. Meaning that 2 EUR are generated in the wider economy for 1 EUR invested in the programme during the assessed period.

Therefore, the formula for downstream benefits is as follows:

$$Benefit_{Downstream} = 2 \times Contract\ Value_{Downstream}$$

3.2.4.3.Exploitation - Market

Market benefits are the GVA benefits accrued by the market of EU sold GNSS devices and services. London Economics (2018) estimates this based on the European GNSS market share as well as on the level of R&D funding supporting the GNSS downstream industry.

The figures calculated by LE form the baseline of the G2G CBA, and therefore the impact of G2G is calculated separately. Research done in section 4.2.3.1 illustrates that G2G is delayed by at least two years. While the LE study assumes that the constellation achieves IOC in 2031 and FOC in 2034, we now add at least two years to these numbers, estimating thus IOC not before 2033 and FOC not before 2036.

The implementation of G2G also includes the assumption that IOC will realise 10% of performance of the constellation and FOC will realise 100%, and that there is an exponential ramp up of performance in the intervening years – which in this study are between 2033 and 2036.

Considering however, that this study only covers the launch of batch 1 of G2G, the IOC is not included in this study.

The LE study covered the benefits over the period of 2020 to 2045. PwC has taken the assumption that the benefits grow annually along with overall GNSS revenues in the sector.

³⁶ Based on docs provided by the EC to PwC

³⁷ Based on docs provided by the EC to PwC

This assumption leads to an estimated CAGR of 7.2% as per the EUSPA EO and GNSS Market Report 2022³⁸.

As the LE study used 2025 prices, PwC discounted the values to 2023 using a discount rate of 4% as per the Better Regulation Toolbox

The LE study has taken a geographic scope of EU28 + Norway and Switzerland, these are included because they have signed international agreements to join EGNOS and Horizon.

Without G2G the assumed benefits for each sector are as follows:

Table 90: Market Benefits of GNSS (Source: adapted from London Economics)

Vertical	GNSS Benefit (M EUR) (2017-35) (2023 prices)
IoT / LBS	€ 55,424.14
Safety Critical and Liability Critical Transport	€ 2,508.25
Terrestrial Vehicles monitoring & Automation	€ 49,274.90
Drones	€ 809.11
Critical Infrastructure	€ 1,254.12
High Precision Professional Applications	€ 26,174.76
TOTAL	€ 135,445.28

A caveat to this is that these benefits are not solely the result of Galileo, and include the benefits to Europe of the exploitation of GPS, Beidou and GLONASS signals. As mentioned earlier, it is not possible to separate these benefits as the users (and user devices) are signal agnostic for most cases in the case of multi-constellation receivers.

3.2.4.4. Exploitation - Utility

The utility benefits are estimated by London Economics (2018) in the same way as the market benefits. These were then adapted for the existing timeframe by PwC to produce the following result:

Table 91: Utility Benefits of GNSS (Source: adapted from London Economics)

Vertical	GNSS Benefit (M EUR) (2017-35) (2023 prices)
IoT / LBS	€ 85,361.27
Safety Critical and Liability Critical Transport	€ 25,729.75
Terrestrial Vehicles monitoring & Automation	€ 412,849.19
Drones	€ 43,772.94
Critical Infrastructure	€ 1,213.67
High Precision Professional Applications	€ 121,649.93
TOTAL	€ 690,576.74

In the case of EGNOS, the utility benefits were calculated based on a 2022 study conducted by Oxera and adapted for the same temporal and geographic scope as the rest of the study. As there are fewer impact assessments done for EGNOS, PwC has used another study to adapt the benefits focusing on the domain where EGNOS is the most critical: aviation.

Table 92: Utility Benefits of GNSS (Source: adapted from Oxera)

Vertical	EGNOS Benefit (M EUR) (2017-35) (2023 prices)

³⁸ EUSPA (2022) EO and GNSS Market Report. Available: https://www.euspa.europa.eu/sites/default/files/uploads/euspa_market_report_2022.pdf

3.2.4.5. Vertical Deep dive

To further elaborate on the benefits estimated in the above studies, this section will go vertical by vertical to qualitatively describe some of the market and utility benefits.

1 IoT and LBS

IoT and LBS in this context refer to mass market devices. These devices use GNSS for a range of tasks. A use case that would fall into this category would be personal navigation in the sense of using a smartphone to navigate to a destination.

Similarly, a user could use the location on their smartphone to hail a taxi, to call for a delivery, to locate nearby amenities, and so on. All of these are use cases wherein the GNSS element adds value to a user's smartphone. Market revenues thus are clearly from the GNSS SoC (system on chip) within the smartphone, but also would stem from the applications themselves. Consumers may directly pay through the app (ride hailing, delivery, gaming, etc.) or the app may use their location data for targeted advertising which is another source of revenue. This latter case is the largest source of revenues based on the GNSS Market Report.

Globally, the market is extremely large, but the European market is smaller due to most SoC manufacturers being located in the USA or East Asia (Qualcomm, Mediatek, Samsung, Apple, HiSilicon). Multi-constellation is generally the norm in consumer devices, and multi frequency is increasing in market penetration, through chipsets from manufacturers such as Broadcom and Samsung.

Many GNSS apps are developed for personal navigation. While some apps rely on direct payments, the majority of GNSS revenues stems from data collection. Many of these apps are developed by European companies, for example Deliveroo, Food Panda, Blablacar, Drivy (although currently owned by American GetAround), CityScoot, Bolt, Kapten, and many others.

Wearable technology is also on the increase, further increasing the market size. European players have a more prominent role in wearables, with the European brand Suunto being a large player in the higher end sport watch market, targeting a niche of extreme outdoorsmanship (mountaineering, hunting, diving, etc.).

The aging population in Europe presents another use of GNSS technology for elderly monitoring. While East Asia is also experiencing an aging population, a UN study shows that most elderly in non-western cultures (Asia included) live with their children, potentially reducing demand in this region making it more interesting for Europe. Most firms who product GNSS trackers for the elderly also produce such for tracking children and pets, as well as low power asset trackers for tracking objects and vehicles. These firms include Weenact, Spotter, PAJ GPS, Invoxia and others, although foreign trackers from Asia have presence on the market.

These LBS applications have large potential to improve quality of life and productivity of mass market users. For example, some quantifiable benefits of this technology include

- Travelling benefits: reductions to time and pollution through improved travel efficiency (better driving, cycling, transit use, etc.) due to turn by turn navigation, traffic alerts, etc.
- Reduced driving time also reduces the risk of accidents.
- App benefits: increases in incomes and utility or reductions to time and pollution through novel apps – such as food delivery, rideshare, gaming, advertising, etc.
- Emergency benefits: support to emergency services that use cell phones to locate emergency callers.

A 2011 study by Lohan et al.³⁹ polled students at two European universities on their willingness to pay for LBS. The study revealed that students were, on average, willing to pay between 5% and 10% more than their current phone subscription costs for LBS related to emergency services, navigation, wellbeing, and disasters.

Another study by Alphabet⁴⁰ estimated the willingness to accept forgoing the use of digital maps for navigation for a discount to their phone bill. The study revealed that globally, people were willing to accept a discount of USD 105 per month, while in Europe the result was USD 127. Extrapolating for population (in the year of the study), digital maps were worth a total of USD 347 B to the world, and USD 72 B to Europe.

The study also estimated that overall, digital maps reduce travel time by 12% on average, and by incentivizing better transport decisions they save 22 B liters of fuel annually, translating to **reduced CO2 emissions of approximately 50.6 million tCO2e**, globally in the study year (2016).

2 Safety Critical and Liability Critical Transport

This macro segment refers to aviation, rail, and maritime safety-critical and liability-critical applications. When transporting people or valuable or dangerous cargo, all these modes of transport become safety or liability critical.

AVIATION

Aviation is one of the core domains for satellite navigation and is indeed the core domain for SBAS as EGNOS and other SBAS technologies were built originally to augment GPS for this use case. Outside of GNSS, there are various methods generally used by aircraft – visual/celestial navigation, dead reckoning, communication with ATC, radar navigation, VOR, etc.

Many earlier cases generally required a dedicated flight navigator especially over trans-ocean flights, at least until the 1970s when more sophisticated electronic methods were developed. Inertial navigation systems, automatic direction finders, VOR stations – but many of these have their drawbacks. Both ADFs and VORs require ground-based infrastructure, which usually does not exist over large water bodies like the oceans – TACAN beacons (a sophisticated form of VOR for military) were often placed aboard ships.

LORAN was another technology that could have been used, but this would have required its own infrastructure to be built at a global scale – not to mention that LORAN-C could not achieve precision that rivals GPS or Galileo.

While these methods were generally accurate enough, none were as precise as GNSS, often being at least an order of magnitude less precise. Additionally, they often required costly equipment of the installation of a ground network, and rarely had global, all-weather coverage.

GNSS effectively counters the problems of all the other methods. It was affordable, required no additional infrastructure, required little specialized training to use, and for security applications, was radio silent. Inertial navigation systems are still in use however, as they are

³⁹ Lohan, E. S., & Rusu, A., Cramariuc, O., Ion M., & Cramariuc B. (2011). End-User Attitudes towards Location-Based Services and Future Mobile Wireless Devices: The Students' Perspective. Information. 2. 426-454. 10.3390/info2030426.

⁴⁰ AlphaBeta. (2016). The economic impact of geospatial services: How consumers, businesses and society benefit from location-based information. Retrieved from https://accesspartnership.com/wp-content/uploads/2023/03/GeoSpatial-Report_Sept-2017.pdf

similarly effective. The technologies are synergetic as inertial systems can be used if GNSS is jammed or spoofed.

Were it not for GNSS, aviation would likely not be the same as other technologies would need be upgraded to achieve its precision. Not to mention that GPS itself is also not precise enough for some applications, notably for LPV-200 approaches, and thus EGNOS (or other SBAS such as WAAS in the US and GAGN over India) is needed for this.

While SBAS is one solution, it should be noted that there is ongoing work in Europe and beyond on developing ARAIM receivers. These receivers can use multi constellation GNSS signals from multiple satellites and dual frequency processing to verify the integrity of each individual signal, effectively providing a similar service to SBAS. While not yet implemented, it is possible that one day ARAIM receivers could provide global LPV-200 approaches⁴¹ – another layer of security on top of SBAS.

LPV-200 means that a pilot approaching an airport can decide later (at a lower altitude of 200 ft) whether they can continue the landing or need to abandon **without ground-based ILS** supporting them. This is of importance in bad weather when the pilot cannot establish visual contact with the ground from higher altitudes. If a pilot cannot establish visual contact, they will need to retry landing at another airport with ILS or where there is better weather. This can cause delays because ATC might not allow planes to take off if there is risk that the pilot cannot land at the destination. Without LPV-200, flights will either be cancelled, delayed, or diverted to larger airports with ILS.

In principle, this leads to two main ways to quantify the impacts. Either they could be quantified by valorizing the total cost of the flights being cancelled, delayed or diverted – such as the monetary cost to passengers, the time cost to passengers, the fuel costs to airlines, the environmental impacts and so on, or they could be quantified by estimating the cost to small airports to install ILS.

The former approach was used in 2022 by Oxera to estimate the value of EGNOS to the UK economy⁴². They estimated that the benefits to the UK were 2.3 times the cost of participation to EGNOS, or rather, that the yearly benefits were approximately GBP 77 M in 2022.

PwC can extrapolate this value to the entire EU-28 + NO + CH using the number of airline passengers in 2022⁴³ as a proxy⁴⁴. This results in a value for EGNOS in aviation of GBP 500.47 M, or EUR 579.28 M in 2022. The results can be calculated for the preceding years using historical data, and extrapolated forward by estimating the growth rate of the aviation sector (based on the 3 years preceding the pandemic).

The following numbers were used:

Table 93: EGNOS calculation inputs

⁴¹ Cozzens, T. (2023) FAA researching Advanced RAIM for GPS + Galileo approaches. GPS World. Available: <https://www.gpsworld.com/faa-researching-advanced-raim-for-gps-galileo-approaches>

⁴² Oxera (2022) The value for money for a temporary reinstatement of EGNOS. Available: <https://www.oxera.com/wp-content/uploads/2022/07/20220623-The-value-for-money-of-a-temporary-reinstatement-of-EGNOS.pdf>

⁴³ There is no figure in the world bank database for 2022, but IACO estimates that seat numbers have reached 9

0% of pre pandemic levels, so a simple 90% of the 2019 figure was applied. Source: <https://www.icao.int/Newsroom/Pages/Air-traffic-recovery-is-fastapproaching-prepandemic-levels.aspx>

⁴⁴ ICAO via World Bank (2021) Air Transport, Passengers Carried: https://data.worldbank.org/indicator/IS.AIR.PSGR?most_recent_value_desc=true

Data	Value	Source
EGNOS Revenue UK (2022)	GBP 77 M	Oxera
UK Passengers 2019	142,392,528	ICAO via World Bank
Aviation Industry Recovery Rate 2022	80%	ICAO
EU28+NO+CH Passengers (2016-2021)	Various	ICAO via World Bank
Exchange Rate	1.158094	Forbes

The following outputs were calculated:

Table 94: EGNOS calculation outputs

Data	Value	Source
UK Passengers 2022	113,914,022	Recovery rate * 2019 value
EGNOS Utility per passenger	GBP 0.6759	Revenue / Passengers (2022)
Industry Growth Rate	5%	CAGR 2016-2019
EU28+NO+CH Passengers (2023-2035)	18.95 B	Using growth rate
EGNOS Total Utility (2021 Prices)	€ 14,215 M	Using passengers and utility
EGNOS Total Utility (2021 Prices)	€ 15,375 M	Using discount rate of 4%

RAIL

The rail sector benefits from GNSS in many ways. While rail based transportation is certainly safety and liability critical, there are several use cases within the sector that are somewhat similar to IoT or LBS type use cases. For example, passenger information systems are useful for users as they enable the user to know with precision where they are in their journey. This can enable users to see landmarks as they pass them, or estimate how much time remains in the journey, without having to rely on their smartphone – which may not have a clear view of the sky to calculate position.

In more critical use cases, GNSS can enable real time freight tracking, which can help move freight shipping back to rails in Europe. This move would reduce shipping costs, but more importantly drastically reduce cost to society as heavy commercial vehicles cost society nearly four times more than electric rail, and light commercial vehicles cost over 30 times more - according to a study conducted by the University of Applied Sciences, Upper Austria⁴⁵.

Table 95: External costs of freight transport EU 28 per transport mode

MODE	EXTERNAL COST (EUROCENT PER TONNE KM)
ROAD (LIGHT)	35.6
ROAD (HEAVY)	4.2
INLAND SHIPPING (MARITIME)	1.9
RAIL (DIESEL)	1.8
RAIL (ELECTRIC)	1.1

Aside from tracking, GNSS can serve the rail sector through supporting fleet management and maintenance activities. Predictive maintenance, for example, can benefit from real time

⁴⁵ Hofbauer, F., Putz, L. (2020) External Costs in Inland Waterway Transport: An Analysis of External Cost Categories and Calculation Methods. Sustainability. MDPI. 12 (5874): 9. doi:10.3390/su12145874

information on train position, time, and data from various sensors. It can also feed into data on speed, acceleration, deceleration, etc.

All that can feed into a maintenance system in real time. This can enable more efficient maintenance as the data can be processed before the train arrives at the station.

GNSS can also simplify train management. In conventional signaling, a track is divided into blocks and only one train is allowed on a block at a time – as there was no way to know the exact position of the train. Moving block signaling enables trains to run closer together as the “block” is moving with the train, but for this the exact position and speed of the train must be known.

While this does not need GNSS, it can be supported by GNSS. Moving block signaling requires trackside infrastructure as well as on board tachometers and speedometers. GNSS can add an additional layer of security or even function theoretically with less infrastructure. A drawback is that GNSS cannot work in tunnels, precluding its use on certain sections of track and on metros.

ERTMS level 3 enables trains to travel as close as the absolute breaking distance. Going further is virtual coupling, which allows two trains to be closer to each other than the absolute breaking distance – much in the same way as cars. The trains are coupled via vehicle-to-vehicle communication, and then they travel in a synchronous manner as a sort of convoy. GNSS is a useful technology for this as it enables a train to know and communicate its exact position and speed to the other train, so the exact distance between the two trains can be maintained.

GNSS technology is also expected to support the roll out of autonomous trains.

All these safety critical use cases can benefit from Galileo, as they must have a high level of resiliency. Services like the OS NMA can help ensure that a signal is authentic, and services like the PPP (provided on the HAS) or ENGOS SoL can ensure signal integrity.

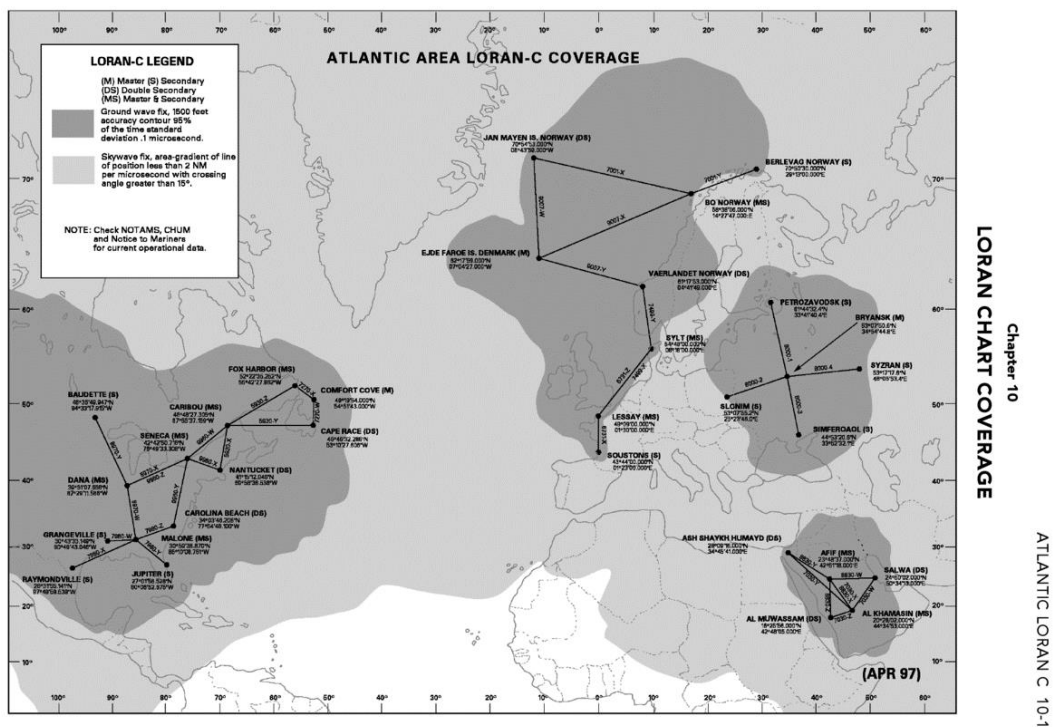
MARITIME

In the maritime sector, navigation is extremely important. Many navigation, mapping, and timekeeping techniques were originally developed for the maritime sector. GNSS has added another layer of benefit on top of the previously extant techniques, making marine navigation easier than before.

Coupled with satellite communication, open ocean vessels can know their exact position and report it, as well as receive the exact position of other ships to avoid collisions.

Like with aviation, prior to GNSS, navigators would use dead reckoning and celestial navigation. Once advance electronics were made available, inertial units greatly supported navigation along with radio navigation technologies such as LORAN C – although each had its limitation.

Figure 75 - LORAN C Coverage, 2006, Atlantic (Source: US DoD)



Radio navigation like LORAN-C requires stations, usually with some kind of timekeeping device. In the case of LORAN, this was atomic clocks. Once a certain distance is passed from LORAN, the accuracy drops significantly. In the open ocean, skywave signals could actually interfere with the PNT calculation of ships.

GNSS on the other hand puts the stations in space, meaning that with significantly fewer satellites, the global ocean could be covered. GNSS is also orders of magnitude more precise than any other technology on the list, and with Galileo-OS NMA, much more secure.

Indeed, several systems are enabled by GNSS – such as VMS, AIS, ECDIS and GMDSS. While these may be possible without GNSS, they would likely have been more expensive or complicated, and likely less precise.

In the open ocean, however, precision is often not necessary and even traditional methods of navigation that can provide position accurate at the kilometer scale is sufficient. Where GNSS begins to really be a differentiator is in coastal operations (where precision is key) and search and rescue (where both precision and rapidity are key).

For the former case, GNSS provides precision positioning and velocity information that it can relay to other ships which can further help with collision prevention. This can enable ships to sail closer to each other in busy waterways with less risk. Similarly, with the concept of autonomous ships gradually becoming a reality, GNSS can play a role adding a further layer of security.

Search and rescue will be covered separately.

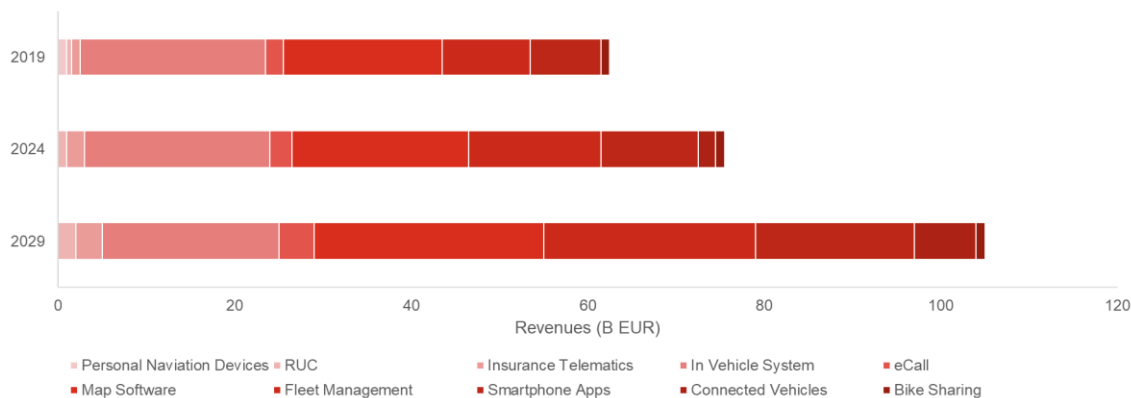
3 TERRESTRIAL VEHICLE MONITORING & AUTOMATION

This segment is similar to the previous segment but deals with non-safety critical applications such as the use of GNSS in road based applications, agriculture, surveying. This section also deals with autonomous vehicles.

ROAD

Road is estimated by the EUSPA GNSS market report to be the highest value GNSS segment due to the large number of road vehicles – as compared with other use cases – and the generally higher value of the receivers in the sector.

Figure 76: Road GNSS Revenues by Type (Source: GNSS Market Report)



For example, this can include personal navigation devices aimed at being used in a vehicle, such those normally attached to a vehicles windshield. Similarly, in vehicle navigation systems are also a use case (aimed at the same market). Other use cases include fleet management units, telematics, bike sharing services.

With the emergence of connected and automated vehicles (CAVs), there is expected increasing scrutiny of the reliability and precision of the associated GNSS technology. CAVs are far from the only safety and liability critical use case for GNSS, however, as others like eCall compliance, road user charging, dangerous goods tracking, and smart tachographs are also expected to be among the many critical use cases for GNSS.

Most of the cases of GNSS use in road is not safety critical. For example, navigation with IVS or PND just helps a driver get from point A to point B. GNSS in a private car generally does not function as a driving aid, as the driver’s own senses and intuition, combined with other ADAS features like radars, cameras or lidars are generally more suited to this application.

There are some liability critical use cases in road that fall under this category as well. GNSS is important for road users charging, which can increase the efficiency of toll booths and avoid traffic congestion.

In the EU, there is also work being done to incorporate GNSS into smart tachographs. This would ensure that professional drivers drive as per their contract and do not drive extra hours. This would have significant impacts for safety as fatigued drivers (especially driving heavy commercial vehicles) are significant danger on the road.

The figure above shows the very high revenues of the automotive sector alone, illustrating why this segment is the biggest. This is only the market, however, and the actual benefit to this sector are likely much higher.

Two notable exceptions that can be quantified are lives saved and environmental benefits. Road injury is among the leading causes of death globally and is the leading non-medical cause of death⁴⁶. In those under 18, road accidents are the leading cause of death globally⁴⁷.

⁴⁶ WHO (2020) Top 10 causes of death: <https://www.who.int/news-room/fact-sheets/detail/the-top-10-causes-of-death>

As GNSS makes driving simpler, journeys are shorter reducing the time on the road and therein reducing the risk of road accidents. GNSS can also support better mobility solutions such as transit or cycling which can further help reduce deaths. For the same reasons, GNSS can help reduce the environmental burden of road.

Galileo in particular can support saving lives on the road through the e-Call regulation. eCall involves a device aboard the vehicle that will automatically dial 112, share sensor information, and Galileo coordinates immediately in the event of a serious crash. It is estimated that eCall will greatly reduce response times.

AUTONOMOUS VEHICLES

GNSS is important for autonomous vehicles. Autonomous vehicles appear to be a major, if not the main driver of GNSS advancement in the sector. General automotive GNSS does not require high precision as it functions as mainly an aid to navigation for drivers – this means that smartphone grade GNSS (single frequency, no corrections) is generally enough as a navigation aid.

However, autonomous vehicles are a much more demanding use case if GNSS becomes more than a navigational aid and becomes a safety critical concern, thus require more reliable and precise GNSS. In this sector, more advanced GNSS technology is needed like multifrequency and PPP or RTK.

This being said, many currently operational autonomous vehicles do not yet use GNSS for safety critical positioning, rather using cameras, lidars, radars and IMUs for this purpose. Rather, such vehicles use GNSS much in the same way as a human driver – as a navigational aid. Nevertheless, there is work being done in the EU for using GNSS as a positioning aid as well, such as through the ESCAPE project and its follow on, the ERASMO project.

AGRICULTURE

Agriculture is a major user of GNSS, particularly in the case of precision agriculture (PA). The technology greatly increases the efficiency of the sector, enabling more to be produced with less cost and a lower environmental impact.

Agriculture is the oldest industry on this list, and for most of history it has functioned without GNSS. Indeed, in most of the world (including parts of Europe) many farmers still operate using traditional methods – not taking advantage of PA techniques.

PA techniques really began only after GNSS became available to civilians in the 1990s. These techniques, however, are not impossible without GNSS as prior to the 1990s, other technologies such as radio navigation were used to some degree (mostly for research). Although most users relied on visual markers like flags. This lacked the precision of GNSS, and so the technique could only be applied in small fields.

It is possible that Loran or a similar technology could have been developed with enough precision for PA, but it would have taken longer and been expensive, and possibly would never have worked. In fact, GNSS alone is rarely precise enough and usually have to be augmented in some way. Early on, the most common way was via DGNS, although today PPP and RTK are used as well.

⁴⁷ UNICEF Child and adolescent injuries: <https://www.unicef.org/health/injuries>

Therefore, without GNSS it is unlikely that PA techniques would be as effective. Currently, PA techniques use GNSS to manage agricultural inputs such as agrochemicals and seeds, as well as other inputs such as fuel and labor.

Three of the most common categories of technology are yield and soil mapping, machinery guidance and control systems, and variable-rate technologies (VRT).

In the first case, GNSS helps farmers to make more informed choices regarding inputs to their fields. With GNSS, a sensor can collect geolocated data from various parts of the farm and map them over a field painting a picture of the current status and needs of the field. Without GNSS, it is likely that for the same yield (or even lower yield), farmers would need to increase inputs and labor, as well as would have a bigger environmental impact due to overuse of agrochemicals and fossil fuels.

In the case of guidance, farmers can benefit from automatic steering and precision application of agrochemicals. The automatic steering software can use GNSS to precisely steer farm machinery, reducing overlaps or skips when driving through a field. Indeed, without GNSS, a farmer would need rely on visual markers as non-GNSS navigation technology is not precise enough. Similarly, when harvesting, a farmer can harvest a field in fewer passes due to the precision of GNSS. Without GNSS, the operator would need to be both highly skilled and highly diligent, leading to fatigue.

Variable rate technologies link to the previous two. Because of the mapping, a farmer can know exactly when, where, and how much agrochemical is required. With automatic steering, a farmer can precisely apply the chemicals where they need to be applied. And finally, with VRT, a farmer can vary the input based on how much input is required at different parts of the field. Without GNSS, a farmer would either use the same rate – and therefore overapplying or underapplying at different areas – or manually adjust the rate, which requires even more skill and operator focus.⁴⁸

Indeed, precision agriculture helps the farmer become a “decision maker,” by outsourcing monotonous tasks that do not require human intuition to a machine. This gives the farmer more time to focus on higher value-added tasks.

At an administrative level, GNSS is also used in the EU for the CAP. Paying Agencies rely on GNSS for supporting their activities in paying out agricultural subsidies to farmers. While not necessary for the CAP, it can greatly reduce the cost of implementation and the administrative burden on both the Paying Agencies and the farmers.

4 DRONES

Drones are a sector that is enabled by GNSS. Without GNSS, drones may have not had their large impact on society as they would not easily and economically be able to geolocate themselves. In many industries, drones provide cost savings through supporting infrastructure maintenance, transport (incl. delivery), agriculture, surveying, research, entertainment / media. The London Economics study that this section leverages deems drones as “enabled by GNSS.”

GNSS is important for a drone to georeferenced itself so that the data they collect can also be georeferenced. This is particularly important for when drones operate beyond visual line of sight.

⁴⁸ RTI (2019) Economic Benefits of the Global Positioning System. NIST

As more drones are expected to enter urban spaces, the domain of UTM (UAS traffic management) becomes more important. Proper UTM will be reliant on drones ability to know their exact position in 3D space relative to all other drones in the sky at that moment.

Also important is the role of the OS NMA, as drones are potentially dangerous. As they are remotely piloted or autonomous, drones are susceptible to being spoofed which could lead to accidents. As a drone cannot simply stop (it would need to land), authentication of GNSS signals is extremely important.

The benefits of the drones themselves has the potential to be very large. A drone can traverse all terrain faster than any other vehicle, making them exceptional emergency response vehicles. They are immune to traffic in urban areas and to dangerous terrain in rural areas. With GNSS, a drone can rapidly locate and navigate to the emergency, potentially saving many lives. According to the London Economics (2020), ambulance drones could improve the survival rate of cardiac arrest (which require extremely rapid response) from 8% to 36%.

Similarly, in most sectors a drone can cover large areas to perform quick surveys. This would reduce the need for humans, meaning that employees can focus on more important decision-making tasks rather than travelling to and from sites.

5 CRITICAL INFRASTRUCTURE

GNSS plays a key role in supporting increasingly accurate and resilient systems that are critical to society in sectors such as telecoms, finance, and energy. The uptake of GNSS in the Critical Infrastructure market is driven by the need for resilience in timing functionality, which is central to so many key sectors, many of which depend on each other. This level of cross-sectoral interdependence emphasizes the need for protection against cybersecurity threats that might otherwise lead to a toppling effect if exposed.

The top three segments in the Critical Infrastructure market for GNSS are Digital Cellular Network, Professional Mobile Radio and Small Cells.⁴⁹ The Digital cellular network (DCN) GNSS enables consistent frequency and time alignment between base stations that are part of a given digital cellular network. This is expected to be key in accompanying 5G roll out. Beyond this, the synchronisation of time slots and handovers between base stations is a relevant application of GNSS technology to PMR. In the case of small cell networks, GNSS plays a key role in frequency and phase alignment.

Critical infrastructures place high demands on GNSS system performance across most parameters due to the high stakes nature of the sectors it serves, requiring global high-end performance. Key technologies for critical infrastructure applications are largely focused on highly precise timing and strong levels of resilience, in particular:

- Emerging **Time-as-a-Service** schemes offer a way to enable precise timing where reliability, integrity, authentication and traceability are the primary concern. This is done through stable oscillators tuned by GNSS signals in addition to other timing sources including: multi-constellation, LEO communication constellation or network synchronization propagation (e.g. SYNC-E, Precise Time Protocol). This adds to global robustness and resilience.
- **Open Service Navigation Message Authentication (OS-NMA)** offers an anti-spoofing technology that continuously evaluates the authenticity of a navigation

⁴⁹ EUSPA (2020) GNSS Market Report

signal. The static nature of GNSS installations makes them prone to so-called carry-away spoofing attacks where the attacker sends simulated signals to the GNSS antenna, gradually overpowering authentic GNSS signals and altering their timing. With OS-NMA, Galileo is the first satellite system to introduce a specific anti-spoofing feature on a civil signal. A commercial equivalent exists as the **Galileo Commercial Authentication Service (CAS)**.

- **Network calibration and monitoring** are core to critical infrastructure applications. Verifying and testing the extent of timing accuracy can prove a challenge. Therefore, there is increasing demand for hardware equipment for both scientific and industrial applications to carry out calibration

TELECOMMUNICATIONS

The telco sector requires extremely precise timing and generally uses GPS time. In addition to this, they also use time distributed over a fiber network using PTP, but while PTP can distribute time independent of GPS (using terrestrial atomic clocks), they currently synchronise to UTC using GPS.

Wired networks could get time from other systems such as over Loran, which also used atomic clocks, but GPS proved to be a much more suited technology. This became especially evident when wireless networks became the norm, as “wireless base stations require synchronization (both time and frequency, depending on the wireless technology) to interface with the core wireline network and to communicate between wireless base stations to execute handoffs as a user moves from one base station’s range to another,” according to RTI50

GNSS has enormous social benefits in telecommunications alone, and the results in the LE study could be an understatement of the impacts. Recall that they estimate EUR 1356 M in market benefits and EUR 1312 M in utility benefits.

A way to quantify the benefit of GNSS could be to evaluate a counterfactual scenario in which GNSS did not exist. In this case, a terrestrial network such as Loran could be used (indeed, Loran-C was used as a backup for GPS up to the mid-2000s), but Loran-C likely could not have been used with modern 4G and 5G networks. The technology would either have needed to advance greatly, or these networks would simply not be possible.

Therefore, in a counterfactual scenario, either a terrestrial network would need to be developed increasing the cost but preserving the benefit, or all the benefits of 4G and 5G would not have occurred.

RTI (2019) estimated the value GNSS to this network. An extract from their report is below:

“All experts agreed that any alternative source of precision timing would have been more expensive and difficult to implement than GPS, with the exception of Loran-C, which had similar adoption costs to GPS and was already being used widely in the telecom sector. The added expense of other alternatives, according to three experts from private-sector telecom companies, made it more likely that the industry would have relied more heavily on Loran-C to provide precision timing services to infrastructure given that it was readily available and was similar to GPS in implementation.”

⁵⁰ RTI (2019) Economic Benefits of the Global Positioning System. NIST

If industry would have relied on Loran-C, 4G LTE and 5G would not have been possible. The study therefore estimated the willingness to pay for the enhanced service of 4G LTE. This can be evaluated both from a provider and from a consumer perspective.

In the former case, the some of the bands used by 4G (600 MHz, 700 MHz, 1700 MHz, and 1900 MHz) were auctioned off by the FCC in the US for a total of USD 81 B, which alone is significantly higher than the EUR ~2.6 B benefit estimated by London Economics.

RTI also estimated that this figure is conservative as these 4 bands do not capture the entirety of 4G, although at the same time, it is unfair to attribute all this 81 B to GNSS.

In the latter case, RTI looked at the willingness to pay for fixed bandwidth for consumers. This was done by looking at the cost of monthly subscriptions in the US to certain internet speeds, then calculating the marginal willingness to pay of an additional Mbps, to enable extrapolation to 4G speeds. The result was that the additional bandwidth granted by 4G LTE would create an estimated USD 686 B between 2010 and 2017.

Caveats to this include that RTI believes that 4G LTE and beyond would not be possible without GPS and thus allocates all benefits to GNSS. Also, the timeframe in the current study is different than the RTI study, and subsequently the technologies are different. 4G is significantly faster than 4G LTE, and 5G is significantly faster than that.⁵¹

6 HIGH PRECISION PROFESSIONAL & OTHER

The London Economics report defines high precision services as commercial services requiring high accuracy such as surveying and road fleet management, as well as non-safety critical applications in rail and maritime.

As the road, rail and maritime segments were covered in other sections, they will not be repeated here.

SURVEYING

While surveying has existed for a while, GNSS has been a game changer in the industry. The industry was among the first to adopt GNSS to both increase the precision of their activity and to lower their costs.

Prior to GNSS, surveying was very labor intensive. Even with a highly skilled surveyor, comparable precision would still require a significantly larger timeframe and budget, and still the centimeter and millimeter level precision may not always be possible. Naturally, for this level of precision, RTK is needed.

Pre GNSS surveying involved line of sight through which rangefinders could be used to estimate distance. With GNSS, line of sight is not needed, and the exact distance between two points anywhere on Earth (with a view of the sky) can be found quickly and economically. This is not to say that traditional surveying methods are outdated. They are still used in conjunction with GNSS.

The follow-on benefits to this are large as well. Beyond just providing benefit to surveyors, GNSS enables rapid surveying of changing landscapes and areas, granting more people with

⁵¹ 4G LTE was in the order of up to 100 Mbps, True 4G can reach up to 1000 Mbps. 5G is significantly faster, going up to 20 Gbps.

access to highly updated maps of larger parts of the world. This has significant knock on benefits to other sectors.

7 SEARCH & RESCUE SERVICE

According to EUSPA, Galileo SAR is the largest contributor to the Cospas-Sarsat MEOSAR programme in terms of ground segment and space segment assets. Although, GPS and especially BeiDou also contribute significantly.

The SAR service enables users in distress who have an EPIRB/ELT/PLB to share their location with emergency services over the 406 MHz band. This enables the emergency services to respond rapidly. A unique feature to Galileo and Beidou is their “return link service,” a service that enables people in distress to know that the distress signal from the beacon has been received and localized by the Cospas-Sarsat system and forwarded to government authorities for action.

The benefit of this is that it provides people with peace of mind that the authorities are at least aware of their position and their distress. This can help prevent survivors of an emergency event from making risky decisions.

Since 1982, COSPAS SARSAT has assisted over 50,000 rescue efforts worldwide. This figure, however, cannot fully be attributed to GNSS, as naturally many of those rescues would have been successful with other technologies.

This being said, Galileo SAR service has brought the detection time for ships that launch a distress signal down from 240 mins to 10 mins, and has brought the radius down from 10 km to 2 km.⁵²

3.2.5. Efficiency and Cost Benefit Analysis of Galileo / EGNOS

The following efficiency analysis takes as input the benefit assessment above and adds the costs of the EGNSS component’s development and operations in order to provide a comparison of these two factors through a cost benefit analysis (CBA). The CBA aims to evaluate the extent to which the costs involved are justified and proportionate to the benefits achieved and aims at answering the question on the extent to which the intervention been cost effective.

Benefits of EGNSS

As mentioned in previous sections, the benefits of EGNSS were calculated at two levels. The first level of benefits includes the direct transactional impacts resulting from the investment and spending into the development and operations of the component. The second level of impacts includes the wider socio-economic benefits resulting from the utilization and exploitation of the infrastructure developed.

The direct transactional impacts (the GDP impact) evaluates the Gross Value Added and employment impacts that were assessed in the section above, and the table below summarizes them:

Table 96: GDP impact of EGNSS Component

Transactional Impact	Value

⁵² PwC (2017) Mid Term Review of Galileo and EGNOS

Total GVA (Gross Value Added)	11,279.79 M EUR

On the other hand, the socio-economic benefits, also calculated in the section above are summarized in the table below. To ensure comparability the timeframe for the benefits has been adjusted to 2017 to 2027 to align with those of the costs:

Table 97: socio-economic benefits due to the exploitation of EGNSS

Benefit Type	GNSS Benefit (M EUR) (2017-27) (2023 prices)
GNSS Exploitation – Market	€ 56,627.36
GNSS Exploitation – Utility	€ 288,718.36
TOTAL GNSS	€ 345,345.73
EGNOS Benefit	€ 7,056.47
TOTAL EGNSS	€ 352,402.20

It should be noted that the benefits above are associated with all GNSS as it is not possible to separate the benefits of Galileo from other systems.

Costs of EGNSS

The figures on the total spending on the ENGSS component were provided by the European Commission

Table 98: Total spending on EGNSS per MFF

Spending Type	Time Frame	Amount in M€
Previous MFF: 2014 – 2020		
Total Spending	2014 - 2020	€ 5,765 M
Current MFF: 2021 - 2027		
Total Allocated budget (total expected spending)	2021 - 2027	€ 7,437 M
Total Spending (2014-2027)		€ 13,202 M

Cost-benefit assessment outcome

The cost benefit assessment (CBA) of EGNSS looks at the ratio between the benefits generated by EGNSS, which provides open and free access to its services, and the costs it takes to develop and operate EGNSS.

The costs are those that have accumulated over the assessed period and that are expected till the end of this MFF. The benefits are all the benefits accumulated based on the extrapolation of results and update from the London Economics study.

That said, accounting for the benefits is complicated due to the nature of GNSS. The calculated exploitation benefits stem from GNSS in general, not from Galileo. In practical terms, when a user leverages PNT from a multi-constellation receiver, they are agnostic to the source of the PNT. Their position could be calculated based on GPS, Galileo, Glonass, Beidou, or a combination of satellites. Outside of differentiators, most benefits can be derived from any system as long as the receiver is compatible.

We have therefore taken two different scenarios to calculate the benefits of ENGSS. The scenarios are based on assumptions on how benefit is allocated to Galileo, as benefits cannot easily be spilt between the GNSS.

- **100% of benefit allocated to Galileo.** Takes the assumption that all exploitation benefit in Europe is derived from Galileo. Therefore, this benefit is summed with the EGNOS benefits.

- **25% of benefit allocated to Galileo.** Takes the assumption that all exploitation benefit in Europe is derived equally from each of the four GNSS. Therefore, this is divided by four, and the EGNOS benefits are added on top.

Over the timeframe 2017 – 2027:

Table 99: Cost Benefit ratio over the timeframe 2017 – 2027

Costs	Benefit Scn. 1	Benefit Scn. 2	Benefit Cost Ratio 1	Benefit Cost Ratio 2
€ 13.20 B	€ 352.40 B	€ 93.39 B	26.7	7.1

As shown in the table above, even when assuming that the benefits are split equally between the four constellations, the benefits massively outweigh the costs. This is because of the extremely wide-reaching use cases of GNSS, and the fact that large portions of the global economy are dependent on GNSS.

In fact, the costs only account for 3.7% of the total value of the benefits, meaning that the benefit cost ratio would be greater than one even if only 3.7% of the benefits of GNSS were allocated to EGNSS.

Post 2027

The original benefits assessment goes beyond 2027 (going to 2035), where the benefits are expected to continue growing as GNSS penetrates deeper into the markets due to increasingly data driven and digitalised sectors, as well as due to the general growth of these industries. Costs are also expected to continue to be incurred due to the continuing evolution of EGNSS.

That said, as the budget is not available for the 2027 to 2035 period, a cost benefit analysis cannot be completed. It should still be noted, however, that many benefits beyond 2027 will be due to the investments made before 2027, but this is not possible to extract.

3.2.6. Relevance Assessment of Galileo / EGNOS

Introduction

The relevance assessment evaluates the extent to which the EU interventions are relevant to the end users. This is done by identifying the user needs in different domains and checking to what extent these user needs are met. EUSPA and EC maintain a user consultation platform (UCP) – a periodic forum where users from different sectors can discuss their needs for GNSS applications. This event involves end users, manufacturers, developers and organisations / institutions.

This platform helps ensure that EUSPA interventions consider the needs and requirements of end users, ensuring that space services provided by the agency are driven by these needs. The latest of these UCPs was held in October 2022, and reports were written (and made publicly available) from several sectors. Other sectors were missing from the documentation. However, the previous UCP was held in 2020 and included highly relevant sectors.

These sectors (generally aligned with the EUSPA market report) will be mapped onto the sectors from the benefits assessment (based on London Economics taxonomy) for coherence with previous parts of the assessment.

Table 100 - UCP Sectors

Sector	Year	Mapped to
Aviation	2022	Safety and Liability Crit. Transportation / Drones
Consumer Solutions	2022	IOT / LBS
Emergency Mgmt. and Aid	2022	Search and Rescue
Energy and Raw Materials	2022	Crit. Infra. / High Precision Professional Applc.
Infrastructure	2022	Critical Infrastructure

Insurance	2022	High Precision Professional Applications
Maritime	2022	Safety Critical and Liability Critical Transportation
Agriculture	2020	High Precision Professional Applications
Rail	2020	Safety Critical and Liability Critical Transportation
Road	2020	Terrestrial Vehicle Monitoring
Public Transport	2020	Terrestrial Vehicle Monitoring
Surveying	2020	High Precision Professional Applications
Timing and Synchronisation	2020	Critical Infrastructure

As the 2022 reports are highly recent, they can be used directly to assess whether EGNSS meets these user needs. For the 2020 reports, PwC would update the information where it is deemed necessary.

The EUSPA User Consultation platform identifies multiple sub-segments where GNSS used in each sector. Within each sub-segment are a series of applications investigated to varying levels of detail.

Below the description of the user needs sector by sector, with the related market trends and user communities, and deep dives on relevant applications.

3.2.6.1. Internet Of Technologies (IoT) / Location Based Services (LBS)

SECTOR 1: CONSUMER SOLUTIONS

The Consumer Solutions, Tourism, and Health market segment includes a variety of applications designed to cater to various lifestyle, sports, health, consumer robotics, and IoT needs, such as asset tracking. Primarily, these applications are compatible with smartphones and tablets, but they can also be used with wearables, digital cameras, and laptops, among other devices.

Market Trends

Demand side trends and challenges

Increasing focus on health

Both personal and public health have taken center stage, with a strong focus on mental well-being. As a result, there has been a growing trend of individuals engaging in regular exercise routines, leading to increased usage of sports applications for activities like running and cycling. In the realm of these applications, GNSS play a crucial role in tracking and monitoring progress.

Fight digital fraud

Financial services are now accessible directly to end-users, and the popularity of mobile banking and online shopping is on the rise. However, this trend has also resulted in an increase in digital fraud incidents. In response, the approach to combat these frauds largely centers on user authentication methods.

Sustainability

There is a need for more repairable phones and phone with longer lifetime cycles. In addition, sustainable tourism and tourism conditions' monitoring are just some factors driving the segment on the demand side, trying at the same time to fight the problem of over tourism and to address the necessity of better tourism best practices for the environment.

GNSS technology trends

Accuracy and authentication needs

In recent years a growing group of new applications has emerged that require much more stringent levels of horizontal and vertical accuracy. Moreover, categories of applications such as geo-marketing and advertising, fraud management, and location-based billing require location authentication to protect application users or service providers from malicious signal interference, such as spoofing, and improve the robustness of the services offered.

User Communities

The main three categories of users can be listed as follow:

- Commercial users, that use apps for insights and indicators provided by apps/dashboards/platforms, in the perspective of work optimization, but also, e.g. for decision-making, reporting, etc.;
- Citizens, people who use apps in their daily lives to express themselves, socialize, and integrate them into many different aspects of their lives;
- Public users and authorities, public figures that use apps in their public administration or in the projects and services they support.
- Users with special needs: users with special needs resulting from particular health conditions, who take advantage of applications created specifically for their needs.

User Requirements / Application

The following list of applications enabled by GNSS is not exhaustive, and is expected to grow with the adoption of space technologies in the coming years and the innovations that will come with it.

Health and Lifestyle

SPORT, FITNESS AND WELLNESS (TYPE A)

The user needs segment includes a range of applications, with a particular focus on fitness and performance monitoring. These applications involve the collection of data such as real-time distance, speed, pace, location, vertical oscillation, and traveled distance. Typically, for outdoor activities GNSS serve as the fundamental technology for location tracking. In contrast, indoor fitness monitoring applications rely on other sensors. In the GNSS domain, the primary concern for this category is the battery life, which is crucial for sports activities. Other GNSS applications encompass sport gear retrieval, which involves capturing statistics through microchips installed in golf balls, and fishing assistance to locate the best fishing spots and share them with other users.

Here below a summary of the main requirements in this segment.

Table 102: Performance requirements for Sport, fitness and wellness applications

Indicator	Value	Unit	Notes
Horizontal Accuracy	1-5	m	Confidence level >95%
Vertical Accuracy	1-5	m	Confidence level >95%
Service area	Global		Geographical Coverage
Availability	>95%	Confidence level	Under canopy
Availability	>95%	Confidence level	Urban Canyon
Availability	Yes		Indoors
Timeliness (TTFF)	30 or less	secs	In hot start
Update rate	1-2	Hz	Continuous positioning
Update rate	5-10	Hz	General

Robustness/Resilience	Yes	Susceptibility to interference
Power consumption	Low	
Proportion of GNSS	High	

AUGMENTED REALITY FOR LEISURE (TYPE B)

This segment covers leisure application such as gaming, broadcast and live events, travel applications, sports/adventure, navigation. For these applications, availability indoor and the accuracy are the main relevant indicator, in addition to robustness.

Here below a summary of the main requirements in this segment.

Table 103: Performance requirements for Augmented reality for leisure applications

Indicator	Value	Unit	Notes
Horizontal Accuracy	2	cm	
Vertical Accuracy	few	cm	Confidence level >95%
Vertical Accuracy	2	cm	Relative positioning
Service area	Global		Geographical Coverage
Availability	>95%	Confidence level	Under canopy
Availability	>95%	Confidence level	Urban Canyon
Availability	Yes		Indoors
Timeliness (TTFF)	30 or less	secs	In hot start
Update rate	15	Hz	Continuous positioning
Robustness/Resilience	Yes		Susceptibility to interference
Robustness/Resilience	Yes		Against spoofing threats

HEALTH (TYPE B)

In combination with other technologies, GNSS enables a vast array of applications from patient monitoring to guidance systems for vulnerable groups (people with reduced mobility, visual impairment and seniors). Some sub-applications are vulnerable people tracking or fall detection.

Here below a summary of the main requirements in this segment.

Table 104: Performance requirements for mHealth applications

Indicator	Value	Unit	Notes
Horizontal Accuracy	1	m	Confidence level >95%
Vertical Accuracy	1-5	m	Confidence level >95%
Service area	Global		Geographical Coverage
Availability	>95%	Confidence level	Under canopy
Availability	>95%	Confidence level	Urban Canyon
Availability	Yes		Indoors
Timeliness (TTFF)	15 or less	secs	In hot start
Update rate	NA	Hz	Continuous positioning
Robustness/Resilience	Yes		Susceptibility to interference
Robustness/Resilience	Yes		Against spoofing threats
Integrity	Provide timely		When the data provided should not be used

	warnings
Power consumption	Low
Proportion of GNSS	Medium

SAFETY AND EMERGENCY (TYPE B)

GNSS in combination with network-based methods provides accurate emergency caller location. Under this type of application stand two different and specific sub-applications: search and rescue and E112. Search and rescue services allow to locate people quickly in the event of an emergency while E112 follows the EU directive of 2003, which requires mobile phone networks to provide emergency services with information about the location. This application places stringent requirements on position accuracy, availability and response time. Since 2018, GNSS is mandatory in all new smartphones in the EU. The GNSS chip must be compatible and interoperable with at least the Galileo system, thus being able to automatically send more accurate location data as part of any emergency call to 112.

Here below a summary of the main requirements in this segment.

Table 105: Performance requirements for Safety and emergency applications

Indicator	Value	Unit	Notes
Horizontal Accuracy	1-5	m	Confidence level >95%
Vertical Accuracy	1-5	m	Confidence level >95%
Service area	Global		Geographical Coverage
Service area	Regional		For E112
Availability	>95%	Confidence level	Under canopy
Availability	>95%	Confidence level	Urban Canyon
Availability	Yes		Indoors
Timeliness (TTFF)	10 or less	secs	
Update rate	Yes		On request positioning
Robustness/Resilience	Yes		Susceptibility to interference
Robustness/Resilience	Yes		Against spoofing threats
Power consumption	Low		
Proportion of GNSS	High		

SOCIAL NETWORK (TYPE B)

GNSS technology is also used in some specific functions of social network. For example, it can be exploited to facilitate keeping in touch, for sharing travel information and for providing new networking services to users. The most popular applications are friend locator, such as in Snapchat, dating, chat and instant messaging services.

Here below a summary of the main requirements in this segment.

Table 106: Performance requirements for Social network applications

Indicator	Value	Unit	Notes
Horizontal Accuracy	10	m	Confidence level >95%
Service area	Global		Geographical Coverage
Availability	>95%	Confidence level	Under canopy
Availability	>95%	Confidence level	Urban Canyon
Availability	Yes		Indoors

Timeliness (TTFF)	30 or less	secs
Update rate	Yes	On request positioning
Robustness/Resilience	Yes	Susceptibility to interference
Robustness/Resilience	Yes	Against spoofing threats
Power consumption	Low	
Proportion of GNSS	Medium	

Corporate

BILLING AND FRAUD MANAGEMENT (TYPE B)

When using GNSS, most of the LBS commercial applications often require the high level of accuracy and authentication, as these are especially commercially sensitive applications for both users and companies. These include banking services (mobile payments) and other fraud management applications, in which a precise location of a user (centimeters accuracy) can be crucial to protect the assets. As a consequence, these applications are potential target of GNSS spoofing and jamming.

Billing within this segment encompasses public transport, gyms, theme parks, and parking, and it makes use of location-based billing (LBB). LBB enables the dynamic charging of users for a specific service based on their location when using or accessing that service. Fraud management in this sector leverages location data derived from GNSS and other sources to assess the probability that the individual requesting access with a card is the rightful owner. Fraud management applications can also extend to controlling computer systems or building access.

HERE BELOW A SUMMARY OF THE MAIN REQUIREMENTS IN THIS SEGMENT.

Table 107: Performance requirements for Billing and fraud management applications

Indicator	Value	Unit	Notes
Horizontal Accuracy	High		Confidence level >95%
Vertical Accuracy	3	m	Confidence level >95%
Service area	Global		Geographical Coverage
Availability	>95%	Confidence level	Under canopy
Availability	>95%	Confidence level	Urban Canyon
Availability	Yes		Indoors
Timeliness (TTFF)	2 or less	secs	In hot start
Update rate	Yes		On request positioning
Robustness/Resilience	Yes		Susceptibility to interference
Robustness/Resilience	Yes		Against spoofing threats
Integrity	Provide timely warnings		When data provided by the solution should not be used
Time to alert	10	secs	To alert after the occurrence of a failure
Power consumption	Low		

SATCOM USERS (TYPE C)

GNSS are typically used in Satellite Control Stations and Telecommunications Gateways, mostly for frequency control.

WORKFORCE MANAGEMENT (TYPE B)

Mobile workforce management revolves around tracking and navigation services that enable workers to plan their routes more efficiently and to support dispatch services. In order to determine the location of a worker and transmit the data to the workforce manager, it relies on GNSS and mobile communication technologies. Many companies in the field of construction, distribution and field services now use standardized workforce management apps for smartphones.

Here below a summary of the main requirements in this segment.

Table 108: Performance requirements for Workforce management applications

Indicator	Value	Unit	Notes
Horizontal Accuracy	5	m	Confidence level >95%
Vertical Accuracy	1-5	m	Confidence level >95%
Service area	Global		Geographical Coverage
Availability	>95%	Confidence level	Under canopy
Availability	>95%	Confidence level	Urban Canyon
Availability	Yes		Indoors
Timeliness (TTFF)	1 or less	min	In hot start
Update rate	Yes		Continuous positioning
Update rate	<5	secs	Between usable fixes
Robustness/Resilience	Yes		Susceptibility to interference
Robustness/Resilience	Yes		Against spoofing threats
Availability	Yes		PPP data via terrestrial links
Power consumption	Low		
Proportion of GNSS	NA		

Navigation & Tracking

NAVIGATION (TYPE B)

Navigation apps enable route planning and turn-by-turn instructions thanks to GNSS for both pedestrian and road users through a smartphone. They provide directions for a selected route a continuous basis in form of spoken or visual instructions, together with real-time public transport for buses and taxi tracking, and eco-driving carbon emission footprint.

Here below a summary of the main requirements in this segment.

Table 109: Performance requirements for Navigation applications

Indicator	Value	Unit	Notes
Horizontal Accuracy	1	m	Confidence level >95%
Vertical Accuracy	1-5	m	Confidence level >95%
Service area	Global		Geographical Coverage
Availability	>95%	Confidence level	Under canopy
Availability	>95%	Confidence level	Urban Canyon
Availability	Yes		Indoors
Timeliness (TTFF)	30 or less	secs	In hot start
Update rate	Yes		Continuous positioning once started
Robustness/Resilience	Yes		Susceptibility to interference

Robustness/Resilience	Yes	Against spoofing threats
Power consumption	Low	
Proportion of GNSS	High	

PERSONAL & ASSET TRACKING (TYPE B)

In personal & asset tracking applications, GNSS facilitate innovative tracking solutions, including the deployment of local geofences that trigger an alarm when users and/or goods leave a specific perimeter. Some applications involve children locators, since most child trackers rely on GNSS.

Here below a summary of the main requirements in this segment.

Table 110: Performance requirements for Personal & asset tracking applications

Indicator	Value	Unit	Notes
Horizontal Accuracy	1-5	m	Confidence level >95%
Vertical Accuracy	5	m	Confidence level >95%
Service area	Global		Geographical Coverage
Availability	>95%	Confidence level	Under canopy
Availability	>95%	Confidence level	Urban Canyon
Availability	Yes		Indoors
Timeliness (TTFF)	15 or less	secs	In hot start
Update rate	4	secs	Continuous positioning once started
Robustness/Resilience	Yes		Susceptibility to interference
Robustness/Resilience	Yes		Against spoofing threats
Power consumption	Low		
Proportion of GNSS	High		

VISUALLY IMPAIRED SUPPORT (TYPE B)

In response to the needs of the visually impaired community, specialized portable devices with associated mobility services have become available in the market. These dedicated portable devices have emerged as a common solution for this application. Nevertheless, it's important to note that GNSS standalone solutions do not offer the requisite level of positioning precision and reliability necessary to assist visually impaired individuals in their mobility effectively. GNSS technology, however, can be harnessed to create solutions that provide turn-by-turn directions based on accurate positioning, thereby enhancing the ease with which visually impaired individuals navigate their surroundings.

Here below a summary of the main requirements in this segment.

Table 111: Performance requirements for Visually impaired support applications

Indicator	Value	Unit	Notes
Horizontal Accuracy	1-5	m	Confidence level >95%
Vertical Accuracy	3-4	m	Confidence level >95%
Service area	Global		Geographical Coverage
Service area	Regional		For E112
Availability	>95%	Confidence level	Under canopy
Availability	>95%	Confidence level	Urban Canyon

Availability	Yes		Indoors
Timeliness (TTFF)	10 or less	secs	
Update rate	Yes		On request positioning
Robustness/Resilience	Yes		Susceptibility to interference
Robustness/Resilience	Yes		Against spoofing threats
Power consumption	Low		
Integrity	Few seconds	secs	Time to alert
Proportion of GNSS	High		

Robotics

CONSUMER ROBOTICS (TYPE B)

Consumer electronics integrate GNSS signals with other sensors for the specific purposes of localization and navigation. These applications encompass a variety of robotic tasks, including gardening robots, delivery robots, security and surveillance robots, personal assistant robots, painting robots, and automated guided vehicles for logistics. Moreover, within the realm of robotics with limited reliance on GNSS technology, there are painting assistant robots and personal assistant robots designed to assist people in their everyday household activities. These robots can be especially beneficial for the elderly or individuals with disabilities.

Here below a summary of the main requirements in this segment.

Table 112: Performance requirements for Consumer robotics applications

Indicator	Value	Unit	Notes
Horizontal Accuracy	1	m	
Vertical Accuracy	1	m	
Service area	Regional		Geographical Coverage
Availability	>95%	Confidence level	Under canopy
Availability	>95%	Confidence level	Urban Canyon
Availability	Yes		Indoors
Timeliness (TTFF)	2-30	secs	In hot start
Update rate	Yes		Continuous positioning
Robustness/Resilience	Yes		Susceptibility to interference
Robustness/Resilience	Yes		Against spoofing threats
Power consumption	TBD		
Integrity	Few seconds	secs	Time to alert
Proportion of GNSS	Low		

IoT

The diversity of IoT applications leads to significant disparities in terms of performance requirements. IoT can be considered one of the most picked and discussed topic in the GNSS for consumer solutions area, and its development can lead to potentially even more applications than the one listed below.

HIGH END SPORT TRACKER (TYPE B)

The positioning information is used in sport to assess athletes' performances and manage their rest time according to the covered distance and maximum speed for example.

Here below a summary of the main requirements in this segment.

Table 113: Performance requirements for High end sport tracker applications

Indicator	Value	Unit	Notes
Horizontal Accuracy	2	m	
Vertical Accuracy	2.5	m	
Service area	Global		Geographical Coverage
Availability	Yes		Under canopy
Availability	Yes		Urban Canyon
Availability	Yes		Indoors
Update rate	10	Hz	Continuous positioning
Robustness/Resilience	Yes		Susceptibility to interference

LOW-END SPORT TRACKER (TYPE B)

To foster the expansion of this use-case, the consumer adoption is primarily influenced by the comfort, efficiency, and pricing of the devices, which exert the most significant impact. These factors drive the demand for more affordable, compact sports devices with improved accuracy. Furthermore, the inclusion of long-range connectivity enhances the value of sport trackers, enabling features like social interaction through position sharing.

Here below a summary of the main requirements in this segment.

Table 114: Performance requirements for Low end sport tracker applications

Indicator	Value	Unit	Notes
Horizontal Accuracy	2.5-10	m	
Service area	Global		Geographical Coverage
Availability	Yes		Under canopy
Availability	Yes		Urban Canyon
Timeliness (TTFF)	2 or less	secs	In hot start
Update rate	5	Min	Continuous positioning

ASSET TRACKER FOR LOGISTICS (TYPE B)

Various modes of transportation are employed in logistics for the movement of goods, whether from factories to consumers or between different manufacturing facilities. These methods encompass a wide spectrum, starting from small packages, commonly utilized in retail, to large containers designed for international shipping. The geolocation of these transportation units consistently provides valuable information, serving to enhance the efficiency of logistics processes. This data is instrumental in monitoring transport efficiency, notifying the final destination, and proactively addressing potential delays.

Here below a summary of the main requirements in this segment.

Table 115: Performance requirements for Asset tracker for logistics applications

Indicator	Value	Unit	Notes
Service area	Global		Geographical Coverage
Availability	Yes		Under canopy
Availability	Yes		Urban Canyon

Availability	Yes	Indoors
Update rate	>240	Min Continuous positioning

TRACKING OF TRAILERS (TYPE B)

The primary goal of this application is to maximize the utilization of trailers. Tracking these trailers enables their precise location, facilitating optimization of their usage. Moreover, this tracking element contributes to enhancing transparency and traceability within supply chain management.

Here below a summary of the main requirements in this segment.

Table 116: Performance requirements for Asset tracker for logistics applications

Indicator	Value	Unit	Notes
Horizontal accuracy	>20	m	
Service area	Global		Geographical Coverage
Availability	Yes		Urban canyons
Update rate	<5	min	Continuous positioning

TRACKING OF CONTAINERS (TYPE B)

This application's foremost aim is to provide the end customer with precise delivery information. Container tracking plays a crucial role in locating and safeguarding valuable assets, resulting in time savings and optimized asset utilization. Furthermore, it contributes to enhancing safety when managing assets in isolated and challenging work environments. Ultimately, the tracking system bolsters transparency and traceability within supply chain management.

Here below a summary of the main requirements in this segment.

Table 117: Performance requirements for Tracking of containers applications

Indicator	Value	Unit	Notes
Horizontal accuracy	<10	m	
Service area	Global		Geographical Coverage
Availability	Yes		Urban canyons
Update rate	6-8	Positions/day	Continuous positioning

TRACKING OF PACKAGES (TYPE B)

The central goal of this application is to enhance the efficiency of the logistics chain. Tracking packages serves the dual purpose of locating and safeguarding them, while also streamlining their transit through the logistics chain, thus saving valuable time and optimizing operations. Furthermore, this tracking capability contributes to bolstering transparency and traceability in supply chain management.

Here below a summary of the main requirements in this segment.

Table 118: Performance requirements for Tracking of containers applications

Indicator	Value	Unit	Notes
Horizontal accuracy	<10	m	
Service area	Global		Geographical Coverage
Availability	Yes		Urban canyons
Availability	Yes		Indoors
Update rate	15	Mins	Continuous positioning, additional positioning every time a movement occurs.

TRACKING OF STAFF (TYPE B)

The tracking of staff is primarily geared towards bolstering worker safety. It not only facilitates their location but also results in time savings and task optimization while providing an additional layer of protection. Furthermore, it plays a vital role in promoting safety when managing employees in isolated and challenging work environments.

Here below a summary of the main requirements in this segment.

Table 119: Performance requirements for Tracking of staff applications

Indicator	Value	Unit	Notes
Horizontal accuracy	<20	m	
Service area	Regional		Geographical Coverage
Availability	Yes		Urban canyons
Update rate	5	Mins	Continuous positioning, during 12 hours.

ARTISANAL FISHERIES (TYPE B)

This application serves the purpose of monitoring and regulating fishing activities to safeguard fishing resources. Fishermen can utilize it to send alerts and receive real-time weather notifications. Additionally, the application offers valuable analytics regarding the operational efficiency and downtime of their fishing assets.

Here below a summary of the main requirements in this segment.

Table 120: Performance requirements for Artisanal Fisheries applications

Indicator	Value	Unit	Notes
Horizontal accuracy	10	m	
Service area	Global		Geographical Coverage
Robustness	Yes		Against interference
Robustness	Yes		Against spoofing threats
Update rate	1	Position/h	Continuous positioning

LIVESTOCK MONITORING (TYPE B)

This application helps to monitor the animals wandering around. By get the position and health data of the animals, Farmers improve productivity and automate their work.

Here below a summary of the main requirements in this segment.

Table 121: Performance requirements for Livestock Monitoring applications

Indicator	Value	Unit	Notes
Horizontal accuracy	10	m	
Vertical accuracy	10	m	
Service area	Global		Geographical Coverage
Availability	Yes		Under canopy
Update rate	1	Position/day	Continuous positioning

SMART FARMING (TYPE B)

Smart farming represents a significant transformation characterized by data management that supports agricultural decision-making. Its core objectives include enhancing production quality, promoting animal health, achieving sustainability targets, bolstering competitiveness, and reducing operational costs. While geolocation based on GNSS is a fundamental component of smart farming, its application is currently more prevalent in cases where the

cost of GNSS systems is not a critical concern, such as in centimeter-level precision guiding systems.

Here below a summary of the main requirements in this segment.

Table 122: Performance requirements for Smart Farming applications

Indicator	Value	Unit	Notes
Horizontal accuracy	2.5-10	m	
Service area	Global		Geographical Coverage
Availability	Yes		Under canopy
Availability	Yes		Urban canyon
Update rate	>240	min	Continuous positioning

Gap Assessment

The applications that are more studied today are gaming, metaverse, blockchain, augmented reality, robotics and IoT. In these applications the critical user requirements are related to power consumption, Time To First Fix, high accuracy and availability indoors.

Overall, it has to be considered that Galileo and GNSS in general nowadays cannot cover some user requirements standalone. A clear example is the availability of the GNSS signal indoor. This is however not considered a gap, since it comes from technological limitations. Hybridization of GNSS and other sensor (like seamless switch outdoor-indoor) is a one of the ways to fulfil unmet needs.

Gaps planned to be addressed

To meet the needs of power consumption and Time To First Fix in the best way, EUSPA is collaborating with ESA and other entities to innovate both on the satellites' side and user service side. For example, Fundamental Elements and Horizon Europe are two funding mechanism that are exploited to find new solutions.

Considerations

The Consumer Solutions sector is slightly different from the others in terms of user needs. In fact, most of the sector is pulled by a single hardware, the smartphones, and assessing the user need of every single smartphone user is impossible. For this reason, from consultations it is evident that EUSPA assesses the needs by discussing with industry associations and specific user communities.

3.2.6.2.Safety Critical & Liability Critical Transportation

SECTOR 1: AVIATION

The aviation industry, as mentioned in previous sections, relies on GNSS. The technology revolutionized how aircraft navigate, going from using ground-based radio navigation and celestial navigation to using GNSS as the prime mode of navigation.

We also discussed in previous sections more advanced uses of GNSS for positioning, notably in PBN and in landing approaches (LPV-200).

Market Trends

Demand side trends and challenges

PBN modernization.

Performance based navigation is a modern air navigation concept that allows aircraft to navigate more accurately and efficiently. It relies on the capabilities of the aircraft's onboard navigation systems rather than ground-based navigation aids. PBN enables more precise and

flexible flight paths, leading to improved safety, increased airspace capacity, and reduced fuel consumption and emissions.

It is comprised of two procedures:

- Area Navigation (RNAV): RNAV allows aircraft to navigate along specific paths defined by waypoints and coordinates rather than being confined to fixed routes based on ground-based navigation aids.
- Required Navigation Performance (RNP): RNP is a measure of the navigational accuracy required for a specific flight operation. It defines the containment of an aircraft within a specified airspace volume, ensuring that the aircraft stays within certain lateral and vertical tolerances from its intended flight path.

Both the Single European Sky ATM Research (SESAR) and the Next Generation Air Transportation System (NextGen) aim at modernizing their air traffic rules through widespread implementation of PBN.

Naturally, this will require GNSS, as achieving RNP in flight will require accurate positioning even over areas where ground contact cannot be established.

Formation Flying

Both Boeing and Airbus estimate that formation flying can reduce fuel consumption of aircraft by ~10%.^{53 54} Work is being undertaken to evaluate the feasibility of formation flying by both companies, and under SESAR, flight trails are anticipated in 2026⁵⁵. It would require aircraft to fly with a relatively low longitudinal separation (sub 5 km).

Its implementation in commercial aviation would necessitate precise positioning to ensure that optimal, and more importantly safe, separation between two aircraft is maintained.

Aircraft Surveillance

ADS-B is increasingly being implemented under airspace modernization initiatives. SESAR in EU, NextGen in USA and ABSU in India all are incorporating ADS-B. This requirement will make the airspace safer, but also necessitates that all aircraft are able to pinpoint their position. Integrity is important for ADS-B to ensure that aircraft are flying where they claim to be flying.

Helicopters

Helicopters used in search and rescue operations often have to face difficult environments such as mountains and valleys where connectivity to traditional infrastructure is limited. GNSS can help these helicopters by giving them improved positioning, notably in the vertical domain.

Airport approaches

⁵³ Aviation Week (2019) Boeing, FedEx 777F Tests Confirm Wake Fuel Burn Benefit: <https://aviationweek.com/air-transport/boeing-fedex-777f-tests-confirm-wake-fuel-burn-benefit>

⁵⁴ Aviation Week (2019) Airbus Seeks Up To 10% Fuel Burn Savings By Aircraft Flying Together: <https://aviationweek.com/shownews/airbus-seeks-10-fuel-burn-savings-aircraft-flying-together>

⁵⁵ Flight Global (2023) Airbus to continue fello'fly flight tests via SESAR-backed Geese project. <https://www.flightglobal.com/air-transport/airbus-to-continue-fellofly-flight-tests-via-sesar-backed-geese-project/152049.article>

Smaller airports often do not have ILS, meaning that aircraft cannot land there in less than idea weather. This can result in flight cancellations, delays or diversions to the wrong airport. EGNOS and other SBAS can perform the role of ILS without any ground infrastructure, enabling reduced congestion at large airports.

COVID-19

While the pandemic of COVID-19 has drastically decreased in severity and society has reached a new normal in most of the world, the effect on the aviation industry was quite severe. Even though the industry as a whole has generally recovered, there was a decrease on spending for activities like research or retrofitting, as resources were generally divert to recovery. This has somewhat slowed the above trends.

GNSS technology trends

GALILEO AND BEIDOU BECOMING OPERATIONAL FOR AVIATION

Both Galileo and Beidou are becoming operational for aviation. In the case of Beidou, there are trails in China demonstrating the system's ability to safely guide aircraft, the system has passed ICAO verification and is on its way to incorporation into ICAO standards. For Galileo, ICAO adopted Galileo into ICAO standards in 2023.

With more satellites and more frequencies being available for aviation, the safety level in aviation will be improved as more frequencies will be more robust and reliable. Additional features like OS-NMA in aviation will further improve security by making signals immune to spoofing.

DFMC AND ARAIM

DFMC can help provide more robust positioning in aviation, as mentioned above, but can also help ARAIM. ARAIM is Advanced RAIM, meaning that it uses DFMC signals to overcome the limitation of RAIM – which is limited to integrity monitoring in the horizontal plane, making it unsuitable for LPV-200. With vertical RAIM (ARAIM) on the horizon (but only in the mid to far future), it is possible that LPV-200 could be implemented on a global scale without the need for ILS or SBAS.

That said, there are ongoing projects under Fundamental Elements that aim at producing ARAIM receivers for aviation. A notable example is the GLAD project.

EGNOS V3 FOR AVIATION

With Galileo being incorporated into ICAO standards, EGNOS V3 will be able to augment the Galileo signals further enhancing vertical guidance to enable LPV-200 capabilities across covered zones.

User Communities

- Institutional users – for decision making, compliance checks, validation, search and rescue
- Airports, ANSPs, pilots – positioning, navigation, surveillance
- Academia – support development of GNSS in aviation

User Requirements per application and its use cases

Communication

Time synchronisation (Type C)

Aviation requires extremely precise timing so that clocks are synchronised across aircraft, giving precise timestamps for all events ongoing in airspace globally. This is important for air

traffic management as surveillance systems need to know where aircraft are at all times to ensure safety in the air.

ATM System Timing (Type C)

ATC ground systems must be precisely timed to ensure synchronisation of logs, communication and traffic handover at system level. This application is linked to the above application.

Gap Assessment

Overall, for timing in aviation, the current ENGOS version does not fully meet the requirements of the user community.

Gaps planned to be addressed

This is expected to change with the implementation of EGNOS v3, but until then timing cannot be conducted via GNSS.

Considerations

The criticality of this as of 2023 is low, since this is mostly applicable to aircraft that are flying LPV which is currently a minority of aircraft. This is expected to change as LPV uptake is increasing, but EGNOS v3 is expected to be online in the interim.

It should be noted that this does not affect LPV approaches as ICAO states that LPV can be used even without timing being provided by GNSS.

Therefore, we can say that this is a gap that is in progress towards being met by EGNOS v3.

Navigation & Positioning

Resilience requirements for a total PBN environment (Type A)

As mentioned above, the implementation of PBN requires GNSS, and indeed, it also requires a level of resilience from GNSS. EC 2018/1048 mandates the implementation of EGNOS approaches on all instrument runways by 2024, and a preference for PBN approaches and ILS CAT I network to be minimised by 2030.

In this case GNSS has several requirements that must be met for different stages of flight and approach. These are detailed in the table below:

Table 123: Requirements for total PBN environment

Indicator	Value	Unit	Notes
Horizontal Accuracy (95%)	0.4	NM	En route and arrival route (STAR)
	220.0	meters	Departure (SID)
Vertical Accuracy (95%)	6 to 4	meters	
Horz. Alert Limit and Time toAlert	10	seconds	alert within 10 seconds if protection level exceeds
	1	NM	in en route and arrival route (STAR)
	0.3	NM	in departure (SID)
Vert. Alert Limit and Time toAlert	10	seconds	alert within 10 seconds if protection level exceeds
	50	meters	
Integrity	$1 - 1 \times 10^{-7}$ / h		
Availability	99% to 99.99%		
Continuity	$1 - 1 \times 10^{-4}$ / h to $1 - 1 \times 10^{-8}$ / h		Or better

Looking forward, the UCP report expects these requirements to remain constant for the future. Developments in the future (such as the mentioned DFMC trend) may eventually alter the user requirements from a technology push perspective, but progress is slow at the ICAO.

As also mentioned above, ARAIM enabled by DFMC could one day be a gamechanger for aviation, but this is in the far future.

RNP / RNAV for En Route and Terminal Operations (Type A)

GNSS is the main source of navigation and positioning in PBN. As discussed in previous sections, RNP requires that aircraft maintain containment in a certain volume of airspace around the flight path. For this, GNSS is used to pinpoint the aircraft position and it needs to have a certain level of lateral precision 95% of the time.

Table 124: Requirements for RNAV 10 and RNP 4 for En Route and Terminal Operations

Indicator	Value	Unit	Notes
Horizontal Accuracy (95%)	2	NM	
Horz. Alert Limit and Time to Alert	5	min	alert within 5 mins if protection level exceeds
	4	NM	oceanic airspace
	2	NM	continental airspace
Integrity	$1 - 1 \times 10^{-7}$ / h		
Availability	99% to 99.99%		
Continuity	$1 - 1 \times 10^{-4}$ / h to $1 - 1 \times 10^{-8}$ / h		Or better

Table 125: Requirements for RNAV 5 for En Route and Terminal Operations

Indicator	Value	Unit	Notes
Horizontal Accuracy (95%)	0.4	NM	
Horz. Alert Limit and Time to Alert	15	sec	alert within 15 sec if protection level exceeds
	1	NM	
Integrity	$1 - 1 \times 10^{-7}$ / h		
Availability	99% to 99.99%		
Continuity	$1 - 1 \times 10^{-4}$ / h to $1 - 1 \times 10^{-8}$ / h		Or better

Table 126: Requirements for RNAV 1 and 2 and RNP 1 and 2 for En Route and Terminal Operations

Indicator	Value	Unit	Notes
Horizontal Accuracy (95%)	0.4	NM	En route and arrival (STAR)
	220	meter	Departure (SID)
Horz. Alert Limit and Time to Alert	10	sec	alert within 10 sec if protection level exceeds
	1	NM	en route and STAR
	0.3	NM	departure (SID)
Integrity	$1 - 1 \times 10^{-7}$ / h		
Availability	99% to		

	99.99%	
Continuity	$1 - 1 \times 10^{-4}$ / h to $1 - 1 \times 10^{-8}$ / h	Or better

RNP APPROACH (APCH) (TYPE A)

LNAV means lateral navigation, therefore in this context the GNSS only provides horizontal positioning to the aircraft, while vertical positioning is based on barometric data.

Table 127: Requirements for RNP APCH LNAV

Indicator	Value	Unit	Notes
Horizontal Accuracy (95%)	220	m	
Horz. Alert Limit and Time to Alert	10 0.3	sec NM	alert within 10 sec if protection level exceeds
Integrity	$1 - 1 \times 10^{-7}$ / h		
Availability	99% to 99.99%		
Continuity	$1 - 1 \times 10^{-4}$ / h to $1 - 1 \times 10^{-8}$ / h		Or better

LNAV/VNAV approaches were originally designed to use barometer assisted GPS (baro-VNAV), but today will usually use SBAS when available (USA, Europe, India, etc.). As shown in Table 123, the horizontal requirement is within 16 m 95% of the time for APV-I and APV-II approaches, and the vertical requirement is 20 m or 8 m for APV-I or APV-II approaches respectively.

Table 128: Requirements for RNP APCH LNAV/VNAV

Indicator	Value	Unit	Notes
Horizontal Accuracy (95%)	220	m	
Horz. Alert Limit and Time to Alert	10 40	sec m	alert within 10 sec if protection level exceeds
Integrity	$1 - 1 \times 10^{-7}$ / h		
Availability	99% to 99.99%		
Continuity	$1 - 1 \times 10^{-4}$ / h to $1 - 1 \times 10^{-8}$ / h		Or better

LPV approaches are APV approaches that are more sensitive than LNAV/VNAV. These enable the aircraft to reach 200 feet before making visual contact with ground on non precision approach runways.

Table 129: Requirements for RNP APCH LPV 200

Indicator	Value	Unit	Notes
Horizontal Accuracy (95%)	16	m	
Vertical Accuracy (95%)	4	m	
Horz. Alert Limit and Time to Alert	6 40	sec m	alert within 6 sec if protection level exceeds
Vert. Alert Limit and Time to Alert	6 35	sec m	alert within 6 sec if protection level exceeds

Integrity	$1 - 2 \times 10^{-7}$ / apch	
Availability	99% to 99.99%	
Continuity	$1 - 8 \times 10^{-6}$ / 15 s	Or better

Table 130: Requirements for RNP APCH LPV

Indicator	Value	Unit	Notes
Horizontal Accuracy (95%)	16	m	
Vertical Accuracy (95%)	20	m	
Horz. Alert Limit and Time to Alert	10	sec	alert within 10 sec if protection level exceeds
	40	m	
Vert. Alert Limit and Time to Alert	10	sec	alert within 10 sec if protection level exceeds
	50	m	
Integrity	$1 - 2 \times 10^{-7}$ / apch		
Availability	99% to 99.99%		
Continuity	$1 - 8 \times 10^{-6}$ / 15 s		Or better

RNP AR APCH is an “authorization required” operation for when a straightforward LPV approach cannot be developed due to obstacles.

Table 131: Requirements for RNP AR APCH

Indicator	Value	Unit	Notes
Horizontal Accuracy (95%)	16	m	GPS/ABAS & barometric altimetry down to LNAV/VNAV minima but may use GNSS/SBAS for both horizontal and vertical guidance
Horz. Alert Limit and Time to Alert	10	sec	alert within 10 sec if protection level exceeds
	0.3	NM	
Integrity	$1 - 2 \times 10^{-7}$ / apch		
Availability	99% to 99.99%		
Continuity	$1 - 1 \times 10^{-4}$ / h to		Or better
	$1 - 1 \times 10^{-8}$ / h		

It should be noted that that in EC No 2018/1048, provisions were made for:

- By 2020: ENGOS LPV approaches available to all instrument runways without ILS
- By 2024: EGNOS approaches LPV and CAT-I available to all instrument runways
- By 2030: Preference given to PBN approaches (LNAV/VNAV and LPV) and ILS will be rationalized to a minimum network level.

Therefore, ILS will be used only for CAT-II and CAT-III runways, while not needed for CAT-I.

GBAS CAT I (Type B)

Satellite-Based Augmentation System (SBAS) can be leveraged to improve the performance of Ground-Based Augmentation System (GBAS) and enhance the functionality of current GBAS avionics. This approach offers notable operational enhancements for users equipped with GBAS, capitalizing on SBAS's worldwide monitoring of ionospheric disturbances. This solution is seen as a transitional measure towards achieving Category II/III capabilities.

Table 132: Requirements for GBAS CAT I

Indicator	Value	Unit	Notes
Horizontal Accuracy (95%)	16	m	
Vertical Accuracy (95%)	4	m	
Horz. Alert Limit and Time to Alert	6	sec	alert within 6 sec if protection level exceeds
	40	m	
Vert. Alert Limit and Time to Alert	6	sec	alert within 6 sec if protection level exceeds
	10	m	
Integrity	$1 - 2 \times 10^{-7}$ / apch		
Availability	99% to 99.99%		
Continuity	$1 - 8 \times 10^{-6}$ / 15 s		Or better

GBAS CAT II/III (TYPE C)

GBAS CAT II/III is under development and standardization. The GBAS CATII/III L1 system will enable automatic approach and landing down to Cat IIIB minima for mainline aircraft, and down to CAT II or CAT IIIa minima for business and regional aircraft, CAT IIIB considerations for business aircraft for possible future use.

PRECISION APPROACHES WITH AUTOLAND (TYPE C)

Autoland function has been certified on some aircraft using GBAS. Using ENGOS for this purpose is under investigation.

TRANSITION FROM P-RNAV / RNP / RNP AR TO LPV (TYPE C)

SESAR project 5.6.3 is studying the possibility to make a transition to final approaches using SBAS 3D guidance.

TRANSITION FROM CONTINUOUS DESCENT APPROACH (CDA) TO LPV CONTINUOUS DESCENT APPROACH (TYPE C)

SESAR is studying how to combine CSA with SBAS approaches like LPV.

PBN APPROACH PROCEDURES IN SIMULTANEOUS OPERATIONS TO INSTRUMENT PARALLEL RUNWAYS (SOIR) (TYPE C)

There is also work being done to evaluate implementing PBN approaches into SOIR, increasing the operation capacity of airports with parallel runways.

VFR COMPLEMENT (TYPE B)

GNSS helps pilots flying under VFR by supplementing map readings and visual navigation, improving situational awareness, and for flight tracking. Continual improvements to GNSS improve its penetration into VFR flights – such as through moving maps – through GNSS can never replace visual navigation in VFR.

Table 133: Requirements for VFR Complement

Indicator	Value	Unit	Notes
Horizontal Accuracy (95%)	2	NM	
Time to Alert	5	min	
	40	m	
Integrity	$1 - 2 \times 10^{-7}$ / h		

Availability	99%	
Continuity	$1 - 1 \times 10^{-4}$ / h	Or better

Gap Assessment

All requirements are met, however consultations also reveal that the service provided by EGNOS v2 generally meets the lower end of the requirement and not the higher end.

Gaps planned to be addressed

With EGNOS v3, the higher ends of the requirements will also be met. Indeed, even for CAT-I GBAS approaches, EGNOS currently meets the needs.

Considerations

More stringent CAT-II and CAT-III approaches are not a priority as these are considered longer term goals in aviation for SBAS.

Regarding Galileo, it is interesting to note that since Galileo is validated for aviation, SBAS and GBAS will start to augment Galileo, increasing the coverage, continuity, and availability of signal in aviation. Additionally, with Galileo, ARAIM becomes technically feasible in aviation. This is highly interesting to end users in the longer term as ARAIM is a potential alternative to SBAS. In the meanwhile, RAIM is also highly interesting to end users as it is complementary to EGNOS.

To conclude, EGNOS and Galileo are meeting all the user needs as they currently stand, and going forward the future user needs are being anticipated in EGNOS v3. Therefore it can be said that there are no gaps.

SURVEILLANCE

ADS-B is an important technology in aerial awareness. As ADS-B relies on an aircraft broadcasting its position, its naturally reliant on resilient GNSS.

Table 135: Requirements for ADS-B Airport

Indicator	Value	Unit	Notes
Horizontal Accuracy (95%)	10	m	
Integrity (Horz. Alarm limit)	10	m	
Integrity (Integrity Risk)	1×10^{-4} / h	SDA	
Velocity Accuracy	1 to 3	m/s	
Continuity	$1 - 3 \times 10^{-4}$ / h		Or better

Table 136: Requirements for ADS-B Airborne Situational Awareness

Indicator	Value	Unit	Notes
Horizontal Accuracy (95%)	0.5	NM	
Velocity Accuracy	10	m/s	

Table 137: Requirements for ADS-B Visual Separation in Approach

Indicator	Value	Unit	Notes
Horizontal Accuracy (95%)	0.3	NM	
Integrity (Horz. Alarm limit)	0.75	NM	
Integrity (Integrity Risk)	1×10^{-3} / h	SDA	
Velocity Accuracy	10	m/s	

Table 138: Requirements for ADS-B Surface Traffic Awareness

Indicator	Value	Unit	Notes

Horizontal Accuracy (95%)	30	m	
Velocity Accuracy	10	m/s	
Integrity (Source Integrity Level)	1×10^{-5} / h		

Table 139: Requirements for ADS-B In Trail Procedure

Indicator	Value	Unit	Notes
Horizontal Accuracy (95%)	0.5	NM	
Integrity (Horz. Alarm limit)	1	NM	
Integrity (Integrity Risk)	1×10^{-5} / h	SDA	
Velocity Accuracy	10	m/s	

Table 140: Requirements for ADS-B Non Radar Airspace (NRA 3 NM separation)

Indicator	Value	Unit	Notes
Horizontal Accuracy (95%)	0.3	NM	
Integrity (Horz. Alarm limit)	10	sec	alert within 10 sec if protection level exceeds
	1	NM	
Integrity (Integrity Risk)	1×10^{-5} / h	SDA	
Continuity	$1 - 2 \times 10^{-4}$ / h		

Table 141: Requirements for ADS-B Non Radar Airspace (NRA 5 NM separation)

Indicator	Value	Unit	Notes
Horizontal Accuracy (95%)	0.5	NM	
Integrity (Horz. Alarm limit)	10	sec	alert within 10 sec if protection level exceeds
	2	NM	
Integrity (Integrity Risk)	1×10^{-5} / h	SDA	
Continuity	$1 - 2 \times 10^{-4}$ / h		

Table 142: Requirements for ADS-B (Independent and parallel Approach)

Indicator	Value	Unit	Notes
Horizontal Accuracy (95%)	121	m	
Integrity (Horz. Alarm limit)	0.2	NM	
Integrity (Integrity Risk)	1×10^{-5} / h	SDA	

Table 143: Requirements for ADS-B (RAD < 2.5 NM separation)

Indicator	Value	Unit	Notes
Horizontal Accuracy (95%)	171	m	
Integrity (Horz. Alarm limit)	0.2	NM	
Integrity (Integrity Risk)	1×10^{-5} / h	SDA	
Integrity (Source Integrity Level)	1×10^{-7} / h		

Table 144: Requirements for ADS-B (RAD 3 NM separation)

Indicator	Value	Unit	Notes
Horizontal Accuracy (95%)	0.1	NM	EU
	0.05	NM	US
Integrity (Horz. Alarm limit)	0.6	NM	EU
	0.1	NM	US

Integrity (Integrity Risk)	$1 \times 10^{-5} / \text{h}$	SDA
Integrity (Source Integrity Level)	$1 \times 10^{-7} / \text{h}$	
Velocity Accuracy	10	m/s

Table 145: Requirements for ADS-B (RAD 5 NM separation)

Indicator	Value	Unit	Notes
Horizontal Accuracy (95%)	0.1	NM	EU
	0.05	NM	US
Integrity (Horz. Alarm limit)	1	NM	EU
	0.2	NM	US
Integrity (Integrity Risk)	$1 \times 10^{-5} / \text{h}$	SDA	
Integrity (Source Integrity Level)	$1 \times 10^{-7} / \text{h}$		
Velocity Accuracy	10	m/s	

Gap assessment

Regarding ADS-B implementation, ADS-B is mandated in the EU and EGNOS meets all the requirements for what is mandated. This said, EGNOS also meets the requirements for evolutions, but as these are not mandated, they are neither implemented nor enforced.

Therefore, at this stage there realistically is no gap as the current system is capable of serving both existing and expected user needs.

Search and Rescue (GADSS) (Type B)

Various flight monitoring systems have the capability to transmit aircraft's position at regular intervals or in the event of a malfunction using various communication methods like ACARS or FANS 1/A. These systems rely on communication service providers to function. Currently, around 80% of large aircraft have these systems installed. Nevertheless, the frequency of reporting doesn't always meet the criteria for Search and Rescue needs.

The Global Aeronautical Distress and Safety System (GADSS) is an idea formulated by ICAO with the aim of improving the effectiveness and timeliness of search and rescue operations following aviation accidents. This framework ensures the continuous monitoring of aircraft and the preservation of the most recent GPS-derived position, thereby maintaining an updated record of the aircraft's trajectory.

GADSS comprises three main parts: Aircraft Tracking, Autonomous Distress Tracking, and Post Flight Localization and Recovery. Aircraft Tracking relies on the on-board GNSS equipment, which can be either the PBN (Performance-Based Navigation) system or an Electronic Conspicuity device. The other aspects are facilitated by Emergency Locator Transmitters.

Table 146: Requirements for Aircraft Tracking and Autonomous Distress Tracking

Indicator	Value	Unit	Notes
1st Gen 406Mhz distress beacons ELT Accuracy	500	m	2D static
	700	m	Altitude static
2nd Gen 406Mhz distress beacons ELT Accuracy	30	m	2D static
	50	m	Altitude static
Functionality	NA	NA	Galileo RLS enabling ELT remote activation from ground offering possibility to localize in-flight a non-cooperative aircraft
Repetition Period	5 + 0.0 / - 0.2	Sec	During first 120 sec after activation
	10 + 0.0 / -	Sec	During 120 to 300 sec after activation

0.2 Between 27 & 30	Sec	After 300 sec, randomised with mean of 28.5 sec

Gap assessment

ELTs enabled with Galileo and EGNOS can meet all the requirements in aviation.

Furthermore, the User Consultation Platform (UCP) highlighted the users' expressed need for remote beacon activation. This capability underwent testing in 2019 as part of the H2020 project, HELIOS, and is currently in the process of implementation within the Search and Rescue (SAR) service.

Gaps planned to be addressed

Presently, remote beacon activation is being integrated for Emergency Locator Transmitters (ELTs) and Emergency Position-Indicating Radio Beacons (EPIRBs), but not yet for Personal Locator Beacons (PLBs). This distinction arises primarily for two reasons. Firstly, the demand for remote beacon activation stems from the aviation and maritime sectors. Secondly, from a technical perspective, the implementation of remote beacon activation is simpler for beacons equipped with an external power source (which PLBs lack).

Therefore it can be said that there is a gap, but it is also in the process of being addressed.

SECTOR 2: RAIL

Market Trends

Demand side trends and challenges

Overall there are several trends on the demand side that can be divided into safety critical and non safety critical.

Safety critical

There are some applications emerging using GNSS for safety critical tasks, in particular, in Europe several applications energy with ERTMS 3.

ERTMS level 3 enables trains to travel as close as the absolute braking distance. Going further is virtual coupling, which allows two trains to maintain even closer proximity to one another than the absolute braking distance, akin to the behavior of vehicles on a road. The trains are coupled via vehicle-to-vehicle communication, and then they travel in a synchronous manner as a sort of convoy. GNSS is a useful technology for this as it enables train to precisely ascertain and communicate its exact position and speed to the other, thereby enabling the maintenance of an exact distance between the two trains.

Non-Safety critical

Non safety critical applications such as passenger assistance technology are widely used in the EU. There are other uses for GNSS such as fleet management.

GNSS technology trends

User Communities

- Rolling stock manufacturers
- Train owners and operators
- Infrastructure managers

User Requirements / Application

Safety Relevant Applications

Automatic Train Protection

Automatic Train Protection (ATP) aims at ensuring that a train is running on the right track at the right speed. If a train exceeds the speed for that section of track, the train will automatically apply brakes.

The European Automatic Train Protection System is part of the ERTMS and aims to provide a new generation of train control and signalling (ETCS – European Train Control System) which includes ATS for supervising train speed and braking. There are different levels, with lower levels relying on trackside systems and balises, while the higher levels reduce the reliance on track infrastructure for trainboard systems like GNSS.

Table 147: Former requirements for General Automatic Train Protection, no requirements in 2020 report

Indicator	Value	Unit	Notes
Accuracy (High Speed)	1 - 10	m	
Accuracy (Low Speed)	10	m	
Availability	"High"		
Integrity	"Very High"		
Safety Level Integrity	2-4	level	
Time to Alarm	10	sec	

Within automatic train protection, enhanced odometry plays a role. Traditional odometry relies on counting the turns of a wheel with special adjustments for slip and slide phenomena. GNSS enhanced odometry increases the precision of traditional odometry and could be used as a substitute for or complement to other sensors.

Similarly, absolute positioning is an ATP application that aims at providing the precise absolute position of the train, independent of the expected position based on the number of wheel turns from traditional odometry.

Cold movement detection detects train movements while equipment is in No Power mode.

Table 148: Requirements for cold movement detection

Indicator	Value	Unit	Notes
Accuracy	1	m	
Availability	"high"		
Integrity	"very high"		
Safety Level Integrity	4	level	
Time to Alarm	10	sec	

Train integrity monitoring is an application assessing the level of confidence that a train has not left coaches or wagons behind. Train length monitoring is an application that can achieve this, and can leverage satellite positioning. These functions are essential in ERTMS level 3 and level 2 high density.

Table 149: Requirements for train integrity and train length monitoring

Indicator	Value	Unit	Notes
Accuracy	1 - 10	m	
Availability	"high"		
Integrity	"very high"		
Safety Level Integrity	4	level	
Time to Alarm	10 - 30	sec	

Track identification is an application that could use GNSS to identify on which track the train is currently running.

Table 150: Requirements for track identification

Indicator	Value	Unit	Notes
Accuracy	1.9	m	
Availability	“high”		
Integrity	“very high”		
Safety Level Integrity	2 - 4	level	
Time to Alarm	10 - 30	sec	

Level crossing protection is another application where GNSS can be leveraged. A level crossing needs to know the location of incoming trains, and trains must know the position of upcoming level crossings.

Table 151: Requirements for level crossing protection

Indicator	Value	Unit	Notes
Accuracy	1 – 10	m	
Availability	“high”		
Integrity	“very high”		
Safety Level Integrity	4	level	
Time to Alarm	10	sec	

Protection & Emergency Mgmt.

Trackside personnel protection is one application for protection and emergency mgmt. Trackside personnel work in risky locations next to the track, therefore trains approaching maintenance areas should be subject to speed restrictions or should be diverted around such areas. Personnel working should also be made aware of an approaching train. GNSS naturally can play a role in this by transmitting the position of working teams and assets and trains themselves to a central system that can then issue alerts.

Table 152: Requirements for trackside personnel protection

Indicator	Value	Unit	Notes
Accuracy	1 – 10	m	
Availability	“high”		
Integrity	“high”		
Safety Level Integrity	2	level	

Door Control Supervision is another application. Some trains are longer / shorter than the platform so a system could communicate to passengers where they should be for boarding / disembarking. Similarly, the doors should only open when there is a platform, therefore information about the station length can be provided to the train based on the train location to inform the train of which doors to open (which carriages, left or right).

Table 153: Requirements for door control supervision

Indicator	Value	Unit	Notes
Accuracy	1	m	
Availability	“high”		
Integrity	“high”		
Time to Alarm	10	sec	

Gap Assessment

From a technical standpoint, the requirements for each application are generally quite vague, as “high” and “very high” are not numeric values against which Galileo or EGNOS can be measured. Stakeholder consultations reveal, however, that while the system in space can meet technical requirements, the system is not tailored to the needs of the rail sector as the current system is built for aviation.

Therefore, there is a gap currently, as the rail sector is requesting that an EGNOS safety of life service be developed for the rail sector. This would have advantages for the rail sector in similar ways that EGNOS has had advantages for the aviation sector. The current system for signaling largely relies on physical balises, EGNOS could serve as a complement to these balises, reducing the need for them. Obviously this would have benefits for cost (less physical infrastructure to maintain), but more importantly it would have benefits for increasing the interoperability of rail – particularly in the case of newly developing infrastructure.

Gaps’ current situation

Currently EUSPA is working with the rail user community to develop a rail safety of life service for the sector to address this user need. So there is a gap, but it is one that is currently being addressed.

Non-Safety Relevant Applications

Fixed Asset Management

Fixed asset mgmt. deals with the non-moving railway environment, such as trackside infrastructure. The accuracy required for some applications involved in knowing the exact location of railway assets can be quite demanding.

For example, infrastructure surveying requires accuracy at the decimetre level. Increasing demand for rail services has put pressure on access to the trackside environment, as more trains pass areas of the track, requiring maintenance and survey crews to vacate the area.

To allow data to be collected on the railway infrastructure, while accommodating the constraints of obtaining access, mobile surveying systems have been developed which combine GPS with digital images, video and laser measurements (data geo-referencing).

Table 154: Requirements for infrastructure surveying

Indicator	Value	Unit	Notes
Accuracy	0.01 - 1	m	
Availability	“low”		
Integrity	“high”		
Time to Alarm	30+	sec	

A sub application of infrastructure surveying is gauging surveys, which involves surveying clearances when new structures or rolling stock are being introduced. The term “loading gauge” refers to the maximum height and width of a rail vehicle on a section of route – which can vary significantly even when track gauge is constant. The loading gauge of tracks must be assessed through dedicated surveys using techniques like clearance cars or 3D scanning.

GNSS can in principle provide the required level of accuracy with a georeferenced output.

Table 155: Requirements for gauging surveys

Indicator	Value	Unit	Notes
Accuracy	0.01 - 1	m	
Availability	“low”		
Integrity	“very high”		
Safety Level Integrity	4	level	
Time to Alarm	30+	sec	

Another sub application is in GSM reports. This consists of site surveying for GSM-R (technology used for wireless communication in railway), which is important due to the link budget being affected by the placement and environment of GSM-R stations.

Table 156: Requirements for location of GSM reports

Indicator	Value	Unit	Notes
Accuracy	100	m	
Availability	"low"		
Integrity	"high"		
Time to Alarm	30+	sec	

The increasing need for accurate and cost-effective condition monitoring systems for bridges and other major structures drives the need for GNSS in the rail sector. Monitoring is important for efficiently planning for maintenance of bridge stock to simultaneously ensure the safety of the bridges while maximising operational efficiency. Slope stability is another important area to ensure that embankments are stable and risks of landslides are minimised.

GNSS is used to provide real-time position sensing of critical locations which can be used to inform infrastructure operators and train operators of any behaviour that is not within tolerances.

Table 157: Requirements for structural monitoring

Indicator	Value	Unit	Notes
Accuracy	0.01 - 1	m	
Availability	"low"		
Integrity	"low"		
Time to Alarm	30+	sec	

Odometer Calibration

Odometers can be compromised by wheel slips, as they function by counting the number of turns of the wheel. GNSS could assist in calibration of the odometer.

Table 158: Requirements for odometer calibration

Indicator	Value	Unit	Notes
Accuracy	1	m	
Availability	"high"		
Integrity	"not low"		
Time to Alarm	10	sec	

Management of Emergencies

Emergencies can occur, and when they do it is important that the location of a train is communicated to the appropriate services promptly. GNSS can assist teams in locating a train and arriving at the location of the emergency quickly.

Table 159: Requirements for mgmt. of emergencies

Indicator	Value	Unit	Notes
Accuracy	5	m	
Availability	"high"		
Integrity	"high"		
Time to Alarm	10 – 30	sec	

Rolling Stock Management

This is often considered a liability critical application as it deals with managing the moving assets on a railroad. Fleet management is one of the core areas of rolling stock management, and tracking these assets is important to optimisation of fleet operations – knowing exactly how far a train has travelled can help organise maintenance for example.

GNSS is sometimes used in fleet management, especially since automated tracking can greatly improve the efficiency of operations.

Table 160: Requirements for fleet management

Indicator	Value	Unit	Notes
Accuracy	10	m	
Availability	“high”		
Integrity	“low”		
Time to Alarm	30+	sec	

Similarly, monitoring of cargo also falls under the umbrella of rolling stock management. The accurate estimation of arrival times of trains is important for preparing for unloading and loading. Late arrivals can disrupt subsequent steps in the supply chain, especially if they were unknown.

GNSS can track individual containers, or even individual goods (for multimodal transport), making for efficient supply chain management.

Table 161: Requirements for cargo monitoring

Indicator	Value	Unit	Notes
Accuracy	10	m	
Availability	“high”		
Integrity	“low”		
Time to Alarm	30+	sec	

Infrastructure charging is another area under rolling stock management that can be supported by GNSS. As the rail sector is being liberalised, train operators are charged for their use of track based on their use of infrastructure, and penalties are imposed according to delays.

GNSS location services can be used to help in calculating the accurate billing, and is a transparent way for railroad operators to charge train operators.

Table 162: Requirements for infrastructure charging

Indicator	Value	Unit	Notes
Accuracy	10	m	
Availability	“high”		
Integrity	“high”		
Time to Alarm	30+	sec	

In a similar vein, GNSS can be used to calculate the energy consumption of a train in conjunction with energy meters.

Table 163: Requirements for energy charging

Indicator	Value	Unit	Notes
Accuracy	10	m	
Availability	“high”		
Integrity	“low”		
Time to Alarm	30+	sec	

Some goods transported by rail can be dangerous, such as petroleum, dangerous chemical products, or waste products. GNSS can be used to track these goods, and importantly to

provide alerts for when these products deviate from expected position through geofencing.

Table 164: Requirements for Hazardous Cargo Monitoring

Indicator	Value	Unit	Notes
Accuracy	1-10	m	
Availability	"high"		
Integrity	"high"		
Time to Alarm	10 - 30	sec	

Passenger Information

Passengers increasingly can get access to information on the status of their train, such as through knowing in advance about delays and expected time of arrival, to interesting facts about the train and surrounding areas.

Table 165: Requirements for Passenger Information

Indicator	Value	Unit	Notes
Accuracy	100	m	
Availability	95%		

A subset of this is train warning systems for certain stations, wherein the station is required to inform passengers when a train is about to pass at a higher speed than the defined level. This application can be served by GNSS as GNSS can help a train report its position and speed, automating the station announcement.

Table 166: Former requirements for train warning systems, currently no requirements

Indicator	Value	Unit	Notes
Accuracy	1 – 10	m	
Availability	"high"		
Integrity	"high"		
Time to Alarm	10 - 30	sec	

Gap Assessment

Like with safety critical applications, the technical requirements here are also very vague. In this case, however, stakeholder consultations reveal that EGNOS and Galileo in their current state with their current services are sufficient to serve these applications.

SECTOR 3: MARITIME

The maritime sector in this context includes fisheries and inland waterways. GNSS is used in this context for navigation, positioning and surveillance.

Market Trends

Demand side trends and challenges

Autonomous Vessels

The concept of autonomous vessels is still very young., however various entities like the Maritime Safety Committee and the International Maritime Organisation have brought up this issue. These so called Maritime Autonomous Surface Ships (MASS) are not expected to enter operation soon, but the regulatory and technological groundwork is currently being laid.

E Navigation

The International Maritime Organization (IMO) has introduced the concept of e-Navigation, an initiative aimed at integrating navigational tools on ships' bridges to enhance safety and navigation ease. This initiative, set to be implemented from 2020 onwards, seeks to standardize and enhance maritime information systems to reduce errors, improve traffic management, and protect the environment. e-Navigation involves cooperation among stakeholders in the maritime sector, with the IMO, International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA), and International Hydrographic Organization (IHO) being key players.

The IMO has outlined a Strategy Implementation Plan (SIP) comprising tasks to prioritize five e-navigation solutions, such as user-friendly bridge design and standardized reporting. Compliance with IMO's performance standards for Bridge Alert Management (BAM) is required for bridge systems on EU vessels from August 2021. Additionally, the IHO's implementation of the S-100 standard will lead to changes in electronic navigational charts. As of 2022, digital maritime technology is still in the maturation phase.

Recreational Vessels

There are more than 8 times as many recreational vessels in operation than every other type of watercraft. Therefore these vessels represent a significant area of interest for improving GNSS penetration. Generally, recreational vessel operators are conducive to using navigation aids and often have higher spending power.

SAR

Search and rescue is a large market for GNSS in maritime sector, as the marine environment is inherently hostile. A particular driver for SAR in the EU are migrant vessels crossing the Mediterranean which are occasionally not seaworthy.

Monitoring, Control, Surveillance

Authorities need to track their fishing fleets as part of Vessel Monitoring Systems to ensure that they are fishing in authorised zones. These systems track the location, course and speed of EU fishing vessels. AIS is another technology used (but not limited to fisheries), it allows the identification of ships for maritime safety, security and control.

Accident investigation

Reliable and accurate position information is important in investigating the causes leading up to an accident. It is crucial that GNSS signals are of high integrity in these investigations as the data will be used in court and insurance procedures to reconstruct the accident.

Fisheries

As consumers are increasingly aware of issues related to overfishing, certain relevant trends open in the fisheries sector. First, as mentioned above, there is surveillance. Monitoring of IUU fisheries is an important activity that can regulate the spread of overfishing and unethical fishing practices. Secondly, traceability has emerged as an important trend in the sector, privileging the use of space technology like GNSS.

Aquaculture

Seafood is a large industry, but due to sustainability concerns, fisheries are losing market share to aquaculture. Indeed, aquaculture is the fastest growing food industry in the world.

Currently, aquaculture technology (aquatech) lags behind tech in agriculture and fisheries, but time will tell whether this industry will not catch up

GNSS technology trends

AIS

Automatic Identification System (AIS) benefits from the GNSS technology. GNSS-equipped AIS systems offer precise real-time positioning data, which enhances navigational safety in the maritime domain. Vessels equipped with GNSS-enabled AIS can provide accurate location information to other vessels and coastal authorities, reducing the risk of collisions and facilitating efficient traffic management.

GNSS integration also aids in rapid and accurate search and rescue operations by providing precise coordinates of distressed vessels. Moreover, GNSS-equipped AIS enhances vessel tracking and surveillance capabilities, making it an invaluable tool for maritime security, environmental monitoring, and efficient cargo management in the shipping industry. The synergy between AIS and GNSS has greatly changed maritime safety, navigation, and management, ensuring smoother and more secure maritime operations.

User Communities

- Maritime authorities
- Vessel operators
- Farmers (aquaculture)
- Logistics companies
- Port authorities
- NGOs

User Requirements / Application

GNSS requirements for the maritime sector are largely defined by the IMO resolution A.915, which defines three main categories of requirements corresponding roughly to 10, 1 and 0.1 m horizontal accuracy. Within each category, additional requirements are defined.

The categories are listed below.

Table 167: Requirements for Category 1 operations

Indicator	Value	Unit	Cat 1 +	Cat 1++	Cat 1+++
Horiz. Acc. (95%)	10 (100 for ocean)	m	As cat 1	3m	As cat 1
Vert. Acc. (95%)	NA	m	As cat 1	As cat 1	10 m
Availability	99.8	% per 30 days (2yr for ocean)	As cat 1	As cat 1	As cat 1
Horiz. Alert Limit	25	m	As cat 1	As cat 1	As cat 1
Time to Alarm	10	sec	As cat 1	As cat 1	As cat 1
Integrity Risk	10 ⁻⁵		As cat 1	As cat 1	As cat 1
Coverage	global		As cat 1	As cat 1	As cat 1
Position fix period	2	sec	As cat 1	As cat 1	As cat 1
Continuity	NA	% per 15 mins	99.97%	As cat 1	As cat 1

Table 168: Requirements for Category 2 operations

Indicator	Value	Unit	Cat 2 +	Cat 2++	Cat 2+++
Horiz. Acc. (95%)	1	m	As cat 2	As cat 2	1 to 2 m
Vert. Acc. (95%)	NA	m	As cat 2	1 m	0.1 m

Availability	99.8	% per 30 days	As cat 2	As cat 2	
Horiz. Alert Limit	2.5	m	As cat 2	As cat 2	2.5 to 5
Time to Alarm	10	sec	As cat 2	As cat 2	
Integrity Risk	10 ⁻⁵	per 3 hrs	As cat 2	As cat 2	10 ⁻⁵ /2min (bridge warning)
Coverage	region (local for VTS)		local	local	local
Position fix period	1	sec	As cat 2	As cat 2	
Continuity	NA	% per 15 mins	99.97%	As cat 2	

Table 169: Requirements for Category 3 operations

Indicator	Value	Unit	Cat 3 +	Cat 3++
Horiz. Acc. (95%)	0.1	m	As cat 3	As cat 3
Vert. Acc. (95%)	NA	m	As cat 3	As cat 3
Availability	99.8	% per 30 days	As cat 3	As cat 3
Horiz. Alert Limit	0.25	m	As cat 3	As cat 3
Time to Alarm	10	sec	As cat 3	1 sec
Integrity Risk	10 ⁻⁵	per 3 hrs, per 1 hr (for conning display), per 10 mins for mooring assist	As cat 3	As cat 3
Coverage	local		As cat 3	As cat 3
Position fix period	1	sec	As cat 3	As cat 3
Continuity	NA	% per 15 mins	99.97%	As cat 3
Speed over Ground	NA	m/s	0.1	As cat 3

As per the IMO resolution A.915(22), the following applications are defined for each category wherein the position or velocity of a craft is required.

Table 170: Applications by category

Application	Cat
General Navigation (SOLAS), ocean	1
General navigation (recreation & leisure), ocean & coastal	1
Casualty analysis, ocean & coastal	1
SAR initial rescue approach	1
Fisheries: location of fishing ground, positioning, yield analysis, monitoring	1
General Navigation (SOLAS), coastal, port approach & entrance	1+
General Navigation (recreation & leisure), port approach & entrance	1+
Traffic mgmt., ship to ship coordination, ship to shore coordination, shore to ship traffic mgmt.	1+
Operations: automatic collision avoidance and track control	1+
General Navigation (SOLAS), inland	1++
Oceanography	1+++
Marine Engineering, construction, maintenance and management: cable and pipe laying	2
Aids to Navigation management	2
Port Operations: Local VTS Casualty Analysis: Port approach, restricted waters and inland waterways	2
Search and Rescue: final rescue approach	2
Leisure boat applications in congested areas (geofencing, boat inspections, docking assistance)	2
Offshore explor. & exploit.: Explor., Appraisal drill., Field dev., Support to production, post prod.	2

General Navigation (SOLAS): Ports and restricted waters.	2+
General navigation (recreation and leisure): Ports and restricted waters	2+
Operations of Locks, Tugs, Pushers and Icebreakers	2+
Ports operations: Container / Cargo management & Law enforcement	2++
Hydrography	2+++
Bridges operation (IWW)	2+++
Marine Engineering: Dredging and construction works	3
Inland Waterways: bridge collision warning sys, auto. guidance, mooring assist, conning display	3
Operations: docking	3+
Port Operations: Cargo handling	3++

1 Merchant Vessels

Ship Route Optimization (Type A)

Through synergies with EO, a ship route can be optimized taking advantage of geographic and meteorological condition awareness. In the case of GNSS, a vessel will use satellite to calculate its position and relay back to the route planning system via AIS.

In terms of user requirements, this application would fall under several different applications.

- General navigation (SOLAS) in ocean and casualty analysis for ocean and coastal, therefore cat 1.
- General navigation (SOLAS), coastal and traffic management (ship to ship, ship to shore, shore to ship) and therefore cat 1+.
- Aids to navigation management and casualty analysis in port approach, restricted waters and inland waterways and therefore cat 2.
- General navigation (SOLAS): Ports and Restricted Waters and therefore cat 2+

Sea Ice Navigation (Type B)

EO generated updated ice maps can be used in conjunction with GNSS to enable craft to avoid icebergs. As this falls under operations of Locks, Tugs, Pushers and Icebreakers, the requirements correspond to 2+.

Collision Avoidance (Type B)

In addition to navigation receivers, Merchant ships with a gross tonnage exceeding 300GT are mandated by the IMO SOLAS regulation to carry a RADAR and an Automatic Identification System (AIS). The AIS facilitates communication of position and course information between nearby ships and shore-based facilities, enhancing navigation safety and traffic management, especially in proximity to ports.

Automatic collision avoidance employs auto-tracking that integrates the vessel's navigation data with that of other vessels. Its purpose is to issue warnings when the system forecasts that a predetermined minimum closest approach distance will be violated. It can also be employed to observe traffic conditions and establish navigation goals.

Operations: automatic collision avoidance and track control are categorised as Category 1+.

GNSS vessel engine management systems (Type C)

GNSS enables remote monitoring of ship conditions, such as engine diagnostics. This provides ship operators with essential data for conducting regular engine inspections and enhancing the maintenance of critical components of the vessel.

Merchant navigation (Type B)

All passenger ships, cargo ships larger than 500 gross tonnage or larger than 300 tons if engaged on international voyages are regulated and rely heavily on GNSS to support navigation activities.

In terms of user requirements, this application would fall under several different applications.

- General navigation (SOLAS) in ocean, therefore cat 1
- General navigation (SOLAS); Coastal, Port Approaches and Entrances therefore cat 1+
- Aids to navigation management and casualty analysis in port approach, restricted waters and inland waterways, therefore cat 2
- General navigation (SOLAS): Ports and Restricted Waters therefore cat 2+
- Bridge collision warning systems, automatic guidance, mooring assistance, and conning display in inland waterways therefore cat 3

MASS

As the enabling technologies for MASS are maturing, requirements are being outlined for GNSS in MASS. Notably in UCP2022, the outcomes of a project (GSA/OP/09/16/Lot 3/SC10) related to an EGNSS adoption roadmap were presented. The requirements for MASS are defined as follows:

Table 171: User requirement for MASS Ocean

Indicator	IMO res. A.915	EGUS-SC4 (above project)	Proposed requirement (UCP)
Horiz. Acc. (95%) (m)	10	15	10
Continuity Risk (over 15 min)	NA	NA	NA
HAL (m)	25	37.5	25
Time to Alarm (sec)	10	8	8
Integrity Risk (>3hr)	10^{-5}	7.2×10^{-5}	10^{-5}
Integrity Risk (>15min)	8.33×10^{-7}	6×10^{-6}	8.33×10^{-7}
Integrity Risk (per sample)	1.39×10^{-7}	1×10^{-9}	1.39×10^{-7}
Availability	99.8%	99.8%	99.8%

Table 172: User requirement for MASS Coastal Nav. & Port Approach

Indicator	IMO res. A.915	EGUS-SC4 (above project)	Proposed requirement (UCP)
Horiz. Acc. (95%) (m)	10	0.3	1
Continuity Risk (over 15 min)	NA	3×10^{-4}	3×10^{-4}
HAL (m)	25	12.5	7.5 – 12.5
Time to Alarm (sec)	10	6	6
Integrity Risk (>3hr)	10^{-5}	7.2×10^{-6}	7.2×10^{-6}
Integrity Risk (>15min)	8.33×10^{-7}	6×10^{-7}	6×10^{-7}
Integrity Risk (per sample)	1.39×10^{-7}	1×10^{-7}	1×10^{-7}
Availability	99.8%	99.8%	99.8%

Table 173: User requirement for MASS Port Navigation

Indicator	IMO res. A.915	H2H for aut docking (EUSPA project)	Proposed requirement (UCP)
Horiz. Acc. (95%) (m)	1	0.3	1
Continuity Risk (over 15 min)	3×10^{-4}	9×10^{-4}	3×10^{-4}
HAL (m)	2.5	50	2.5
Time to Alarm (sec)	10	10	6
Integrity Risk (>3hr)	10^{-5}	3.6×10^{-7}	7.2×10^{-6}

Integrity Risk (>15min)	8.33×10^{-7}	3×10^{-8}	6×10^{-7}
Integrity Risk (per sample)	1.39×10^{-7}	5×10^{-9}	1×10^{-7}
Availability	99.8%	99.8%	99.8%

Gap Assessment

In general, the priority is to meet the user requirements as outlined in IMO A.1046(27) which are applicable only to navigation in ocean waters, where the requirement are as they are written in category 1.

As with the rail sector, the current system can meet the requirements for cat 1 operations. In fact, EGNOS can effectively replace DGNSS for maritime, reducing the need for terrestrial infrastructure and further increasing safety of life at sea. The problem is that the system is not designed for the maritime sector. Therefore, there is a user requirement for a dedicated maritime SOLAS service.

Gaps planned to be addressed

Stakeholder consultations revealed that such a service is under development and is expected to be completed by the end of 2024. There is no need to change the signal in space but rather EUSPA will develop a dedicated service. Additional standards would need to also be developed for this.

Considerations

While cat 1 requirements – that is ocean, coastal, and inland SOLAS navigation - can be met by the current system, more advanced applications under cat 2 and 3 such as those related to ports (generally the additional requirements from A.915(22)), cannot be met with the current system based on internal studies done by EUSPA.

EGNOS v3 and further versions are expected to meet the requirements of cat 2 and 4, although naturally further standards would need be developed for this. Therefore it can be said that there are two gaps here: the lack of a dedicated maritime service and inability of the current system to meet more advanced use cases. Both these gaps, however, are currently being addressed.

INLAND WATERWAYS

INLAND WATERWAY NAVIGATION (TYPE A)

Satellite services can enable users of inland waterways to make informed decisions based on updated information. Rivers are used for commercial shipping by large ships that are not as maneuverable as smaller craft, while all types of inland waterways are used for recreational activities such as fishing, sailing, canoeing, and others.

As this is a large area, there are several applications where different categories are applicable:

- General navigation (SOLAS); Inland waterways falls under Category 1++.
- Casualty analysis in Port approach, restricted waters and inland waterways falls under Category 2
- Bridges operations in inland waterways falls under Category 2+++
- Bridge collision warning systems, automatic guidance, mooring assistance and conning systems in Inland Waterways falls under Category 3

Gap Assessment

As mentioned above, inland waterway navigation can be achieved by the current system, but there is the need for development of a dedicated EGNOS service for maritime.

Gaps planned to be addressed

This service is expected by the end of 2023.

Considerations

Other use cases that fall under category 2 and beyond will not be possible with EGNOS until v3.

The gaps are the same as the above case

MARINE ENGINEERING

MARINE SURVEYING AND MAPPING (TYPE A)

This application covers a range of activities (seabed exploration, tide and current estimation, offshore surveying, etc.); which are collectively important for maritime navigation. There are two main application categories here:

- Oceanography deals with understanding the behavior of the ocean, mapping boundaries, geology, physics, chemistry and biology. Oceanography falls under Category 1+++.
- Hydrography provides data for charting maritime environments, which is important to support the safety of navigation. Position and depth must be undertaken with sufficient accuracy to ensure safety. Hydrography falls under Category 2+++.

DREDGING (TYPE A)

Dredging is the process of excavating and removing sediment, silt, mud, rocks, and other materials from the bottom of bodies of water such as rivers, lakes, harbors, and channels. This is done using specialized equipment such as dredgers or dredging vessels. Dredging serves several purposes, including maintaining navigable waterways by removing accumulated sediments that can hinder ships' passage, deepening and widening channels, creating or maintaining ports and harbors, land reclamation, environmental restoration, and flood prevention.

Dredging concerns Marine Engineering, dredging construction, maintenance and management: cable and pipe laying; also, Offshore exploration and exploitation: Exploration, Appraisal drilling, Field development, Support to production, Post-production and falls under Category 2 and 3.

Gap Assessment

As mentioned above, marine engineering use cases like oceanography that fall under cat 1 can be achieved by the current system, but there is the need for development of a dedicated EGNOS service for maritime.

Gaps planned to be addressed

This service is expected by the end of 2023.

Considerations.

Other use cases that fall under category 2 and beyond will not be possible with EGNOS until v3.

The gaps are the same as the above case.

PORTS

GNSS ASSISTED PORT OPERATIONS (TYPE B)

GNSS supports automated port operations for activities like traffic mgmt., container tracking and asset mgmt., law enforcement and cargo handling. Cargo handling operations fall under Category 3++.

PILOTING ASSIST AT PORT (TYPE B)

GNSS supports ports with real time navigation information. This provides pilots with greater control, safety and accuracy during port approach and manoeuvres. This falls under:

- General navigation (SOLAS); Coastal, Port approach and entrances fall under Category 1+.
- Port Operations: Local VTS and Casualty Analysis: Port approach fall under Category 2.
- Operations of Locks, Tugs, Pushers and Icebreakers and General navigation (SOLAS): Ports and Restricted Waters fall under Category 2+.
- Ports operations: Container / Cargo management & Law enforcement fall under Category 2++.

PORT SAFETY (TYPE B)

The safety of port terminal operations is ensured by GNSS positioning information.

- Law enforcement falls under Category 2++
- Cargo handling operations fall under Category 3++.

PORT BASED NAVIGATION DEVICES, PPUS, AND VESSEL DOCKING (TYPE B)

Vessel transit progress, docking and loading/unloading operations at ports are monitored by GNSS-based technologies. Professional portable devices known as portable pilot units (PPUs) are employed by maritime pilots to guide vessels through confined areas like locks and ports. When used alongside a ship's bridge and connected to high-precision GNSS, PPUs enhance the safety, efficiency, and fuel savings of piloting large maritime vessels during docking.

Docking assistance systems ensure effective and secure manoeuvring throughout the port area, providing precise positioning and speed measurements in centimetres (encompassing the entire port/harbour region). This results in improved vessel trajectory and simplifies ongoing monitoring of moored or docked ships.

This is a relatively large grouping which may be concerned with multiple applications.

- This application is concerned with port approach and entrances; Traffic management; Ship to ship coordination, Ship to shore coordination and Shore to ship traffic management; Operations: automatic collision avoidance and track control, all of which fall under Category 1+.
- Port Operations: Local VTS; Casualty Analysis: Port approach all fall under category 2, with the caveat that for Local VTS, only local coverage is needed.
- Ports operations: Container / Cargo management & Law enforcement is classified under Category 2++.
- Docking operations fall under Category 3+.
- Cargo handling operations fall under Category 3++.

Gap Assessment

As most port related use cases fall under cat 2 or the more stringent cat 3, the majority of port operations cannot be served by EGNOS in its current state. The system will need to first be developed to EGNOS v3.

The gaps are the same as the above case.

RECREATIONAL CRAFT

RECREATIONAL NAVIGATION (TYPE B)

In general, the needs for recreational navigation are similar as that for commercial navigation and largely fall under the same categories:

- General navigation (recreation & leisure), ocean & coastal fall under category 1
- Leisure boat applications in congested areas (geofencing, boat inspections, docking assistance) fall under Category 2
- General navigation (recreation and leisure): Ports and restricted waters falls under Category 2+.

Considerations and Gap Assessment

As mentioned above, recreational craft use cases like general navigation that fall under cat 1 can be achieved by the current system, but there is the need for development of a dedicated EGNOS service for maritime.

Gaps planned to be addressed

This service is expected by the end of 2023.

Considerations

Other use cases that fall under category 2 and beyond will not be possible with EGNOS until v3.

The gaps are the same as the above case.

VESSEL TRACKING

DARK VESSEL MONITORING (TYPE C)

GNSS is an important tool, as it forms the basis of several technologies such as AIS, LRIT and VMS. These technologies can be used to monitor vessels. When a vessel disables their technology, they can still be tracked by EO satellites, which can cross reference signals from AIS and LRIT with imagery to locate dark ships.

It should be noted that ships are allowed to turn off their AIS when travelling through hostile and dangerous waters. AIS would enable pirates or hostile vessels to locate merchant fleets.

As all use cases are type C, no gap analysis is done.

FISHERIES

IUU FISHING CONTROL (TYPE C)

As mentioned above, illegal fishing operations can be tracked using GNSS technology such as AIS. If a fishing vessel is identified in a protected area, appropriate action can be taken by law enforcement. If AIS is disabled, EO can still serve to locate ships that are trying to hide.

As all use cases are type C, no gap analysis is done.

FISH AGGREGATING DEVICES (TYPE B)

FADs are buoys placed in the ocean, exploiting the natural tendency of many fish species to aggregate around floating objects. Smart FADs are modern devices with both sonar and GNSS, enabling fishing fleets to remotely estimate the biomass below the FAD and dispatch a ship to the exact location of the FAD to harvest the fish, greatly reducing fuel consumption. It should be said that FAD fishing has significantly higher rates of bycatch than traditional free-school fishing⁵⁶.

FADs do not fall under established categories, but the UCP found that for this application, Galileo and GPS were well beyond all requirements.

FISHING VESSEL NAVIGATION (TYPE C)

Fisheries: location of fishing grounds, positioning during fishing, yield analysis and fisheries monitoring all fall under Category 1. But can fall under other categories such as for port approach and in land waterways.

As all use cases are type C, no gap analysis is done.

AQUACULTURE

AQUACULTURE OPERATIONS OPTIMIZATION (TYPE C)

GNSS plays a role when the operation of offshore farms is carried out by fully automated vessels that rely on accurate positioning and navigation, or in the upcoming use of GNSS for the localization of networks of buoys in a similar manner as the FAD.

As all use cases are type C, no gap analysis is done.

SAR

BEACONS FOR MARITIME (TYPE B)

⁵⁶ Marine Stewardship Council. FADs. <https://www.msc.org/what-we-are-doing/our-approach/fishing-methods-and-gear-types/fish-aggregating-devices-fads>

SAR beacons would fall under category 1 and category 2.

Gap Assessment

As mentioned above, SAR use cases that fall under cat 1 can be achieved by the current system, but there is the need for development of a dedicated EGNOS service for maritime.

Gaps planned to be addressed

This service is expected by the end of 2023.

Considerations

Use cases that fall under category 2 and beyond will not be possible with EGNOS until v3.

The gaps are the same as the above cases.

3.2.6.3. Terrestrial Vehicle Monitoring

SECTOR 1: ROAD

The road market segment has been marked by GNSS use since the 90s, when road navigation systems appeared. Nowadays people generally prefer to use personal navigation devices, or their familiar smartphones, with respect to using car-integrated GNSS devices. However, the use of GNSS in the road segment will grow significantly, and already plays a huge role with important applications.

Market Trends

Demand side trends and challenges

Advent of connected, autonomous cars

Autonomous vehicles will bring a new set of requirements although it is not yet very clear what will be the final role of GNSS in the complex guiding system installed in such cars. Advanced Driver Assistance Systems (ADAS), one of the fastest growing segments in automotive electronics today, are paving the way to a large series of applications based on real-time communications between roads users themselves and infrastructures.

Other applications

E-call and the smart tachograph are examples of use of GNSS in EU policy. The directive on interoperability of road toll systems in the European Union is another one. The market is moving from specific devices, supporting specific applications, to the vehicle becoming a platform of connected services requiring more stringent performances for positioning, timing and navigation.

Pushed by regulators, E-call and tachograph have a strong impact on the market development. Same involvement of public authorities will be welcome to incorporate the GNSS positioning and timing in legal metrology: this action will facilitate the deployment of road tolling, taximeters and various payment applications.

New players

Tier 1 suppliers and vehicles manufacturers will continue to be the main market players. Nevertheless, the deployment of in-vehicle connected platforms will attract the attention of telematics services providers. For the majority of them, accurate localization, and time stamp of collected data is a guarantee for the quality of services they provide.

GNSS technology trends

Galileo role, coupling and standardization

Despite some limitations in urban environment and tunnels, the GNSS service will stay the cornerstone of many road applications. It is worth mentioning that with multi-constellations

and multi-frequencies the positioning provided by GNSS signals will be significantly improved. Thanks to its great interoperability with GPS, and some wide band signals, Galileo has a major role to play in this evolution. High accuracy and authentication could be another valuable asset. Nevertheless, for the most demanding applications like automatic braking, lane keeping and autonomous cars, the coupling with other on-board sensors and 3D mapping will be inevitable. Like in civil aviation, the in-vehicle positioning system will have a complex architecture to go through the standardization process of safety critical applications.

Prospective use of GNSS

In the global automotive industry, today there are three major areas that will make an intensive use of GNSS P&T: Advanced Driver Assistance, Vehicle to Vehicle/Infrastructure communication, and autonomous vehicle. The performance criteria will have to reach the highest values in terms of availability, horizontal accuracy, integrity, authentication sensitivity and robustness. These values will be reachable only with receivers capable of exploiting all the added values brought by multi constellations, multi frequencies wide band offered by Galileo in addition to other constellations.

The three main prospective use cases are:

- ADAS: safety features are designed to avoid collisions by alerting the driver or implementing safeguards. Adaptive features may automate lighting, provide adaptive cruise control, automate braking, incorporate GNSS/ traffic warnings, connect to smartphones, alert driver to other cars or dangers, keep the driver in the correct lane, or show what is in blind spots.
- V2X: Cooperative Intelligent Transport Systems (C-ITS) use technologies that allow road vehicles to communicate with other vehicles of traffic signals, roadside infrastructure and other road users. The communications are based on standardized messages CAM (Cooperative Awareness Message) and DENM (Decentralized Environmental Message), where positioning and timing play a major role. Some of these applications such as traffic monitoring or traffic congestion detection need a 10 meters accuracy, but others like green light optimal speed advisor or red-light violation warning will need higher GNSS performances. “Day 1 benefits”, which are expected in the short-term because of technology maturity and their potential benefits, vary from hazardous location notifications and signage applications, smart routing, parking and road safety.
- Autonomous vehicles: "autonomous" or "self-driving" vehicles are those in which operation of the vehicle occurs without direct driver input to control the steering, acceleration, and braking and are designed so that the driver is not expected to constantly monitor the roadway while operating in self-driving mode (definition according to the National Highway Traffic Safety Administration).

User Communities

- Group 1: Research institutes, universities working in the PNT for automotive field.
- Group 2: Public authorities at national and EU level aware of GNSS created opportunities.
- Group 3: Standardization bodies such as ETSI, CEN/CENELEC informed of GNSS performance criteria for their purpose.
- Group 4: Automotive industry, including Tier 1 suppliers and aftermarket device vendors.
- Group 5: Other affected industries: insurance companies, fleet operators, road network operators, shippers, logistic companies, public transport companies etc.

User Requirements / Application

Four application categories fall under the road market segment for GNSS.

SAFETY CRITICAL

Safety-critical applications are those where the malfunction of GNSS-based in-vehicle positioning systems can result in severe injuries to drivers, passengers, and other road users. The key performance indicators in this context include availability, integrity, accuracy, GNSS sensitivity, and resistance to interferences. Presently, these applications rely on contextual information, employing GNSS in conjunction with RDS TMC location tables and TPEG on cell phones, and the requirements are not excessively stringent.

However, as these safety applications transition to being supported by V2X communications, the requirements will undergo a significant and more stringent transformation. For instance, features like red-light violation warnings and 360° all-around views will demand meter-level accuracy in horizontal positioning. The applications within this category can be classified into four main types.

- *Traffic Warnings: general warnings for speed limits, congestions etc.*
- *Safety Warning: urgent warnings that require human interventions.*
- *Automated Interventions: an example Is emergency braking.*
- *Driving Automation: ADAS etc.*

Here below the specifications of user requirements for Traffic and Safety Warning application.

Table 174: Performance requirements for Traffic and Safety Warning applications

Indicator	Value	Unit	Notes
Availability	>99.5%		
Horizontal Accuracy	<3(D1); <1(D2)	m	D1: day one applications, meaning developed in the short-term D2: day two applications meaning developed in the long-term
Horizontal Accuracy	<1	secs	
Integrity and Reliability	Yes		Shall provide an integrity message
Authentication	Yes		Shall provide robustness against spoofing threats
Interference Detection	Yes		Shall be able to detect interferences and inform of it

Here below the specifications of user requirements for Automated intervention and autonomous driving application.

Table 175: Performance requirements for Automated intervention and autonomous driving applications

Indicator	Value	Unit	Notes
Availability	>99.9%		
Horizontal Accuracy	<20	cm	
Integrity and Reliability	Yes		Shall provide an integrity message, with 10-15m of protection level
Authentication	Yes		Shall provide robustness against spoofing threats

PAYMENT CRITICAL

Payment-critical applications heavily rely on in-vehicle GNSS devices for billing, where charges are primarily determined based on the position and timing information provided. As future applications like dynamic ride sharing with the exchange of small sums of money emerge, there will be a need to elevate the legal status of GNSS metering as a recognized means of metrology. This type of service could be beneficial for taxis and offer a more cost-effective alternative to mechanical methods of measuring distance. Key performance

indicators in this context include accuracy, availability in urban areas, and the authenticity of GNSS data.

It's worth noting that cybersecurity threats pose a significant challenge to the reliability of many payment applications. In conclusion, GNSS positioning and timing do not yet hold an adequate legal status in metrology to facilitate financial transactions. This deficiency may hinder the deployment of taxi meters and dynamic ride-sharing services for short distances, where accurate positioning and billing are essential.

To sum up, the main payment critical applications are:

- Road user charging
- Pay as you drive insurance.
- Pay per use insurance.
- Taxi meter.
- Parking fee calculation.

Here below the specifications of user requirements for payment critical applications.

Table 176: Performance requirements for *Payment critical* applications

Indicator	Value	Unit	Notes
Availability	>99.5%		
Horizontal Accuracy	<3	m	
Horizontal Accuracy	<1	secs	
Integrity and Reliability	Yes		Shall provide an integrity message
Authentication	Yes		Shall provide an authentication message
Interference Detection	Yes		Shall be able to detect interferences and inform of it

REGULATORY CRITICAL

The requirement for on-board GNSS-based positioning and timing equipment due to national or international legislation is relatively limited at present. However, new legislations are emerging in this regard. The adoption of GNSS technology is gaining momentum, especially through applications like the Digital Tachograph and pan-EU E-call, which mandate its use.

In the future, Geo-fencing technology can further expand the scope of GNSS applications. It may be leveraged for initiatives such as implementing progressive urban pricing or restricting polluting vehicles from entering low emission zones. This marks a growing trend towards integrating GNSS into regulatory frameworks to address various social and environmental challenges.

Here below the specifications of user requirements for regulatory critical applications.

Table 177: Performance requirements Regulatory critical applications

Indicator	Value	Unit	Notes
Availability	>99.5%		
Horizontal Accuracy	<5	m	
Horizontal Accuracy	<1	secs	
Integrity and Reliability	Yes		Shall provide an integrity message
Authentication	Yes		Shall provide an authentication message
Interference Detection	Yes		Shall be able to detect interferences and inform of it

SMART MOBILITY

In this category, the paramount criteria are availability, continuity, and Time To First Fix. This category can be further divided into two distinct market segments: traffic managers and transport companies on one side, and individual drivers on the other. These applications are primarily shaped by market demand and are subject to the dynamic innovation of startup companies. Examples of these applications include freight, fleet, and cargo asset management; vehicle access and clearance control; floating car data for real-time traffic information; dynamic speed harmonization for traffic flow optimization; emergency vehicle priority to enhance response times; bus and tram priority at traffic lights to improve public transportation efficiency; and origin-destination surveys, among many others. These applications play a crucial role in enhancing transportation management, safety, and efficiency.

Here below the specifications of user requirements for smart mobility applications.

Table 178: Performance requirements Smart Mobility applications

Indicator	Value	Unit	Notes
Availability	>99.5%		Performance related
Horizontal Accuracy	<5	m	Better than 3m if the application includes payment functions
Horizontal Accuracy	<1	secs	Performance related
Authentication	Yes		Shall provide an authentication message
Interference Detection	Yes		Shall be able to detect interferences and inform of it

Gap Assessment

For now, Galileo meets all the identified requirements in the Road sector. In addition, it represents a strong support to policy makers: E-calls and Tachographs strongly rely on Galileo optimal performances.

Considerations

Even though some applications are used and established, such as Smart Tachographs and e-Call, the utilization of GNSS in the Road sector still holds more potential. Both in terms of technology and regulations, there is a lot to discover and standardize: as pointed out during consultations, the market of autonomous cars and automated vehicles will grow, and new requirements will emerge on the positioning side.

3.2.6.4.Drones

SECTOR 1: DRONES

GNSS is a technology that can augment the impact that drones have on society by making advanced features of drones more accessible for a wide range of use cases.

Market Trends

Demand side trends and challenges

Miniaturization

Drones historically were large, often military or government craft. Smaller drones were generally recreational craft used by hobbyists. As technology got smaller and lighter, smaller drones could perform more intensive tasks, carrying more sophisticated or heavier payloads, flying for significantly longer, and further and faster.

This has led to more use cases being developed for drones, such as for remote sensing. Small civilian drones can now carry sensors over areas of interest – such as cities, natural habitats, or farms – and collect data. Similarly, improvements in battery life and motors mean that

drones can realistically be used for deliveries – including deliveries of essentials such as medicines and first aid before first responders can arrive at a scene.

Delivery and e-commerce

The market for deliveries is growing as more customers prefer to shop online and fewer at brick-and-mortar stores. Deliveries may be a core use case for drones, as traditional deliveries are both expensive for the companies, and stressful for delivery drivers. Drones can work constantly and can avoid urban traffic, getting to destinations significantly faster, freeing up human drivers for more critical tasks.

U Space and UTM

Regulators in the EU have taken major steps towards traffic management in the “U-Space.” The first regulatory frameworks were developed in 2021 (2021/664, 2021/665 & 2021/666). Similarly, registration of drone operators and drones has also become mandatory in the EU as of 2020. UTM is being trailed in several locations to demonstrate the feasibility of UTM.

GNSS technology trends

Miniaturization and low power

Miniaturization of GNSS receivers and lowering their power draw enable them to be fit onto drones without affecting their flight.

User Communities

- **DRONE MANUFACTURERS**
- **INDUSTRIAL DRONE USERS**
 - **AGRICULTURE**
 - **SEARCH AND RESCUE**
 - **LOGISTICS**
 - **ENVIRONMENTAL PROTECTION**
 - **PUBLIC AUTHORITIES**
- **REGULATORS**

User Requirements / Application

Drones

POSITIONING FOR NON-NAVIGATION FUNCTIONS (TYPE B)

Aside from navigation, as with aviation, GNSS still has important roles to play in drones. A notable case would be in e-conspicuity and surveillance. Airspace users and other entities (such as ANSPs) would need to know the position and velocity of each drone in the airspace at any given time. Therefore, GNSS is important for e-conspicuity to avoid mid air collisions. This is particularly notable in urban areas as a drone has the potential to cause severe accidents. There are industry standards applicable to this, such as ED-279 and ED-280.

In urban areas, pure GNSS alone may not be enough. Multi path errors could present a substantial risk if not mitigated. 5G and LTE may be used for surveillance of these drones, but DFMC receivers could also be powerful tools for this use case.

Galileo specific differentiators could also prove beneficial. Of note would be the OS-NMA, which would ensure that drone positions are not being spoofed.

Table 179: Requirements for Drone Positioning for non-navigation functions - GNSS

Indicator	Value	Unit	Notes
Horizontal Accuracy (95%)	1 to 3	meters	
Vertical Accuracy (95%)	1.5 to 4.5	meters	
Horizontal Alert Limit	3 to 10	meters	
Vertical Alert Limit	4.5 to 15	meters	
Integrity	$1 - 1 \times 10^{-4}$ / h		Specific Assurance and Integrity Levels (SAIL) 3
TTA	3 to 4	seconds	
TTFF	30	seconds	
Update rate	0.1	seconds	

PBN APPLICATIONS (TYPE A)

If drones are to be operated beyond line of sight, which is already the case for many applications, there would need to be a high-performance navigation system. As with aviation, PBN like requirements could be very useful in this case.

Performance based navigation is a modern air navigation concept that allows aircraft to navigate more accurately and efficiently. It relies on the capabilities of the aircraft's onboard navigation systems rather than ground-based navigation aids. PBN enables more precise and flexible flight paths, leading to improved safety, increased airspace capacity, and reduced fuel consumption and emissions.

It is comprised of two procedures:

- Area Navigation (RNAV): RNAV allows aircraft to navigate along specific paths defined by waypoints and coordinates rather than being confined to fixed routes based on ground-based navigation aids.
- Required Navigation Performance (RNP): RNP is a measure of the navigational accuracy required for a specific flight operation. It defines the containment of an aircraft within a specified airspace volume, ensuring that the aircraft stays within certain lateral and vertical tolerances from its intended flight path.

For this concept to be applied to drones, GNSS must be able to provide sufficiently precise and reliable solutions even in complex environments, as drones do not exclusively fly in the open as commercial aircraft do.

Table 180: Requirements for Drone en route PBN (based on EUSPA background work)

Indicator	Value	Unit	Notes
Horizontal Accuracy (95%)	3 to 8	meters	
Vertical Accuracy (95%)	4 to 13	meters	
Horizontal Alert Limit	25 to 27	meters	Fixed wing
	10 to 14	meters	Rotary wing
Vertical Alert Limit	12 to 22	meters	Fixed wing
	7 to 23	meters	Rotary wing
Integrity	$1 - 1 \times 10^{-4}$ / h		Specific Assurance and Integrity Levels (SAIL) 3
	$1 - 1 \times 10^{-5}$ / h		Specific Assurance and Integrity Levels (SAIL) 4
TTA	1 to 3	Seconds	
Continuity	$1 - 1 \times 10^{-4}$ / h		
Availability	99.99%		

GEO-AWARENESS SYSTEM (TYPE B)

Geofencing is a tool used in the management of the UAS space. It ensures that a drone stays within a predefined airspace and does not venture into restricted airspace. Regulations, however, are moving towards a “geo awareness” system, wherein the responsibility to be aware of restrictions falls on the drone operator, as opposed to on the entity enforcing the restriction to advertise restrictions.

While geo fencing prevents a drone from flying into restricted airspace, geo awareness informs the drone and pilot in case of restricted airspace proximity. Therefore, there is a need for awareness of the drone’s exact position and its velocity to inform the pilot that they are expected to head into or near restricted airspace. EGNOS and Galileo (with authentication) are expected to provide value in this use case.

Table 181: Requirements for Drone geo awareness system

Indicator	Value	Unit	Notes
Horizontal Accuracy (95%)	1 to 3	meters	
Vertical Accuracy (95%)	1.5 to 4.5	meters	
Horizontal Alert Limit	3 to 10	meters	
Vertical Alert Limit	4.5 to 15	meters	
Integrity	$1 - 1 \times 10^{-4}$ /h		
Continuity	$1 - 1 \times 10^{-4}$ /h		
TTA	3 to 4	seconds	
TTFF	30	seconds	
Update rate	0.1	seconds	

Gap Assessment

The drones segment remains relatively immature as of 2023. There are several hurdles to overcome, although there is significant work being done to overcome these.

- *Availability is a challenge for drones since they are expected to fly in difficult environments such cities, mountains, etc. These prevent line of sight with many satellites. Currently, mobile networks like 5G are being explored as a solution. That said, the main idea is that drones avoid areas with significant obstruction if they require GNSS connection.*
- *Multipath is another large issue. Skyscrapers and other tall objects would cause multipath errors, meaning that this would need to be mitigated. DFMC is a solution for this, but again the prevailing opinion is that drones requiring GNSS avoid areas where significant multipath is expected.*
- *Jamming and spoofing is an issue in aviation that can be both intentional by malicious actors, and unintentional. OS-NMA is proposed as a solution to this.*

As shown above, generally GNSS is second to pilot skill and planning as a solution to the main issues that are being faced in the drone sector.

Gaps planned to be addressed

There is progress in DFMC, with GBAS services being developed for both GPS and Galileo, enabling augmentation of these signals. Projects like GAUSS, REALITY and EGNSS4RPAS explore the use of Galileo and EGNOS to overcome some of the challenges associated with drones.

Considerations

Currently, however, the drone sector is still immature and regulators are still working on developing the framework in which drones will operate. There are some gaps, but as the industry is still young, it is difficult to identify the exact ways forward, that said, many ways forward are identified and are being addressed.

3.2.6.5.Critical Infrastructure

SECTOR 1: INFRASTRUCTURE

GNSS is essential to manage infrastructures during their entire lifecycle, notably to increase safety of operations and to improve resilience while safeguarding the environment. The term “infrastructure” here refers to the basic systems and facilities that a country or organisation needs to work effectively. This section covers mainly infrastructures such as construction or telecommunication.

Market Trends

Demand side trends and challenges

Carbon neutrality 2050

The EU commitment to achieve carbon neutrality by 2050 is pushing the imperative to reduce the environmental impact of infrastructure and fortify their resilience to climate change. In this setting, several significant trends in the infrastructure market have emerged. These trends are associated with the proliferation of GNSS-based machine control in the construction sector, where precise positioning technology is increasingly applied for improved efficiency and accuracy. Additionally, there is a growing recognition of the role of GNSS-based solutions in bolstering the infrastructure of the telecommunications segment. These developments signify a proactive approach toward sustainable and technologically advanced infrastructure, aligning with the broader goal of environmental sustainability and climate resilience.

GNSS technology trends

There are various GNSS applications related to infrastructure. These applications primarily revolve around the construction market, encompassing areas like surveying and machine guidance. The construction industry's growth has been a significant driver for GNSS shipments, and this trend is mirrored in the telecommunication market, thanks to the widespread deployment of 5G networks. These developments reflect the increasing reliance on GNSS technology to support infrastructure-related activities and the expanding role of 5G in the telecommunications sector.

User Communities

- Infrastructure owners and/or operators: like private or public entities managing buildings, factories, power plants, dams, airports, but also highways or telecommunication infrastructures.
- Construction and public works companies usually contracted by infrastructure owners and operators to design and construct the infrastructures.
- Public authorities including regulatory bodies at different geographical level.
- Financial institutions involved in the funding of infrastructures and therefore interested in the exposure to risk concerning them.
- International development organizations such as the World Bank
- Telecommunication operators considered the end users when Timing & Synchronization applications are at stake for telecommunication.
- Telecommunication network equipment providers, radio-spectrum regulators and standardization organizations.

User Requirements / Application

The applications are divided in four three groups, that are listed below with their relevant use cases.

INFRASTRUCTURE PLANNING

The group comprises applications related to the selection of sites for the construction of new infrastructures, including applications supporting the obtention of building permits and applications supporting vulnerability assessments.

Infrastructure site selection and planning (Type A)

Before commencing any infrastructure construction, an integral step involves site selection and the planning of construction operations. Site selection aims to assess potential locations and their suitability for the specific needs of the infrastructure project. These needs encompass various aspects, including topography, geology, land cover, land use, terrain stability, susceptibility to risks, and vulnerability to the impacts of climate change.

GNSS technology plays a pivotal role in both the site selection and planning phases, offering solutions like GNSS-RTK (Real-Time Kinematic). GNSS-RTK enables cost-effective and time-efficient topographic measurements and construction surveys. When stringent accuracy requirements are necessary, the PPP-RTK approach, combining Real-Time Kinematic and Precise Point Positioning, is employed. This approach can achieve centimeter-level accuracy within a matter of seconds. Furthermore, through geomatics applications like mapping and Geographic Information Systems (GIS), photogrammetry, laser scanning, and remote sensing, GNSS provides valuable tools for creating detailed specialized maps and establishing GIS databases with precise positions of all infrastructure site features.

In addition to high-accuracy GNSS devices such as smart antennas and integrated mapping/GIS devices, GNSS chipsets can feed high-precision positioning data into LiDAR and imaging devices, whether they are mounted on drones or used in land-based applications. This integration is invaluable for augmented reality technologies, allowing for on-site visualization of the future infrastructure, aiding in the planning and construction phases.

Overall, the GNSS main user requirements for Infrastructure site selection and planning are listed below.

Table 182: Performance requirements for Infrastructure site selection and planning applications

Indicator	Value	Unit	Notes
Horizontal Accuracy	Mm to cm level	m	Depending on construction application
Vertical Accuracy	Mm to cm level	m	Depending on construction application
Availability	>95%		Urban canyons
Availability	>95%		Under canopy
Robustness	Low		
Service area	Mostly Regional		Coverage
TTFF	Few mins	mins	
GNSS contribution	High		
Integrity and Reliability	Low		

INFRASTRUCTURE CONSTRUCTION AND MONITORING

This group comprises applications related to the construction phase (e.g. construction progress monitoring, machine guidance and control) and to the post-construction phase (e.g. ground motion detection, vegetation encroachment detection).

Constructions operations (Type A)

This phase encompasses activities that occur between the completion of the site selection and planning phase and the moment when the infrastructure becomes operational. These activities

span a range of tasks, including earth-moving, excavation, concrete work, and installation work. Two key GNSS applications in this context are monitoring construction progress and machine control.

GNSS-RTK technology is increasingly propelling the rapid expansion of machine control solutions in the construction industry, facilitating both semi-automatic and fully-automatic machine operations. RTK corrections enable machine operations with centimeter-level accuracy. There are two primary modes for GNSS-enabled machine control:

- "Indicate" mode, which provides visual cues to assist the operator in executing earth-moving tasks according to the design specifications.
- "Automatic" mode, which involves controlling the machine's hydraulics to ensure, for example, that graders maintain the blade at the required grade level.

The latter mode typically demands more stringent accuracy requirements and can be achieved with the presence of an on-site base station. Furthermore, by accessing diverse sets of 3D machine control data originating from different vehicles on the construction site, construction managers can more effectively monitor, supervise, and coordinate construction activities. This approach allows them to identify bottlenecks, optimize machine utilization, and ultimately, reduce costs.

Overall, the GNSS main user requirements for Constructions operations are listed below.

Table 183: Performance requirements for *Constructions operations* applications

Indicator	Value	Unit	Notes
Horizontal Accuracy	Mm to cm level	m	Depending on construction application
Vertical Accuracy	Mm to m level	m	Depending on construction application
Availability	>95%		Urban canyons
Availability	>99%		Under canopy
Robustness	Low/Medium		
Service area	Regional/Local		Coverage
TTFF	Few seconds	secs	Few mins for asset positioning
GNSS contribution	High/Low		High for vehicle tracking and asset monitoring, low for machine control and trajectory
Integrity and Reliability	Low		High only for machine control

Post-construction operations (Type B)

Built infrastructures can be vulnerable to various factors, including natural phenomena like ground deformation and human activities such as nearby construction projects. Addressing these challenges involves safeguarding the infrastructures, optimizing maintenance efforts, and potentially extending the infrastructure's lifespan. To achieve these objectives, it's crucial to monitor aging-related damages, enhance maintenance planning for improved efficiency and cost reduction, mitigate risks, particularly in the face of more frequent extreme weather events, and predict potential failures. In the context of GNSS, ensuring the stability of built infrastructure can be accomplished through the utilization of high-precision GNSS methods. This may involve post-processing static relative GNSS observations collected at control points in the field and combining them with data from local or global CORS (Continuously Operating Reference Stations) networks. This approach provides accurate geospatial information that is invaluable for monitoring and assessing the health and stability of the infrastructure.

TIMING AND SYNCHRONIZATION OF TELECOMMUNICATION NETWORKS

This group includes applications related to the timing and synchronization of the various types of telecommunication networks (e.g., Digital Cellular Networks, Public Switched Telephone Network).

Data centre (Type B)

Data centers are specialized facilities within buildings or groups of buildings that house computer systems and their associated components. They offer remote processing and storage capabilities to end-users via telecommunication networks. For the seamless daily operation of data centers, they require a dependable and precise timing and synchronization source. There are various use cases, with the most prominent being enterprise applications, manufacturing processes, and media and entertainment.

For instance, in the broadcasting industry, synchronizing audio and video feeds is essential to prevent "lip-sync" errors. In the realm of professional tools and applications, including distributed transactional systems, databases, artificial intelligence, big data, and machine learning, precise timing and synchronization are vital for efficient operation.

GNSS plays a significant role in providing timing and synchronization to data centers. It offers direct and accurate access to a prediction of Coordinated Universal Time (UTC) and provides GNSS reference time to various receivers, ensuring that the data center's operations remain synchronized and precise. This is crucial for maintaining the integrity and efficiency of data center processes, particularly in environments where precise timing is of paramount importance.

Digital cellular network (Type B)

A digital cellular network (DCN), often referred to as a "mobile network," is a communication network where wireless links connect end nodes. This network is distributed over land areas divided into "cells," with each cell being serviced by at least one fixed-location transceiver. The fixed-location transceiver typically comprises three "base stations" responsible for providing network coverage within the cell, facilitating the transmission of voice, data, and various other types of content.

Telecommunication operators operating in such networks require precise and consistent time and frequency synchronization across various points within their network to meet the increasingly demanding requirements of broadband services. GNSS is employed to ensure that all base stations within the network maintain uniform frequency and time alignment, ensuring the network's reliability and performance. This synchronization is crucial for maintaining the quality of service and supporting the efficient operation of mobile networks.

Professional Mobile Radio (Type B)

"Professional mobile radio" (PMR) denotes person-to-person two-way radio voice communication systems. These systems are essential tools for governmental agencies like the police, fire departments, ambulance services, and emergency responders, as well as commercial enterprises like taxi services and delivery companies. GNSS plays a pivotal role in PMR systems by providing precise timing references. This timing information is used for air interface synchronization, which is critical for seamless roaming and the allocation of communication channels. GNSS also act as a redundancy solution, ensuring that PMR users can transition from one base station's service coverage area to another without experiencing dropped calls. This reliability and continuity of service are of utmost importance in emergency response and professional mobile communication scenarios, where uninterrupted communication is vital for effective operations.

Public Switched Telephone Network (Type B)

The Public Switched Telephone Network (PSTN), also known as the Plain Old Telephone Service (POTS), serves as the infrastructure and service provider for public telecommunications. The PSTN comprises the collective circuit-switched telephone networks

worldwide, operated by national, regional, or local telephone operators. It includes telephone lines, fiber optic cables, microwave transmission links, cellular networks, communication satellites, and undersea telephone cables, all interconnected through switching centers, enabling most telephones to communicate with one another. Telecommunication operators in the PSTN context require precise and consistent time and frequency synchronization across remote points within their networks to meet the growing demands of broadband services. For PSTN applications, GNSS typically serves as a backup to atomic clocks, primarily for time slot management. The utilization of GNSS-derived synchronization by European PSTN operators depends on whether they have already integrated atomic clocks into their networks. Large operators often have their atomic clocks established in their networks during the 1970s and 80s, prior to the availability of GPS.

Satellite Communication (Type B)

Satellite communication (Satcom) is a critical technology that leverages satellites to establish communication links between various points on Earth, enabling a wide range of services, including radio, television, data, and telephone transmissions. Satcom systems are composed of two primary segments: the ground segment, which involves fixed or mobile transmission and reception equipment, and the space segment, which comprises single satellites or constellations of satellites. A typical satellite link begins with the transmission or uplinking of a signal from an Earth station to a satellite. The satellite receives and amplifies the signal before retransmitting it back to Earth. Ground-based Earth stations and terminals receive and reamplify the signal for further use. Satcom receivers on the ground encompass diverse devices, such as direct-to-home (DTH) satellite equipment, mobile reception equipment on aircraft, satellite phones, and handheld devices.

In the realm of telecommunications, operators require precise and consistent time and frequency synchronization across remote points in their networks to meet the growing demands of broadband services. GNSS finds utility in Telecommunications Gateways, primarily for frequency control, and also in Satellite Control Stations for timing applications, serving as either the primary source or a redundancy source. The Satcom industry has gained confidence in GNSS-derived timing, as they have experienced minimal to no performance issues with the received GNSS signals, making it a reliable solution for their synchronization needs.

Small cells (Type B)

A small cell is a cost-effective radio access point characterized by low radio frequency (RF) power output, a small footprint, and limited coverage range. These small cells can be deployed both indoors and outdoors, and they can operate in licensed, shared, or unlicensed spectrum bands. Small cells play a crucial role in providing high-quality, secure cellular coverage across various environments, improving coverage, adding targeted capacity, and supporting new services and user experiences. These cells come in different types, each with varying ranges, power levels, and form factors tailored to specific use cases. The smallest units are designed for indoor residential use. Once again, telecommunications operators require precise and consistent time and frequency synchronization across remote points in their networks to meet the growing demands for broadband services. GNSS is utilized in small cell networks to provide frequency and phase alignment, ensuring that these networks operate effectively and maintain synchronization, which is essential for delivering reliable and high-quality wireless connectivity services.

Overall, the GNSS main user requirements for Timing & Synchronization of Telecommunication Networks are listed below.

Table 184: Performance requirements for Timing and Synchronization of telecommunication networks applications

Indicator	Value	Unit	Notes

Continuity of service	Yes		
Trustable	Yes		
Resilience	Yes		
Robustness	Yes		Able to detect interferences
Service commitment	Yes		
Integrity	Yes		With a certain level of confidence
Update rate	1-10	Hz	
Coverage	Regionally minimum		
Traceability	Yes		Minimum to UTC
Authentication capabilities	Yes		At User Equipment level
Authentication capabilities	Yes		On a continuous basis
Authentication capabilities	5-10	secs	Duration between successive authentications
Authentication capabilities	Yes		No degradation of the time accuracy
Authentication capabilities	Yes		With a transparent key management procedure
Accuracy (timing)	30	ns	To UTC for DCN application
Accuracy	<65	ns	Phase Sync accuracy, DNC applications
Accuracy (Freq Sync)	1.10-11		For DCN applications
Availability	99.9%		For DCN applications
Robustness	Yes		Against non-synchronized GNSS spoofing attacks, For DCN applications
Availability	"Desirable"		Indoor, For DCN applications
Availability	"Desirable"		Urban canyons, For DCN applications
Accuracy	10	us	PMR applications
Availability	99.9%		PMR applications
Robustness	Yes		Against non-synchronized GNSS spoofing attacks, For PMR applications
Availability	"Desirable"		Indoor, For PMR applications
Availability	"Desirable"		Urban canyons, For PMR applications
Accuracy	1	us	PSTN applications
Availability	99.9%		PSTN applications
Availability	"Desirable"		Indoor, For PSNT applications
Availability	"Desirable"		Urban canyons, For PSNT applications
Robustness	Yes		Against "Record and replay" GNSS spoofing attacks for PSTN
Accuracy	>95%		Up to 100ns for Satcom
Availability	>99.9%		For Satcom
Robustness	Yes		Against "Record and replay" GNSS spoofing attacks for Satcom
Availability	"Desirable"		Indoor, For 5G small cells
Availability	"Desirable"		Urban canyons, For 5G small cells
Availability	>99.9%		For 5G small cells

Gap Assessment

In this segment, all the user requirements are generally met by Galileo. However, integrity represents a critical performance for Timing and Synchronization applications, and EUSPA currently does not provide any assurance on the level of trust in the timing solutions provided by Galileo.

Another main problem that arises is that Galileo Time and Synchronization applications are

not as widespread as they could be. In fact, they provide a cost-effective solution, but today they are still used as back-ups to older methods. The main reasons are two: the upfront investments that a company would have to make to be fully dependent on Galileo, and the very high performances expected in terms of resilience and robustness of the signal.

Gaps planned to be addressed

To fulfill this gap, EUSPA is leveraging on Horizon2020 and Horizon Europe to fund projects and increase the confidence in the GNSS solutions. Two examples of project are ROOT and CHRISS, as explicated during consultations. A dedicated timing service is also being developed. Therefore, it can be said that while there are gaps, they are all being addressed.

SECTOR 2: ENERGY

The energy sector is wide and for its long list of stakeholders, from governments to utility companies, satellite technologies can provide invaluable data.

Market Trends

Demand side trends and challenges

Green energy transition and its implications

Governments are actively promoting the rapid transition to green energy in response to the impacts of climate change, evolving geopolitical factors, and a steadily rising demand for energy. Simultaneously, the emphasis on Environmental, Social, and Governance (ESG) considerations is fuelling the necessity to identify optimal locations for large-scale new wind and solar energy installations. These two primary trends are heavily influenced by spatial considerations, largely thanks to the valuable assistance provided by Earth Observation techniques, enabling more efficient goal attainment. While GNSS plays a less prominent role in this context, it assumes a critical role in activities related to grid balancing. In fact, the role of GNSS is increasingly pivotal, especially as intermittent renewable technologies like wind and solar introduce greater variability and reduced predictability into the grid.

GNSS technology trends

Electricity systems rely on a precise equilibrium between demand and supply, and the widespread adoption of decentralized and large-scale renewable energy production has a notable impact on the dynamics of these systems. Earth Observation (EO) aids in weather predictions, and GNSS plays a crucial role by ensuring the synchronized timing of various nodes within the power network.

User Communities

- The International Energy Association (IEA)
- International Renewable Energy Agency (IRENA)
- International Association of Oil & Gas Producers (IOGP)

User Requirements / Application

The following list of applications enable by GNSS is not exhaustive and is expected to grow with the adoption of space technologies in the coming years and the innovations that should come with it.

ENERGY NETWORK FIDELITY

Phasor measurement units (PMUs) (Type B)

GNSS offer precise timing and synchronization for Phasor Measurement Units (PMUs) strategically placed in remote areas of the power network. This enhancement significantly bolsters the reliability of the power network. PMUs measure voltage and current phasors and

attach timestamps to these measurements by utilizing a GPS receiver and a phase-lock oscillator. This approach provides a comprehensive overview of the grid's dynamics, thereby facilitating more effective power system planning, control, and post-incident analysis.

Overall, the GNSS main user requirements for Phasor Measurement Units are listed below.

Table 185: Performance requirements for *Phasor Measurement Units* applications

Description	Type
The Timing & Sync system shall provide continuity of the service	Functional
The Timing & Sync system shall be trustable	Functional
The Timing & Sync system shall be resilient	Functional
The Timing & Sync system shall be able to detect and characterize GNSS interference	Functional
The Timing & Sync system shall provide service commitment	Functional
The Timing & Sync system shall get access to integrity information with a certain level of confidence	Functional
The Timing & Sync system shall provide robustness against "synchronised" GNSS spoofing attacks for Electricity transmission applications	Functional
The Timing & Sync system shall be preferably provided worldwide and regionally as a minimum	Functional
The Timing & Sync system shall provide an update rate of 1Hz to 10 Hz	Performance
The Timing & Sync system shall be able to demonstrate traceability to UTC	Functional
The Timing & Sync system shall be able to provide an authentication capability at User Equipment level	Functional
The Timing & Sync system shall be able to provide an authentication capability on a continuous basis	Functional
The Timing & Sync system shall be able to provide an authentication capability with a duration between successive authentications of 5 to 10 seconds	Functional
The Timing & Sync system shall be able to provide an authentication capability with no degradation of the time accuracy	Functional
The Timing & Sync system shall be able to provide an authentication capability with a key management procedure as transparent as possible	Functional
The Timing & Sync system shall provide an accuracy of 1 μ s for PMU applications (Time tagging with accuracy better than 1 μ s with a magnitude accuracy of 0.1% or better)	Performance
The Timing & Sync system shall not only be dependent on GPS	Functional
The Timing & Sync system shall provide a high level of availability (99.9%)	Performance
The Timing & Sync system shall have an availability "Desirable" in urban canyons	Functional
The Timing & Sync system shall have an availability "desirable" indoors	Performance

Gap Assessment

Timing and Synchronization requirement for Galileo are generally met, as outlined during the consultations. In general, the two most important needs indicators are the timing accuracy and the robustness of the signal.

Gaps planned to be addressed

As highlighted during stakeholders' consultations, Galileo' improvements on this sector are expected thanks to the OSNMA. This aspect is key, and its importance will increase as more infrastructures will rely on Galileo, since their disruption would cause critical problems to the society. EUSPA is also working on a new function called Timing Service Level Monitoring. It helps by signaling when a Galileo satellite is performing worse, and should not be used.

Therefore, while there is a gap in terms of integrity and robustness, it is being addressed through Galileo OSNMA, G2G and new services.

Considerations

The Energy sector utilizes GNSS in different ways, from construction and maintenance of infrastructures to the Timing and Synchronization services for Phasor Measurement Units (PMUs). The first part is covered in the infrastructure section.

Sector 3: Timing and Synchronisation

GNSS is ideally suited to timing and synchronization as the system provides a global timing signal from highly reliable synchronized atomic clocks. As it is highly accurate, global, and freely available, GNSS timing has been adopted by the T&S community.

Market Trends

Demand side trends and challenges

Main trends in telecom

PSTN are maturing, in some cases they are reaching retirement in favor of VoIP. For most operators, there is no purpose in operating separate infrastructure for telephone and internet when technologies like DSL or fiber can do both.

As PSTN reaches its retirement, cellular networks like 4G and 5G are experiencing rapid growth. 4G already would likely have not been possible without GNSS timing, as alternate solutions like LORAN were not precise enough. 5G is even more demanding in terms of synchronization, as advanced solutions like 5G and LTE require phase synchronization in addition to frequency synchronization.

Main trends in electricity transmission

Electrical systems are increasingly complex. The shift towards more diversified energy sources is beneficial from an environmental and strategic perspective, but it does increase the importance of grid synchronization. Similarly, electrical power is being transmitted over longer distances, meaning that these systems are more vulnerable to problems.

Extremely precise timing is needed to ensure that the grid remains stable. The grid operates at a specific frequency and any deviation from this frequency can lead to grid instability and power outages. Accurate timing is necessary to keep generation and consumption in balance.

Main trends in finance

Financial markets rely on timing for precise timestamping. As banking networks are now global, and there are more actors on the market, there is more need for precise timekeeping.

User Communities

- Telecom Sector
- Energy Sector
- Finance Sector

User Requirements and Applications

The following list of applications enable by GNSS is not exhaustive and is expected to grow with the adoption of space technologies in the coming years and the innovations that should come with it.

Telecom

Satcom

GNSS receivers are commonly utilized in Satellite Control Stations and Telecommunications Gateways. These receivers primarily serve for frequency control purposes, although there are also some timing applications, particularly within satellite control stations.

It is estimated that each Satellite Control Station would typically employ a minimum of four local GNSS receivers, but this number can vary based on various factors and criteria. These

GNSS receivers are usually complemented by local (atomic) oscillators. Nevertheless, the SATCOM industry has grown increasingly confident in GNSS-derived timing, as they have encountered minimal to no adverse performance issues related to the received GNSS signal.

Synchronization requirements are typically based on the recommendations outlined in ITU G.811 (Stratum 1), with G.812 offering recommendations for slave clocks in telecoms networks. Accuracy requirements are predominantly shaped by the specific technology needs of telemetry tracking loops and are expected to remain around 100 nanoseconds accuracy.

Professional Mobile Radio

GNSS-based timing is essential for air interface synchronization in mobile communication. It enables seamless handovers between base stations, preventing call drops. TETRA, for instance, demands a precision of 10 microseconds for successful handovers. Ideally, GNSS receivers are placed at each base station to ensure signal continuity between them. In case of GNSS signal loss, local oscillators serve as backups.

With current limitations in data transmission over existing PMR (Professional Mobile Radio) technologies and the increasing capabilities of LTE (Long-Term Evolution), there's a possibility of PMR networks being supplemented by LTE for high-quality video streaming and broadband data services. The role of GNSS timing in this transition remains uncertain, as the industry may explore non-GNSS time solutions or reduce the use of GNSS receivers, depending on protocol developments like PTP (Precision Time Protocol).

Digital Cellular Networks

The digital cellular network is the main driver of timing and synchronization services due to the large size of this market. In the EU, most of the network is a blend of GSM, UMTS, and LTE, with the latter increasing in size as it is the latest technology. The most stringent requirements for LTE requires frequency accuracies of <10 ppb and phase synchronization of $\pm 1.1 \mu\text{s}$, while compensating for delay variation and jitter. Requested frequency accuracy is $\pm 5\text{ppb}$.

The roll out of 5G is expected to bring more challenges beyond those already derived from LTE. 5G requires very precise timing references requiring performance SLA monitoring. According to the UCP report: “the anticipated performance at the end point for 5G (stage 2) is $\text{TAE} \leq 260[\text{ns}]$ $\text{TE} \pm 130[\text{ns}]$. A stricter mobile network timing requirement could even be required for 3GPP High accuracy location capability: $\text{TAE} \leq 10[\text{ns}]$ $\text{TE} \pm 5[\text{ns}]$ – though this figure is relative to radio neighbours sharing the same area. Moreover, network calibration and monitoring (i.e. verifying & testing this level of accuracy in the field) may even be more challenging than network synchronization delivery. In any case, 5G performance requirements are currently only anticipated and will finally be determined by the selection of implemented features.”

Public Switched Networks

As a legacy technology, PSTNs generally had their own atomic clocks installed in their own networks prior to the availability of GNSS. However, GNSS time currently outperforms performance requirements for this technology. As mentioned in the trends section, PSTNs are generally being retired.

Electricity Transmission

GNSS is used in the electricity transmission sector to inform operators on the network status and to determine faults along a transmission line. GNSS can be used in the following cases:

- Time reference and distribution systems: GNSS use in time reference and distribution is a marginal use case. The level of accuracy required is low, in the order of several seconds and so is not crucial. Current technology is more than sufficient

- **Phasor Measurement Units (PMUs):** PMUs have two main purposes: network monitoring, which is the main current use, and automatic protection. The former is not very critical, but widely adopted, the latter is a critical application which requires a very high level of redundancy at PMU level. The required accuracy is about 1 microsecond.

The requirement in this sector is not always to have the right time, but for the time across units to be synchronized. However, in PMUs, captured phasors may also have to be time-tagged based on the time of the UTC Time Reference.

Finance

Banks

GNSS devices are employed for time-stamping purposes, recording events in a chronological order, enabling the reconstruction of cause-and-effect relationships. While the standard accuracy requirement for most applications is 1 millisecond, there is a growing trend toward enhanced accuracy driven by regulatory mandates.

Stock Exchanges

Stock exchanges require timestamps for the execution of orders in the right order. These timestamps need to be extremely precise. Almost all stock exchanges leverage GNSS time for this application, and thus this is a mature market. Currently PTP adoption is underway and the required precision is in the microsecond level.

Gap Assessment

So while Galileo timing can be used in some applications, it is not used in critical applications. There is a user need for integrity over timing that currently is not met.

Gaps planned to be addressed

This user need is currently being addressed however, as there is plans for a timing service in the G2G infrastructure. Therefore while there is a gap, it is associated with the uptake of Galileo (since GPS can already serve the user needs in this industry). This gap is also in the process of being addressed through the establishment of the Timing Service.

Considerations

Currently, the standard practice is to use GPS time. Galileo and ENGOS can provide timing information, but since most of these applications are safety or liability critical, the users require some level of integrity monitoring. EUSPA currently does not provide any assurance on the level of trust in the timing solutions provided by Galileo

3.2.6.6.High Precision Professional Applications

SECTOR 1: RAW MATERIALS

Raw material is mainly related to the mining activity. Mining companies can harness services facilitated by EO and GNSS data for a variety of purposes. These applications include pinpointing optimal areas for raw material extraction, streamlining the permitting process, strategizing development, and overseeing their operations. Specifically, GNSS is integral to the planning and day-to-day operations of mining companies. It aids in surveying sites and provides safe guidance for heavy machinery like earth movers and bulldozers, which have transitioned to fully autonomous operation thanks to GNSS assistance. Satellite data is also invaluable in the post-operational phase of the mining industry, supporting activities such as site clean-up, land rehabilitation, and effective waste management.

Market Trends

Demand side trends and challenges

ESG monitoring and safety protocols

Ambitious decarbonization and environmental target are driving mining companies to track their work with EO: it can help, for instance, as a support for receiving a certification, or monitor safety-critical activities such as tailing dams.

Transparency and new opportunities

Evaluating the entire value chain, particularly with regard to emissions, plays a pivotal role in maintaining stakeholder engagement and securing funding. Meanwhile, mining exploration projects often necessitate venturing into the world's most distant and isolated regions, resulting in costly and time-consuming manual surveys. In conclusion, adopting more efficient upstream solutions, such as advanced machinery, is of utmost importance as it opens up avenues for cost savings and time efficiency for mining companies.

GNSS technology trends

Overall, the main use of GNSS in the raw material sector is related to the implementation of autonomous or semi-autonomous machinery, which usually requires a high level of accuracy that today is supported by RTK technology, and mining sites planning and monitoring.

User Communities

- International Council on Mining and Metals (ICMM)
- Euromines
- European Raw Materials Alliance (ERMA)
- EIT Raw Materials

User Requirements / Application

The following list of applications enable by GNSS is not exhaustive, and is expected to grow with the adoption of space technologies in the coming years and the innovations that should come with it.

Mining

Mining machinery control (Type B)

GNSS machine control refers to the control and semi-automatic guidance of vehicles. When the accuracy needed is at centimeter level, RTK corrections are used, thus productivity is increased and costs are reduced significantly: less labour time, fuel used, and maintenance needed. The GNSS system can be used, for example, both in excavators and dozers.

Overall, the GNSS main user requirements for PTN in Mining machinery control are listed below.

Table 186: Performance requirements for Mining and Machinery control applications

Indicator	Value	Unit	Notes
Horizontal Accuracy	20-80	mm	
Vertical Accuracy	Cm/mm level	m	
Availability	Yes		Regionally or locally
Availability	>95%		Under canopy
Availability	>95%		Urban Canyon
Integrity and Reliability	High		
TTFF	10 or less	secs	
Update rate	10	Hz	
Trustable	Medium		

Mining vehicle tracking & asset management (Type B)

By tracking the locations of mining vehicles and other mining assets, mining operators can see what is happening versus what is planned. GPS-driven data regarding the location and status can allow operators to manage issues and make effective decisions, boosting production rates while enhancing safety and minimizing downtime.

Overall, the GNSS main user requirements for PTN in Mining vehicle tracking & asset management are listed below.

Table 187: Performance requirements for Mining vehicle tracking & asset management applications

Indicator	Value	Unit	Notes
Horizontal Accuracy	1-5	m	
Vertical Accuracy	m level	m	
Availability	Yes		Regionally or locally
Availability	>95%		Under canopy
Availability	>95%		Urban Canyon
Integrity and Reliability	Low		
TTFF	10 or less	secs	
Update rate	1	Hz	

Mining site exploration, planning and monitoring (Type A)

Mining companies undertake various tasks, including the identification of optimal sites for raw material extraction, the planning of their development, and continuous monitoring, even post-abandonment. These essential activities involve assessing field intensity and the probability of finding substances on or below layers of overburden, conducting geomorphological studies to map geological structures and mineralization-influencing faults, the preliminary delineation of valuable mineral and metal deposits, studying regional geological trends and structures, integrating remote sensing with subsurface imaging techniques (geophysics) to ascertain basement depth, and establishing domains to optimize sampling strategies and drilling campaigns.

Overall, the GNSS main user requirements for PTN in Mining site exploration, planning and monitoring are listed below.

Table 188: Performance requirements for Mining site exploration, planning and monitoring applications

Indicator	Value	Unit	Notes
Horizontal Accuracy	20-80	mm	
Vertical Accuracy	Cm level	m	
Availability	Yes		Regionally or locally
Availability	>95%		Under canopy
Availability	>95%		Urban Canyon
Integrity and Reliability	Low		
TTFF	5 or less	mins	

Cross sector user requirement specifications

In addition, the GNSS main user requirements that are cross-sector, therefore transversal to the whole raw material sector, are listed below.

Table 189: Cross sector user requirement specifications

Description	Type

The availability of the location information provided by the PNT solution fulfilling its performance requirements shall be high (>95%), including in harsh environments	Performance
The PNT information shall be based on signals transmitted in two or more bands (E1, E5, E6) thus enabling dual or triple frequency RTK and PPP solutions.	Functional
Galileo precise orbit and clock corrections shall be available in a similar way as GPS/Glonass are provided in the IGS Real Time Service	Functional
Documentation related to reference systems, needed data for the compliance to the INSPIRE directive (transformation from GTRF to ETRF2000) shall be available at the GSC portal.	Functional

Gap Assessment

The main utilization of GNSS in the Raw Material segment is related to mining, where surveying is extensively used. As highlighted during consultations, the needs for this segment cannot be met by any GNSS alone since the accuracy required is centimeter or millimeter level. The performances required by Galileo signal are fully met. However, Galileo does not provide the level of performance accuracy of a centimeter level, but decimeter level thanks to the High Accuracy Service (HAS). The corrections needed are provided by commercial actors (RTK or PPP-RTK), which can often ensure also a 24h 7/7 support which Galileo lacks.

Considerations

In a service evolution context, improvements are considered but with special regards to keeping the market environment safe. As mentioned in the consultations, the idea is to innovate in a way that the industrial segment is not disrupted but pushed, and the end market benefits from Galileo even more.

Therefore, there is no gap per se, as the user requirements (while not met) are not meant to be met by Galileo alone in order to not compete with industry.

SECTOR 2: INSURANCE AND FINANCE

This market segment is strongly impacted by EO and its new applications, while GNSS plays an important but limited role in the domain of timing and synchronisation, by providing timestamps for financial applications.

Market Trends

Demand side trends and challenges

EO driven insurance

Thanks to EO data, insurers can achieve greater granularity in risk selection and pricing. Moreover, risk models are becoming more climate change adapted, not relying on post-event damage assessment but on the measured incident itself.

Regulatory-driven GNSS

Since 2018, the European Securities and Markets Authority (ESMA) has imposed on EU member states a series of technical requirements on business clock synchronization in the Commission Delegated Regulation (EU) 2017/574, which complements the MiFiD II Directive 2014/65/ EU in markets of financial instruments in trading especially, time lags as small as 10 microseconds can be a deadly disadvantage.

GNSS technology trends

The utilization of GNSS within the insurance and finance sector is primarily restricted to timing and synchronization applications. GNSS equipment is employed for time stamping functions, enabling the logging of events in a chronological sequence. This chronological record facilitates the recreation of causal links. Notably, all stock exchanges are equipped

with extensive data centers housing their matching engines on racks of interconnected servers, and these data centers employ GNSS receivers as sensors for timing and synchronization.

User Communities

- Exchanges and marketplaces where securities, commodities, derivatives and other financial instruments are traded;
- Banks;
- Other users such as general investors, market makers or hedge funds.

User Requirements / Application

The following list of applications enable by GNSS is not exhaustive and is expected to grow with the adoption of space technologies in the coming years and the innovations that should come with it.

Finance

Timing and synchronization for Finance (Type B)

Timing and synchronization are two functions that can be fulfilled by GNSS.

Timing is the marking of an event with respect to the origin, usually the coordinate universal time (UTC). The user requires the time tagging of events, also called Time stamping, which is the use of an electronic time stamp to provide a temporal order among a set of events.

Synchronization is about understanding the temporal ordering of events produced by concurrent processes. Successful communication between nodes of a network can be ensured thanks to synchronization, and the same is true for applications in which two events have to be initiated within a specific time frame. Synchronization can be about both phase and frequency. *GNSS provides a direct and accurate access to a prediction of UTC; Either synchronization between receivers at different locations can be established and maintained using GNSS reference time.*

Within the finance sector, the distribution of GNSS time extends across a network encompassing several thousand machines. Typically, a GPS antenna is installed on a rooftop and linked to a Precision Time Protocol (PTP) or Network Time Protocol (NTP) server. The availability of precise timing information is of paramount importance for banks and stock exchanges. Historically, GNSS unavailability due to potential denial of service attacks has been managed using alternative solutions. Banks demand an exceptionally high level of security, availability, and reliability for their IT systems. In terms of accuracy, the standard requirement for most applications involving GNSS within this segment is approximately 1 millisecond. As of today, virtually all major European banks have already incorporated timing and synchronization equipment employing GNSS technology. Individual stock exchange servers apply time stamps to the trades they execute and the quotes they establish. It is assumed that nearly all of the major stock exchanges have already implemented synchronization equipment utilizing GNSS technology. The expectation is that the number of GNSS equipment installations within this sector will remain relatively stable. Regulatory requirements mandate the implementation of systems offering accuracy at the microsecond (μ s) level.

Overall, the GNSS main user requirements for Finance are listed below.

Table 190: Performance requirements for Finance applications

Indicator	Value	Unit	Notes
Continuity	Yes		Continuity of service required
Accuracy	100-200	nsecs	Accuracy for timestamping
Availability	99.9%		

Trust	Yes		Shall be trustable
Reliable	Yes		Shall be reliable
Certification	50	msecs	Satisfy the synchronization requirements of UTC as maximum requirement
Resilient	Yes		Shall be resilient
Robustness	Yes		Able to detect interferences
Service commitment	Yes		Shall provide service commitment
Integrity	Yes		Access to integrity information with a certain level of confidence
Authentication	Yes		Able to be robust against spoofing attacks
Trust	Yes		Shall be secure
Coverage	Globally and regionally		
Traceability	Yes		Able to demonstrate traceability to UTC
Authentication	Yes		At User Equipment level
Authentication	Yes		On a continuous basis
Authentication	5-10	secs	Between successive authentication
Authentication	Yes		Authentication capability with no degradation of accuracy
Authentication	Yes		authentication capability with a key management procedure as transparent as possible
Update rate	1-10	Hz	

Gap Assessment

Timing and Synchronization for finance is the main relevant application. The requirements are generally met by Galileo, but two key indicators are more critical: robustness and timing accuracy.

Gaps planned to be addressed

Regarding the first, Galileo OSNMA will represent the main solution to have a secure signal with authentication. As mentioned in other parts of the high precision market, the gaps are expected to be filled by the timing service, which is underway already.

SECTOR 3: AGRICULTURE

One of the oldest economic sectors, agriculture has been essential to human settlements for most of human history. As the environmental impact of feeding the human economy and society is one of the leading causes of climate change, it is important that steps be taken to increase the efficiency of agriculture.

GNSS enables agriculture to be performed more efficiently than through traditional means, by enabling vehicles to operate autonomously, by supporting precision agriculture, and also by supporting regulatory oversight of the sector.

MARKET TRENDS

Demand side trends and challenges

Sustainable development

The environmental impact of agriculture is increasingly scrutinized. Farmers today are required to consider their use of chemical products – notably as per the current Common Agricultural Policy. GNSS can support precision agriculture which can reduce the need for chemical products by adjusting the quantities used to the exact amounts needed.

Rising food demand

As disposable incomes increase, people often switch to purchasing more food, and purchasing food with higher land use such as animal products and away from staples⁵⁷. This puts further strain on the agricultural supply chain, requiring more land, labour and inputs to agriculture. It should be noted that another large cause of rising food demand is high levels of food waste and loss – FAO estimates that 14% of food (by value) is wasted before retail, and a further 17% is wasted at retail and consumer level.

Decreasing number of farmers

Agriculture is increasingly seeing a decrease in the number of farmers, as the children of farmers frequently move toward careers in different fields. That said, the total area farmed is not expected to decrease meaning that there is a decrease in small holders anticipated, moving towards more large farms.

This has consequences both for the sector and for the environment. First that a small group of farmers may benefit from higher revenues due to consolidation of land, this could enable them to invest in more advanced farm equipment – such as those benefitting from GNSS.

The other side of this coin is that larger farms generally have larger impacts on the environment due to lower crop diversity (monoculture / monocropping), which will subsequently negatively impact wildlife biodiversity, soil health, and resilience to pest and climatic shocks⁵⁸.

It is likely that the trend will continue. To counter the negative effects of farm consolidation on the environment, precision GNSS technology can and should be leveraged where possible.

GNSS technology trends

The agriculture sector is no exception to the more data driven, digitalized revolution of most sectors. IoT sensors enable farmers to track and optimize their operations more than before, and robotic or other intelligent solutions lessen the workload on farmers, enabling increased productivity per farmer – necessary in the context of a declining number of farmers.

Globally, major OEMs and suppliers are collaborating to establish distribution networks for cutting-edge technologies, ensuring their competitiveness. These alliances include partnerships like CNH Global and Trimble, AGCO and Topcon, and AgLeader and Autofarm. Additionally, there have been notable acquisitions, such as Monsanto's purchase of The Climate Corporation, followed by John Deere's acquisition of Precision Planting LLC. In June 2018, Bayer finalized its acquisition of Monsanto, solidifying its position as the largest agriculture supplier worldwide.

User Communities

-
- Farmers and agricultural cooperatives
 - Industrial organizations
-

⁵⁷ FAO (2023) Agriculture Outlook 2023-2032

⁵⁸ Mehrabi, Z. *Likely decline in the number of farms globally by the middle of the century*. Nat Sustain 6, 949–954 (2023). <https://doi.org/10.1038/s41893-023-01110-y>

The following list of applications enable by GNSS is not exhaustive and is expected to grow with the adoption of space technologies in the coming years and the innovations that should come with it.

Precision Agriculture

Precision agriculture (PA) refers to the application of the right quantity of the right product at the right time. In the case of GNSS, it relies on precise relative positioning in the farm. This has become increasingly available to farmers due to the development of lower cost and higher accuracy GNSS solutions.

PA can enable farmers to reduce their operating costs by reducing the amount of inputs they need to their farms. It also enables them to increase their crop yield which concurrently would increase their revenues.

Farm Machinery Guidance

Farm machinery guidance in PA refers to providing agricultural vehicles, such as tractors and combines, with provide accurate relative positioning and navigation guidance. This technology allows farmers to operate their equipment and farmers achieve precise and consistent rows, reduce overlap, and improve efficiency during planting, cultivating, and harvesting, ultimately leading to higher crop yields and reduced input costs. It plays a vital role in modernizing and optimizing farming practices.

There are two main forms, prior pass guidance and fixed line guidance. The former refers to the farmer performing the first pass over their field, and the system estimating the optimal distance for the next pass, which is usually based on the swath width of the machine itself. Subsequent passes are based on the previous pass. Fixed line guidance refers to a line being drawn before the farmer starts operating and the passes being defined not by the previous pass but rather by the original lines.

In this context, farm machinery guidance refers to so called “lightbar guidance” wherein a farmer still drives the vehicle but uses a lightbar or a HUD that enables them to know whether they are aligned with the defined path.

Typical pass to pass accuracy is about 10 to 30 cm using techniques like SBAS or DGNSS, but if farmers require more precise positioning, RTK can be used which can achieve centimeter level precision.

Table 191: Requirements for Farm Machinery Guidance

Accuracy	Canopy?	Availability	Robust.	Auth.	Integrity	Size	Autonomy	Fix time
10-30 cm	NO	HIGH	LOW	LOW	HIGH	NA	NA	MINS

Automatic Steering

Automatic steering in PA refers to enabling agricultural vehicles, such as tractors, to navigate and operate autonomously or semi-autonomously in the field. This technology goes one step further than the aforementioned farm machinery guidance in that the farmer does not need to steer anymore. Automatic steering systems help farmers achieve precise and consistent rows, reduce overlap, and improve efficiency during planting, cultivating, and harvesting, ultimately leading to higher crop yields and reduced input costs. It plays a vital role in modernizing and optimizing farming practices.

Such systems are significantly more costly than the lightbar systems, generally an order of magnitude more, but also completely remove the workload from the farmer. Generally, as these systems are much more high end, they usually will leverage RTK as opposed to SBAS or DGNSS.

Table 192: Requirements for Automatic Steering

Accuracy	Canopy?	Availability	Robust.	Auth.	Integrity	Size	Autonomy	Fix time
2.5 cm	NO	HIGH	MED	LOW	HIGH	NA	NA	MINS

Variable Rate Application

A farmer's parcel may not be homogenous, particularly in the case of crop rotation or polyculture, both of which are recommended practices from an environmental perspective. As such, different parts of a parcel may require different quantities of inputs at different times. Variable rate application (VRA) enables farm machinery to alter the amount of input they apply to a field as they make their passes.

There are two main kinds of VRA. First, map based VRA adjusts the rate based on maps that inform the system when to increase or decrease application. The map can be developed by satellite and the system can use geofencing to apply the right amount of product. Second, sensor based VRA uses sensors aboard the vehicle to measure crop and soil properties on the go, applying product based on information from the sensor.

Table 193:: Requirements for VRA low (spraying, spreading, harvesting bulk) and VRA high (seeding, planting)

Accuracy	Canopy?	Availability	Robust.	Auth.	Integrity	Size	Autonomy	Fix time
10-30 cm (low)	NO	HIGH	LOW	LOW	HIGH	NA	NA	MINS
2.5-10 cm (high)								

HARVEST / YIELD MONITORING

In this application, data is collected from sensors aboard a combine as it harvests. This can enable a farmer to understand how much crop they have harvested from each area, and can also measure other relevant characteristics such as soil moisture, etc. and map these on their field.

Over multiple harvests, a farmer can gain important insight into the specific behavior of their parcel, and can see correlations between certain parameters and yields.

Table 194: Requirements for Harvest / Yield Monitoring

Accuracy	Canopy?	Availability	Robust.	Auth.	Integrity	Size	Autonomy	Fix time
Sub meter	NO	MED	LOW	LOW	MED	NA	NA	SEC

SOIL SAMPLING

As mentioned above, crop yield is highly dependent on soil characteristics. A farmer can use GNSS to map soil samples to their parcel using georeferenced soil samples.

Table 195: Requirements for Soil Sampling

Accuracy	Canopy?	Availability	Robust.	Auth.	Integrity	Size	Autonomy	Fix time
Sub meter	NO	MED	LOW	LOW	LOW	YES	8 h	MINS

LIVESTOCK TRACKING AND VIRTUAL FENCING

Precision Livestock Farming (PLF) uses GNSS to monitor the behavior of livestock – such as their grazing habits to monitor grassland use. Such systems can also be used to track livestock health, monitor illnesses, and for virtual fencing.

While this is an interesting use case, there has not been uptake due to the high cost of GNSS collars for livestock.

Table 196 :Requirements for Livestock Tracking and Virtual Fencing

Accuracy	Canopy?	Availability	Robust.	Auth.	Integrity	Size	Autonomy	Fix time
Meter	YES	HIGH	LOW	LOW	MED	YES	24 h	SEC

PRECISION VITICULTURE

PV is involved with applying the right amount of product in the right place but it applies to viticulture instead of to general agriculture. It leverages site-specific observations that provide information on the spatial variability of the vineyards and support the elaboration of recommendations for better field management. Also similar to PA, PV generally requires the submeter precision associated with SBAS or DGNSS, but some applications can require the decimeter or centimeter level precision of RTK.

Table 197: Requirements for Precision Viticulture

Accuracy	Canopy?	Availability	Robust.	Auth.	Integrity	Size	Autonomy	Fix time
Sub Meter	NO	MED	LOW	LOW	MED	YES	8 h	SEC

PRECISION FORESTRY

PF involves site specific forest management and operation to increase produce quality, reduce waste, increase profits and maintain quality of the environment. Generally the GNSS requirements for precision forestry are the same as for precision agriculture and precision viticulture.

Table 199: Requirements for Precision Forestry

Accuracy	Canopy?	Availability	Robust.	Auth.	Integrity	Size	Autonomy	Fix time
Sub Meter	YES	HIGH	LOW	LOW	LOW	YES	8 h	SEC

Gap Assessment

In general, the accuracy requirements are met since they usually care about pass-to-pass accuracy as opposed to actual positioning. SBAS alone is enough for almost all applications here, except for VRA high and automatic steering which require centimeter level accuracy. Since about 98% of GNSS enabled tractors are already EGNOS compatible, the user needs for most of these applications are already met.

Considerations

PPP from the Galileo HAS can also increase the accuracy of Galileo for precision agriculture, but cannot go down to the level required for VRA high and automatic steering. It should be noted, however, that this is by design. Both EGNOS and HAS are freely available with a compatible receiver, thus if the HAS accuracy approached that of commercial PPP and RTK, they would compete with industry. According to consultation with EUSPA, the HAS can serve to create new applications for farmers who will not want to invest in PPP yet, or can serve as a stepping stone for farmers to trial solutions before investing in commercial PPP or RTK.

It should also be noted that applications like autonomous steering and VRA high are advanced solutions that require additional investment beyond a subscription to commercial PPP or RTK. Therefore, farmers who are not willing to invest in PPP or RTK likely would not be willing to invest in the other costs associated with implementing these PA solutions.

Other requirements, such as those for awareness, autonomy, cost and size are often bigger barriers to further uptake. Therefore, it can be said that there are no gaps at the level of the Galileo or EGNOS system, it is just that industrial solutions need to be developed at the downstream level.

AGRI LOGISTIC APPLICATIONS

Logistics in the agriculture sector is a topic of utmost importance. Geotracability is both important from the perspective of reducing costs and increasing efficiency, and from the perspective of increasing consumer awareness of agricultural traceability.

Farm Machinery Monitoring and Asset Management

Telematics can make use of GNSS receivers embedded in farm machinery that can provide georeferenced reports to farmers and farm management software. Generally, the precision required for this application is at the meter or submeter level, and therefore can be satisfied by SBAS.

Table 200: Requirements for Farm Machinery Monitoring and Asset Management

Accuracy	Canopy?	Availability	Robust.	Auth.	Integrity	Size	Autonomy	Fix time
Sub Meter	YES	HIGH	MED	MED	HIGH	NA	NA	SEC

GEO-TRACEABILITY

Growing public awareness on traceability for environmental, health and ethical reasons has led to EU regulation such as farm to fork, and more demand for local, short circuit foods. Similarly, the EU does not permit the transport of livestock more than 8 hours unless the transport conditions and position are accurately recorded, making this a good use case for GNSS.

Traceability is also important for certification schemes and avoiding fraud. In the case of organic food and “locally produced food” GNSS trackers can be placed on food containers. However, this use case is not widely adopted yet.

Table 201: Requirements for Geo-traceability

Accuracy	Canopy?	Availability	Robust.	Auth.	Integrity	Size	Autonomy	Fix time
Meter	YES	HIGH	LOW	HIGH	MED	NA	NA	MINS

FIELD DELINEATION

To support CAP implementation, the size of parcels and their exact boundaries must be known. For this purpose, there is increasing utilization of tablets with external GNSS receivers. The tolerance for these receivers is 1.5 m applied to the perimeter of the parcel, and that the tolerance with regard to the area of the parcel should not exceed 1 hectare.

Table 202: Requirements for Field Delineation

Accuracy	Canopy?	Availability	Robust.	Auth.	Integrity	Size	Autonomy	Fix time
Meter	YES	MED	LOW	HIGH	LOW	YES	5 h	SEC

Gap Assessment

Galileo in its current state would meet the accuracy requirements for all applications in this context. More important would be the downstream, for receivers that meet the autonomy or size requirement. Therefore, there are no gaps.

Sector 4: Surveying

The surveying sector is one of the early adopters for GNSS technology, and generally requires the highest levels of precision of most applications.

Market Trends

Demand side trends and challenges

Price dependent trends

There are four main price dependent trends in the surveying industry.

- High end surveying applications generally have very strict user needs, but also have the higher willingness to pay such that they can quickly uptake

- High capital industries like oil and gas often invest in similar technologies, pushing the GNSS envelope for surveying
- Improving consumer hardware means that some surveyors use consumer electronics for less complex use cases
- Increasing availability of high precision GNSS data and infrastructure to process and analyze it

Geography dependent trends

As the sector correlates generally with construction and urban development, the sector is not expected to grow in the EU as the markets for these sectors are already at full maturity. Growth in this market is overwhelming expected from countries that are actively expanding their economies and built areas, such as the Asia Pacific and ME-A regions.

User Requirements / Application

The following list of applications enable by GNSS is not exhaustive and is expected to grow with the adoption of space technologies in the coming years and the innovations that should come with it.

Land Surveying

Cadastral Surveying and Geodesy

Cadastral surveying is a branch of land surveying that focuses on establishing or re-establishing legal property boundaries. This process involves three main steps: research, fieldwork, and legal drafting. Surveyors examine historical data from various sources such as land deeds, cadastral records, past surveys, and maps. They then conduct fieldwork to collect horizontal and sometimes vertical data of physical features on and near the property to compare with the research data.

Geodesy is an earth science that precisely measures and understands three fundamental properties of the Earth: its shape, orientation in space, and gravitational field. Geodesy also studies how these properties change over time, including phenomena like crustal motion, tides, and polar motion. This field uses global and national control networks, combines space and terrestrial techniques, and relies on datums and coordinate systems to study these Earth properties and changes.

Table 203: Requirements for Cadastral Surveying and Geodesy

Use Case	Accuracy Horizontal	Accuracy Vertical	Availability	Robust.	Integrity & Reliability	TTF	Coverage
Reference Frame Survey	mm	cm	95%	LOW	LOW	20 MINS	GLOBAL
Geodetic Survey	mm	cm	95%	LOW	LOW	20 MINS	REGIONAL
High Order Control Survey	mm	cm	95%	LOW	LOW	20 MINS	REGIONAL
Low Order Control Survey	cm	cm	95%	LOW	LOW	20 MINS	REGIONAL
DGNSS or RTK reference station positioning	cm	cm	95%	LOW	LOW	20 MINS	REGIONAL
High order detail surveys and positioning	cm	cm	95%	LOW	LOW	SEC	REGIONAL
Cadastral Survey	cm	cm	99%	MEDIUM	LOW	SEC	REGIONAL
Land seismic, dimensional control and source positioning	cm	cm	95%	LOW	LOW	MINS	REGIONAL

Land Survey, real time topographic detailing and profiling	cm	cm	95%	LOW	LOW	SEC	REGIONAL
Low-order detail surveys and positioning	m	m	95%	LOW	LOW	SEC	REGIONAL
Temporary DGNSS reference for monitor station positioning	m	m	95%	LOW	LOW	MINS	REGIONAL

Construction Surveying

Construction surveying involves setting reference points and markers for guiding construction projects like roads and buildings. This includes establishing lines, controlling grades, marking corners, defining work areas, measuring ground profiles, and mapping for drainage and site design. Staking also helps verify the location and quantity of completed work. GNSS-RTK solutions are preferred for many construction tasks, offering cost savings and maintaining high horizontal accuracy.

GNSS machine control means guiding vehicles, especially earth-moving machines like dozers and graders, using RTK corrections. This allows for centimeter-level accuracy, increased productivity (fewer passes needed to meet specifications), and significant cost savings (reduced labor, fuel, and maintenance).

Table 204: Requirements for Construction Surveying

Use Case	Accuracy Horizontal	Accuracy Vertical	Availability	Robust.	Integrity & Reliability	TTFF	Coverage
Setting out, staking, alignment, trajectory, machine control	cm	mm	99%	MED	HIGH	SEC	REGIONAL
Vehicle tracking and asset mgmt.	m	m	95%	LOW	LOW	SEC	REGIONAL
Asset positioning at 3m level	m	m	95%	LOW	LOW	MINS	REGIONAL
Low order control survey	cm	cm	95%	LOW	LOW	MINS	REGIONAL
High order control survey	mm	cm	95%	LOW	LOW	20 MINS	REGIONAL
Temporary DGNSS reference for monitor station positioning	cm	cm	95%	LOW	LOW	MINS	REGIONAL

Mapping & GIS

GIS technology enables the digitalization and visualization of data on maps, which is highly important in various industries. GNSS is an increasingly used tool in GIS mapping.

Table 205: Requirements for Mapping GIS

Use Case	Accuracy Horizontal	Accuracy Vertical	Availability	Robust.	Integrity & Reliability	TTFF	Coverage
Photogrammetry / remote sensing high order ground control	mm	cm	95%	LOW	LOW	20 MINS	REGIONAL
Photogrammetry, photo control points	cm	cm	95%	LOW	LOW	MINS	REGIONAL
High order topographical profiles	cm	cm	99%	LOW	LOW	SEC	REGIONAL
Automated mapping facilities management, utilities mapping	m	dm	99%	LOW	LOW	SEC	REGIONAL

Update of special database, digital mapping	m	m	99%	LOW	LOW	SEC	REGIONAL
GIS, assets positioning and attribute collection	m	m	99%	LOW	LOW	SEC	REGIONAL
GIS – high precision asset positioning and attribute collection	cm	cm	99%	LOW	LOW	SEC	REGIONAL
Topographic mapping	cm	cm	99%	LOW	LOW	SEC	REGIONAL
Photogrammetry camera positioning and photo control	cm	cm	95%	LOW	LOW	SEC	REGIONAL

Mining

This field involves measuring, calculating, and mapping to gather information in all stages of mineral deposit exploration and use, whether on the surface or underground. GNSS-based solutions, both static and dynamic, are used for tasks like exploration, autonomous mining, environmental surveys, and more. While most mining applications need decimeter-level accuracy, mine site surveys and machinery guidance, especially for autonomous operations, demand even higher precision.

Table 206: Requirements for Mining

Use Case	Accuracy Horizontal	Accuracy Vertical	Availability	Robust.	Integrity & Reliability	TTF	Coverage
Slope stability, volumetric survey	mm	mm	99%	LOW	LOW	MINS	REGIONAL
Machine Control	cm	cm	99%	MED	HIGH	SEC	REGIONAL
Machine Control	m	m	99%	LOW	LOW	SEC	REGIONAL

Marine Surveying

Marine Cadaster

This discipline refers to delineating boundaries for maritime rights and interested. Unlike land cadaster, where boundaries are physical, marine boundaries are virtual so GNSS technology must be used. Currently, DGNSS is generally used to determine maritime boundaries.

Hydrographic Survey

This is concerned with mapping the water depth below a stated datum precisely. This is often presented as a contour map, showing the sea bed, which can serve marine construction projects and underwater work.

Offshore survey

This is generally used to determine the position and heights of survey equipment for offshore exploration. It requires relatively precise GNSS to ensure the correct positioning of equipment like drills and seismometers.

Table 207: Requirements for Marine Surveying

Use Case	Accuracy Horizontal	Accuracy Vertical	Availability	Robust.	Integrity & Reliability	TTF	Coverage
Marine Cadastre	m	m	95%	LOW	LOW	MINS	GLOBAL
Real time tidal monitoring	cm	cm	95%	LOW	LOW	SEC	GLOBAL
Vessel positioning – docking	cm	cm	99%	MED	HIGH	SEC	GLOBAL
Hydrographic survey and vessel	m	m	99%	MED	HIGH	SEC	GLOBAL

navigation							
Off shore exploration	m	m	99%	MED	HIGH	SEC	GLOBAL

Gap Assessment

Generally for the surveying industry, the precision required is beyond what can be provided by Galileo and EGNOS alone, as it often will require commercial PPP or RTK. At the moment, they care mainly about accuracy, as most applications do not require high levels of integrity or robustness.

Considerations

As commercial PPP provides enough precision for this application, and it is not the role of EUSPA to compete with industry, there is not much more that EUSPA should do other than promote the development of PPP using Galileo signals – which is users are currently demanding. That said, there is increasing demand for HAS receivers, but currently industry is already in the process of developing these.

Therefore it can be said that there are no gaps

3.2.6.7. Search & Rescue

SECTOR 1: EMERGENCY MANAGEMENT & HUMANITARIAN AID

The EMHA segment is composed of two main sub-segments. *Emergency Management*, which deals with organisation, planning and application of measures preparing for, responding to and recovering from disasters. The focus is on creating preparedness and decrease the impact of disasters and the disruption of the functioning of a community or society. The other sub-segment is *Humanitarian Aid*, which delivers life-saving assistance to those in need, without any adverse distinction. The aim is to alleviate the suffering of victims, guaranteeing their subsistence, protecting their fundamental rights and defending their dignity, as well as preparing the community to face natural disaster.

Market Trends

Demand side trends and challenges

The emergency management cycle

EO and GNSS represent highly complementary applications within the realm of emergency management, aligning with distinct phases of the emergency management cycle, each forming primary market clusters: prevention and mitigation, involving risk assessment and impact reduction; preparedness, encompassing applications like early warning systems for forest fires, hazard monitoring, and tsunami alerts; response, typically rapid mapping; search and rescue, facilitated by emergency beacons and situational awareness support; post-event recovery, focusing on damage assessment and structural inspections; and lastly, humanitarian aid, supporting diverse applications initiated by NGOs, including offering assistance to individuals in need of healthcare, medication, and aiding refugees, among others. These technologies play a vital role in bolstering emergency management and humanitarian efforts across all these phases.

New players and applications

The end-user community is increasingly cognizant of the advantages offered by these systems, recognizing the benefits they bring, and emerging technologies like AI and drones are further propelling the utilization of GNSS in this domain. Furthermore, while emergency services and humanitarian responses, falling within this sector, are primarily public services primarily employed by first responders and government agencies, it's often commercial

enterprises or non-governmental organizations (NGOs) that put these emergency services into action. They do so through contractual agreements and by offering on-site support.

GNSS technology trends

GNSS also plays a crucial role in search and rescue operations by providing locations of disasters and distressed persons through beacons used in maritime, aeronautical or land transport. This market includes EPIRBs for maritime emergencies, ELTs for aviation use and PLBs for general emergencies. The PLBs dominate the market and this market will double to more than 2.5M units by 2029. MEOSAR and the Galileo Return Link Service are in full operational capability and bring additional and much awaited-for features to the SAR operations. This allows better and faster response, to ultimately save more lives.

User Communities

The first community is dealing with Emergency Management. It includes public institutions that deal with emergency situations such as civil protection, decision makers or international organization. In addition, it includes industry players that offer products and/or services to the public institutions described above. Lastly, it also comprises of research institutions, laboratories, and other public organizations, which develop new knowledge and study natural events in order to support prevention and early warning.

The second community deals with search and rescue and comprises of end users sending alarm signals (e.g., hikers, vessel crews etc.) and the responders that will organize the SAR activities.

The third community is the Humanitarian Aid community that acts in response to a humanitarian crisis situation. It includes NGOs, UN agencies and other governmental organization delivering aid in the field.

User Requirements / Application

The following list of applications enable by GNSS is not exhaustive and is expected to grow with the adoption of space technologies in the coming years and the innovations that should come with it.

Preparedness

Landslides and terrain deformation monitoring (Type A)

A landslide is a significant displacement of rocks, debris, soil, or mud down a slope, typically driven by factors like soil erosion and gravity. Various triggers, including rainfall, earthquakes, volcanic eruptions, groundwater pressure, and erosion, can lead to landslides. Additionally, human activities such as deforestation, agriculture, and construction can contribute to slope destabilization and trigger landslides. Given the substantial damage they inflict, particularly in terms of property and infrastructure, preventing or mitigating landslides is of paramount importance.

Generally, two primary applications are prevalent in this field: landslide inventory and landslide monitoring. While the latter is often carried out by private companies and national surveying institutes, civil protection bodies are among the key beneficiaries. Multiple technologies are employed for these purposes, and the utilization of Earth Observation and GNSS has been established for years. For instance, the GIMS project has focused on integrating various monitoring technologies, including EGNSS and Copernicus Synthetic Aperture Radar (SAR). EGNSS offers continuous point-wise monitoring.

Furthermore, EO-based satellite monitoring enables multi-temporal interferometric analysis of images, facilitating the identification of reliable measurement points for extracting ground

motion velocity values and deformation time series. While InSAR (Interferometric Synthetic Aperture Radar) provides precise relative measurements between ground points at the millimetric level, it cannot directly measure absolute motion. Therefore, external data, typically derived from GNSS networks, is necessary to reference the ground motion estimates to an absolute frame of reference.

Lastly, GNSS can monitor movements down to the millimetric level using techniques like PPP or RTK. However, this performance is limited to specific points where GNSS stations are installed and does not offer a comprehensive overview of landslide movements.

Overall, the GNSS main user requirements for Landslide and terrain deformation monitoring are listed below.

Table 208: Performance requirements for Landslides and terrain deformation monitoring applications

Indicator	Value	Unit	Notes
Horizontal Accuracy	Cm/mm level	m	
Vertical Accuracy	Cm/mm level	m	
Availability	No		Canopy
Availability	>95%		High
Availability	>95%		High
Robustness	Low		
Integrity and Reliability	Low		
Spectrum	L1		Always needed
Spectrum	L1		Sometimes needed
Size, weight, autonomy (Relevance)	Yes		
Size, weight, autonomy (Time a device can run in the field)	Up to several years		
Size, weight, autonomy (Antenna size)	The smaller the better		
Cost	<1000	€/station	Price of full monitoring station
TTFaF	A few minutes		
Sampling	1	Hz	Frequency of recording
Service Area	Regional/Local		Geographical Coverage

Space debris removal (Type C)

The European Space Surveillance and Tracking (EU SST) program estimates that there are approximately one million objects in orbit, each larger than one centimeter, which currently serve no purpose and are orbiting our planet. This surplus of objects significantly heightens the risk of collisions with each new satellite launch. Moreover, in the near future, we will witness the deployment of multiple satellite constellations operating at various altitudes. These constellations are designed to provide low-latency telecommunications and extensive Earth observation coverage, further intensifying the complexity of managing space traffic and debris in Earth's orbit.

Search and Rescue

SAR operations: at sea, aviation and land (Type B)

With the operational deployment of the SAR/Galileo Return Link Service, Galileo has become a vital tool for locating individuals in distress at sea and automatically relaying their positions to the relevant authorities. Galileo plays a significant role in the COSPAS-SARSAT MEOSAR program by ensuring the timely delivery of Return Link Service (RLS) alerts within 15 minutes. At the user level, alerting systems encompass devices like emergency

position indication radio beacons (EPIRBs) and personal locator beacons (PLBs). Furthermore, in the aviation sector, all aircraft are mandated to be equipped with Emergency Locator Transmitters (ELTs) as part of the COSPAS-SARSAT Programme

In light of aviation incidents like Air France 477 and Malaysia Airlines 370, the development of the Global Aeronautical Distress and Safety System (GADSS) introduced three key functions: Aircraft Tracking utilizing GNSS-derived positioning, Autonomous Distress Tracking guaranteeing minute-by-minute aircraft positioning information (for which GNSS-enabled ELTs are crucial), and Post Flight Localization and Recovery, which again relies on ELTs.

On land, GNSS technology is predominantly used by climbers, hikers, and bikers equipped with Personal Location Beacons. An emerging market includes GNSS receivers that interface with private emergency services, exemplified by entities like Focuspoint International. These beacons not only transmit SOS signals but also allow for periodic position updates and check-in messages. Additionally, GNSS aids rescue teams operating underwater, in snowy conditions, or in collapsed buildings by recording the positions of areas already searched, improving overall efficiency.

Post event recovery

Post crisis damage assessment and building inspection (Type A)

In the recovery phase of a disaster, the assessment of damages to structures such as buildings and infrastructure is essential for two primary reasons: first, to identify which structures are still safe for habitation, and second, to determine the overall impact zone of the event. Both non-governmental organizations (NGOs) and decision-makers, including civil protection bodies and rescue teams, can leverage GNSS technologies for these purposes.

GNSS is frequently integrated into buildings and infrastructure like bridges and viaducts, providing precise tracking of potential movements over time with millimeter-level accuracy. A notable use case is the GEO-PICTURES project, funded by the European FP7 program, which led to the development of the UN-ASIGN application. This app enables the crowdsourcing of geo-tagged photos and text from areas affected by major humanitarian disasters. Within seconds of sending a geo-tagged image from a smartphone, it becomes accessible on a map at the receiving end. The geo-tagging and timestamping of photos are accomplished through the use of device embedded GNSS chipsets, further supported by cellular (3G) and Wi-Fi networks positioning when indoors. This technology greatly aids in assessing structural damage and impacts in disaster-stricken areas.

Overall, the GNSS main user requirements for Post crisis damage assessment and building inspection are listed below.

Table 209: Performance requirements for Post crisis damage assessment and building inspection applications

Indicator	Value	Unit	Notes
Horizontal Accuracy	m-level for geotagging; dm-level for UAV 3D reconstruction	m	Large scale assessment
Vertical Accuracy	M-level for geotagging; Dm-level for UAV 3D reconstruction	m	Large scale assessment
Horizontal Accuracy	2mm cm level for UAV 3D reconstr.	m	Detailed building assessment
Vertical Accuracy	2mm/3-4mm for critical buildings cm level for UAV 3D reconstr	m	Detailed building assessment
Availability	Yes		Urban canyon
Availability	>95%		Medium
Availability	>99%		Medium

Robustness	Low		
Integrity and Reliability	Low		
Size, weight, autonomy (Relevance)	Yes		
Size, weight, autonomy (Time a device can run for geotagging)	>5	h	
TTFaF	A few seconds	secs	In hot start
Service Area	Regional/Local	Geographical Coverage	

Humanitarian Aid

NGO's asset management (Type A)

Humanitarian aid operations aim to reach the most vulnerable populations in crisis zones, often involving the deployment of truck convoys to deliver essential supplies or rescue people. However, various challenges can arise during these missions, including inaccessible roads and security threats such as attacks on convoys. One effective way to enhance the security of these convoys is by implementing regular position reporting, enabling quick alerts and the deployment of assistance when needed. Leading the adoption of such applications are UN agencies and non-governmental organizations (NGOs).

Traditionally, vehicle reporting was accomplished through radio communication, but nowadays, GNSS technology is being harnessed for this purpose. Real-time tracking allows control centers to monitor the locations of convoy vehicles, ensuring situational awareness. GNSS-enabled telematics plays a crucial role in enabling humanitarian organizations operating in crisis areas to track both assets and personnel, ultimately improving safety and security. For many operations, the UNDP MOSS (Minimum Operational Security Standard) guidelines are applied, mandating the use of GNSS-based tracking systems for all field vehicles. Consequently, most UN agencies have equipped their vehicles, including SUVs and trucks, with telematics devices. GNSS telematics not only enhances security but also optimizes fleet performance, leading to up to a 15% improvement in vehicle fleet efficiency. A new approach, notably employed by UN agencies like UNHCR and NGOs, involves vehicle leasing instead of purchasing, contributing to these efficiency gains.

Overall, the GNSS main user requirements for *NGO's asset management* are listed below.

Table 210: Performance requirements for NGO's asset management applications

Indicator	Value	Unit	Notes
Horizontal Accuracy	M-level	m	
Vertical Accuracy	M-level	m	
Availability	Yes		Urban canyon
Availability	Yes		Natural canyon
Availability	Yes		Canopy
Availability	Yes		Indoor
Availability	>95%		High
Availability	>99%		Medium
Robustness	High		
Integrity and Reliability	Low		
Size, weight, autonomy (Relevance)	Yes		When smartphone or handheld based
Size, weight, autonomy (Time a device can run)	>5	h	When smartphone or handheld based
TTFaF	<1	min	In hot start

Service Area	National/Regional	Geographical Coverage

Welcome applications to people in need of humanitarian aid (Type C)

These applications provide crucial support to individuals in need of humanitarian assistance, and a prime illustration of this is the deployment of GNSS technology by the Spanish Red Cross. In this context, a telematics service is established, which relies on a smartwatch application. This application periodically reports the device's GNSS position every 10 minutes, significantly enhancing the effectiveness of emergency response efforts and enabling timely assistance to those requiring help.

Health and medicine response to coordination (Type A)

In this field, the primary focus revolves around counting or estimating the population in locations and moments of crisis, a crucial step in delivering necessary supplies and aid. Effective coordination among different entities is essential, guided by the principle of the "rule of 3W": determining who does what and where. Proper intervention planning is vital for optimizing resources. Given that maps are often generated using satellite imagery, the process often requires geo-referencing, and GNSS plays a critical role in achieving this.

Smartphones offer convenient data-entry capabilities, enabling individuals to communicate their location to organizations like the Red Cross and civil protection bodies. However, it's worth noting that the performance of smartphones, especially concerning battery consumption, is affected when the GPS function is actively in use. This issue is particularly critical in areas with limited options for recharging batteries. Nonetheless, compared to other market segments, this field has relatively low demands in terms of requirements. The most critical considerations here are power consumption in crisis zones and device durability in conflict zones.

Overall, the GNSS main user requirements for Health and medicine response to coordination are listed below.

Table 211: Performance requirements for Health and medicine response to coordination applications

Indicator	Value	Unit	Notes
Horizontal Accuracy	M-level	m	
Vertical Accuracy	M-level	m	
Availability	Yes		Urban canyon
Availability	>95%		Medium
Availability	>99%		Medium
Robustness	Low		
Integrity and Reliability	Low		
Size, weight, autonomy (Relevance)	Yes		When smartphone based
Size, weight, autonomy (Time a device can run)	>5	h	When smartphone based
TTFaF	<1	min	In cold start
TTF	A few seconds	Secs	In hot start
Service Area	Regional		Geographical Coverage

Gap Assessment

Overall, the needs of the users are met in terms of technological performances. However, in the critical and delicate situations of emergency many of the needs are related to non-technical aspects such as interfaces or language/vocabulary that are easier to understand and use. This aspect was clearly highlighted in the consultations, together with the

improvements needed in the power consumption and robustness indicators. Indeed, both are critical for the success of an emergency or humanitarian aid mission.

Gaps planned to be addressed

The potential gaps in these two areas are addressed through open calls for innovation, with Fundamental Elements and Horizon Europe funding programmes.

3.2.6.8. Takeaways on Relevance Assessment of Galileo and EGNOS

EGNSS is used for many applications in different fields. Some sectors rely heavily on GNSS for positioning, such as the transportation sector, emergency, or raw materials. Some instead need accurate timing, such as the energy, finance or telecommunication infrastructure. Each sector or even application has critical performances to meet and they vary among the applications.

EUSPA and EC maintain a user consultation platform (UCP) – a periodic forum where users from different sectors can discuss their needs for GNSS applications. This event involves end users, manufacturers, developers and organizations / institutions, and enables EUSPA to identify and understand the needs of the user communities.

In safety critical & liability critical applications, the main performance requirements are related to accuracy and integrity of the signal, which must be precise and reliable. In these applications, the necessary requirements are generally met by Galileo and EGNOS. There are two main “gaps” in these verticals.

- First, for all these transport applications, there are some emerging safety critical use cases (such as precision approaches in aviation or port operations in maritime) where the requirements exceed that of the current system. In these cases, the gap is already being addressed as G2G and EGNOS V3 are expected to fill these gaps.
- Second, in the case of rail and maritime, users have expressed interest in a dedicated EGNOS service similar to the one in aviation. This does not mean that the space segment or hardware needs to be altered, there just needs to be a dedicated service. This gap is already being addressed as these services are being developed.

In case of timing and synchronization, there is a specific need for integrity. The same is true for the robustness of the signal, especially in the infrastructure segment. In general, G2G is expected to answer these needs, together with Galileo OSNMA and its development.

Moving to other sectors, there are several commonalities. Some of the needs in these sectors cannot often be met alone and usually need some kind of augmentation – either through additional sensors (as is the case in road vehicles), or with GNSS augmentation such as PPP or RTK. There are two main topics to discuss here:

- *Avoiding damaging industry:* Galileo and its augmentation systems (EGNOS, HAS) cannot meet the centimeter level accuracy needed in specific applications, notably those in the “high performance professional applications” group like in the agriculture or in the raw materials sector. This is by design: EGNSS is not supposed to compete with industry, and if such a high-performance level was provided for free, some commercial players would be damaged. As highlighted during stakeholders' consultations, the objective is to push innovation and research without disrupting the industry. At the same time, studies related to a provision of more advanced services and their effect on the market are ongoing.
- *Technological constraints:* notably, availability of the service indoors. In applications such as augmented reality for leisure or tunnels in road, the availability indoors is usually an important aspect and cannot be met by GNSS alone. For these reasons,

EUSPA is working to create opportunities of development in switching from outdoor to indoor positioning in the most efficient, smooth way.

Finally, some user needs pertain to uptake and ergonomics, such as making users more aware of solutions and making those solutions easier to use. These gaps, however, are not associated with the EGNSS and are more relevant to the downstream.

3.2.7. EU Added Value

The primary objective of this evaluation of the Galileo component is to assess the additional benefits realized by the component when compared to what Member States could achieve individually. It offers a qualitative assessment of the component's performance in contrast to what could be accomplished at the national level, taking into account the perspectives of users, Member States, and the overall international perception.

The EU added value can be defined in three main dimensions.

- Firstly, how EGNSS benefits the European Union in terms of technological advantage and increased performances.
- Secondly, for its strategic and soft power related benefits.
- Thirdly, it is worthy to consider what would happen without an initiative at EU level, with only the support of member states.

In the first place, the performances of Galileo/EGNOS systems are very high level, and this is especially true when compared with other GNSS systems (refer to “Additional insights to the EGNSS Component”). In addition, Galileo guarantees interoperability with GPS, increasing its availability and providing the ability to work with 2 frequencies, thus track errors and increase the accuracy of the service. In absolute terms, EGNOS works now mostly in the EU, and the High Accuracy Service produces better corrections in Europe than in other geographical areas (as mentioned during consultations). For these reasons, the value added for the EU in technological terms, is extremely relevant.

The second critical point is the strategic one. As often mentioned in the consultations, Galileo allows the EU to be independent, if necessary, on the positioning, navigation and timing topic. As known, GPS has a dual scope: military and civil. Galileo instead is a civil service, and there is no risk of it being disrupted for conflict-related reasons. The independence also matters on the network layer, since even with a disruption of the terrestrial network Galileo would be still available. On top of this, Galileo has a global coverage. As a summary of the strategic benefits for EU, it is possible to state that EGNSS adds value for EU citizens and reinforce the EU prestige worldwide.

The last important point is related to the comparison of the current situation versus what could be achieved at a national level. It is possible to state that the budget spent on Galileo would be very hard to collect as a single MS in EU. Such a complex system would be also difficult to manage in terms of governance, risk, system procurement and operations. The shared effort and resources of EU allow EGNSS to run smoothly and efficiently. On the expertise side, it is possible to pool from the EU industrial base as a whole, which enables a faster and better service provision. In addition, there are European entities that collect the user needs (e.g., EUSPA) and there are funding schemes that can help the development of new ideas, technologies and solutions, providing networking events, funds and technical expertise.

To conclude, the Galileo/EGNOS component is an essential part of the EU Space Programme and creates (or help in creating) a paramount value for the European Union, its citizens and its industrial layer, and improves the EU prestige and independence with international stakeholders.

3.2.8. Policy Coherence

3.2.8.1.IoT / LBS

Consumer solutions: Coherence with EU policies

Galileo for consumer solutions aligns effectively with standardizations in user requirements across three primary areas: signalling, performance requirements, and testing procedures. Signalling protocols are predominantly developed by organizations such as the third Generation Partnership Project (3GPP) and the Open Mobility Alliance (OMA). These protocols play a pivotal role in ensuring seamless communication and functionality for consumer-oriented applications:

- 3GPP: three positioning protocols, including the LTE Positioning Protocol, likely used for 5G too. It is working on additions to support high accuracy positioning to include potentially both PPP and RTK.
- OMA: Secure User Plane Location, used extensively in smartphones.

In the realm of Consumer solutions, performance requirements can range from basic position or timing accuracy to more complex criteria like authenticity and resistance to interference. These requirements are often presented as either suggested performance benchmarks or single minimum performance thresholds. Additionally, defining testing procedures is essential to ensure the reliability of relevant devices, and these procedures serve as a foundation for industry-wide testing and certification by regulatory bodies. Notably, these testing procedures are primarily developed by entities like 3GPP, OMA, and ETSI TC SES (the technical committee for satellite earth stations and systems).

The synergies of the Galileo component with other EU policies vary in other fields as well. Among them:

- *Promoting healthcare*: by enabling the utilisation and increasing the performances of fitness applications, GNSS related applications stimulate people to be more involved into sport and outdoor activities. In this way, Galileo-enabled services are aligned with the EU4health programme of the European Union, which has as a primary objective to improve and foster the health of EU citizens.⁵⁹
- *Emergency Location*: Galileo-enabled emergency service in consumer solutions are aligned and directly useful for the ability to support the transfer of caller location information from GNSS (at least Galileo) in the event of 112 emergency calls (E112). Indeed, from the 17 March 2022 a Commission Delegated Regulation sets out measures to introduce (GNSS) capability, particularly Galileo capability, in smartphones placed on the European Union market.⁶⁰

⁵⁹ Regulation (EU) 2021/522 of the European Parliament and of the Council of 24 March 2021 establishing a Programme for the Union's action in the field of health ('EU4Health Programme') for the period 2021-2027

⁶⁰ Commission Delegated Regulation (EU) 2019/320 of 12 December 2018 supplementing of Directive 2014/53/EU of the European Parliament and of the Council with regard to the application of the essential requirements referred to in Article 3(3)(g) of that Directive in order to ensure caller location in emergency communications from mobile devices.

Galileo-enabled applications in the consumer solution market are sometimes also synergic with other components of the EU Space Programme. An example is the call for Connectivity – Enabling next generation NAV/COM Hybrid Terminal. This call aims at finding a way to integrate Galileo and Connectivity systems, launched in the context of Fundamental Elements scheme. The high-level objective of the call is “the development of a unified hybrid user terminal (further on referred to as the ‘Terminal’) capable to support TN and NTN communication together with GNSS, and Galileo in particular, and LEO satellite signals in order to support joint Data & PNT services, reaching TRL 7”.⁶¹

Moreover, on the downstream part of the services there are many synergies between Copernicus and Galileo: some use cases involve Sport, fitness and wellness; Geo-advertising and Mapping & GIS; Tourism and Games and Geo-tagging.

3.2.8.2. Safety Critical and Liability Critical Transport

Aviation: Coherence with EU Policy

The principal EU policy pertaining to aviation is the EU Single European Sky initiative. It aims to create a more efficient and unified airspace over Europe. The primary goal is to enhance air traffic management, reduce congestion, improve safety, and reduce the environmental impact of aviation by integrating the fragmented European airspace into a single, harmonized system. The SES aims to streamline air navigation services, reduce delays, and optimize air traffic routes, ultimately benefiting both airlines and passengers. It promotes the use of advanced technologies and collaborative decision-making to achieve these objectives.

One of the core objectives of SES is widespread adoption of PBN as this will improve the efficiency of European airspace, reducing congestion and environmental impact. GNSS is critical for the implementation of PBN and therefore is highly coherent with SES. ENGOS enables more airports to be operational for longer, which is also in line with the same goals. Many smaller airports across EU cannot justify investment into ILS, but EGNSS can enable precision approaches without the need for ILS. As there are more airports operational, there are fewer delayed flights.

EGNSS is highly scalable compared with terrestrial infrastructure such as ILS. As the entirety of Europe would be operating under the same system, it supports the goal of further integrating the European aviation sector.

Aviation: Synergies with other EU Space Programme Components

Aviation is synergetic with other Union Space Programme Components as Copernicus is also used for use cases such as emissions monitoring. Contrails are responsible for a significant portion of the environmental impact of aviation. Predictive models can be used to reduce contrail formation, therein reducing the environmental impact. A prospective use case for synergies between Copernicus and Galileo is where EO data can be used to monitor the conditions in which contrails form, while GNSS data from planes creating contrails can provide a precise location and timestamp to feed further into predictive models.

⁶¹ Call for proposal: “Connectivity: Enabling next generation NAV/COM Hybrid Terminal”; EUSPA, 06/2022

Another potential synergetic case is where aircraft with magnetometers aboard can also provide valuable insight into space weather phenomena. Galileo aboard the same aircraft can georeferenced and timestamp space weather data collected by these aircraft.

Maritime: Coherence with EU Policy

The core EU policy in the maritime sector echoes that of the aviation sector, it is the Integrated Maritime Policy (IMP) of the EU and falls under the wider Common Fisheries Policy. The IMP covers several policy fields that are listed below:

- Blue Growth – the development of the “blue economy,” supporting sectors such as aquaculture, coastal tourism, marine biotechnology, ocean energy and seabed mining
- Marine Data & Knowledge - marine research, as well as the collection and integration of marine data
- Maritime Spatial Planning - ensure sustainable growth of maritime economies and use of marine resources through better conflict management and greater synergy between the different maritime activities.
- Integrated Marine Surveillance - common ways to share information and data among authorities involved in different aspects of surveillance, e.g. border control, maritime pollution and the marine environment, fisheries control, general law enforcement, and defence.
- Sea Basin Strategies - region-tailored approach based on cooperation among countries within the same sea basin to address common challenges and opportunities towards the development of the maritime economy and marine environment protection.

Development of EGNSS contributes to all these objectives and therefore can be said to be strongly coherent with this policy. In the case of blue growth, EGNSS contributes to improved ship route optimisation, including navigation in inland waterways, and aims in the near term to also support port operations and marine engineering. This supports multiple sectors of the blue economy, and therein is certainly highly coherent with the sector.

Regarding maritime spatial planning, Galileo and EGNOS can be leveraged heavily for marine surveying – more than for land surveying due to the lack of visible markers at sea. Similarly, GNSS can be used for geoawareness and geo fencing for vessels. GNSS is also important for dark ship monitoring and IUU fishing reporting. Integrated marine surveillance is also supported by EGNSS, as the synergetic use of EO and GNSS can be used for dark vessel monitoring, and the monitoring of IUU fisheries.

The EU Maritime Safety Strategy aims at making European waters safer. The OSNMA of Galileo can support making the waters safer by ensuring the signals are authenticated so more trust can be placed in the position solution. Similarly, in the field of SAR, the Galileo RLS can improve outcomes for people in distress by providing them with assurance that their distress was received by the authorities

Maritime: Synergies with other EU Space Programme Components

As mentioned above, there are significant overlaps between the use of Copernicus and the use of Galileo in the marine sector, such as for surveillance and maritime spatial planning. GNSS can also be used in conjunction with EO for fish stock monitoring and navigation (mapping).

GOVSATCOM can be synergetic with EGNSS in the context of marine search and rescue, as well as law enforcement operations for border security, illegal fishing, and human smuggling.

Part of the EU Green Deal Initiative is the “Sustainable and Smart Mobility Strategy.” In summary, this initiative aims at a 90% reduction in transport related GHG emissions. Rail is overwhelmingly the lowest carbon intensive mode of transport, globally accounting for approximately 1% of transport emissions⁶². On a per passenger-kilometre basis, rail is one of two (the other being busses_ often overwhelmingly the least carbon intensive mode of transports⁶³, particularly for longer distance travel. Aviation and road by contrast are frequently the highest sources of CO2 emissions in transport, both for freight and for passengers. Decarbonisation of these sectors would therefore rely heavily on transitions to rail where the distance is feasible.

Another critical rail policy is the European Rail Traffic Management System. The main target of ERTMS is to promote the interoperability of trains in the EU. It aims to greatly enhance safety, increase efficiency of train transports, and enhance cross-border interoperability of rail transport in the EU. While a system of balise can perform many of the tasks that EGNSS would do, GNSS can do it without the need for terrestrial infrastructure, and also ensure that all users would be working on the same standards. This would be a step forward toward enhancing interoperability. At the moment, interoperability between member states is one of the largest hurdles towards adoption of rail as a viable alternative to aviation and road for cross border transport. Another barrier to wider rail uptake is the cost – while cost can often be attributed to higher taxation of the rail sector than other modes of transport⁶⁴, some routes are extremely high cost because of supply that cannot keep up with demand. GNSS can enable more trains to travel on the same section of track or travel closer together such that more trains can operate more frequently.

3.2.8.3. Terrestrial Vehicle Monitoring

Road: Coherence with EU policies

The European Commission adopted the “Europe on the Move” package, specific to road safety and that includes the 2021-2030 policy framework, an action plan, two legislative initiatives and a strategy for automated mobility. Galileo and EGNOS can contribute heavily to the development of the strategy and to reaching its goals. In addition, there are several regulations in EU that drive the use of GNSS in the road segment, mainly relative to interoperability of road toll system (Directive 2004/52/EC), inland transport of dangerous goods (Directive 2008/68), traffic information (Delegated regulation 886/2013 and 962/2015). Other regulations involve tachographs, eCalls and animal protection during transport.

On the other hand, one of the latest developments in regulation regarding GNSS utilization in the road segment is about CCAM, namely Cooperative, Connected and Automated Mobility. In the development of CCAM, the integration with space data is key. Overall, space data in the road segment can contribute to the EU Sustainable and Smart Mobility Strategy: for instance, the regulation 2021/0419 of the ITS (intelligent transportation system) directive foresee that developments of future ITS shall ensure the compatibility with Galileo, OSNMA included, and EGNOS. Moreover, the Vehicle General Safety Regulation introduced in July

⁶² IEA data via Our World In Data: <https://ourworldindata.org/co2-emissions-from-transport>

⁶³ Statista : <https://www.statista.com/statistics/1185559/carbon-footprint-of-travel-per-kilometer-by-mode-of-transport/>

⁶⁴ CNN : <https://edition.cnn.com/travel/trains-more-expensive-than-planes-europe-greenpeace-climate/index.html>

2022 introduces some mandatory advanced driver assistant systems to improve road safety. Finally, the UNECE regulation 155 suggests implementing solutions able to verify the authenticity and integrity of messages in order to protect vehicle communication channels.

Galileo OSNMA for GNSS authenticity verification, Galileo HAS for the provision of a decimeter accuracy level and the future Galileo Emergency Warning are key pieces in the contribution to Road segment's safety and regulations. Overall, the added value of Galileo and EGNOS in the CCAM context is very relevant, both in technological terms and in meeting regulations goals, with the a contribution to crafting new regulations.

Road: Synergies with the other EU Space Programme Components

In the road segment, despite the more relevant importance of GNSS also Copernicus plays a role. In fact, Copernicus helps identifying detailed surface type information. This data supports enhanced digital maps, thus enabling Intelligent Speed Adaptation premium systems. In addition, GOVSATCOM will give support to different key infrastructures, and the road ones are included. Therefore, future mutual benefits will derive between Galileo signals and the secure communication that GOVSATCOM will ensure.

Road (Public Transport): Coherence with EU policies

Various EU policies are relevant for public transportation, such as the aforementioned ERTMS, the EU Green Deal Smart and Sustainable Mobility Policy, EU Transport Policy, and others. Many of these have common goals, such as:

- Reduction of congestion
- Sustainability
- Air quality

Beyond the environmental impacts of transport sector, the sector also represents a large dependency of the EU on foreign nations.

According to the IEA⁶⁵, the largest consumer of energy in the EU is the energy sector, consuming approximately 3.4 B TWh in 2019. This can be compared with industry and residential, which each consumed 2.7 B TWh in 2019. This alone does not paint the whole big picture, as 3 B TWh in transport come from oil, representing over 60% of all European oil use. The overwhelming majority of this oil was imported, meaning that European transport is largely dependent on foreign oil.

The simplest solution to move people efficiently both while consuming less foreign oil and without having an environmental impact is public transportation. Busses, light rail, metro, trams, and trains have significantly lower environmental impact and significantly lower petroleum consumption per passenger-km than any other motorised transport, as well as taking up significantly less road space per passenger, therefore avoiding congestion. Public transport faces significant challenges to wider uptake when compared with private vehicles. Poorly managed public transport systems are seen as unreliable, slow, and inefficient. There is also a significant driver shortage in Europe, making situations even worse⁶⁶.

⁶⁵ IEA : <https://www.iea.org/data-and-statistics/data-tools/energy-statistics-data-browser?country=EU27>

⁶⁶ IRU : <https://www.iru.org/news-resources/newsroom/europes-bus-and-coach-driver-shortage-widens-54-grim-outlook-2028>.

Galileo can help improve the efficiency of public transport, as poorly managed systems frequently result in empty runs and waiting time. A core use case for GNSS is in fleet management, which offer insights to companies and enable them to reduce these inefficiencies. It can also mean that the productivity per driver can be increased by ensuring that frequencies are adjusted to account for peak hours. Driver advisory systems can also support reducing the workload on the driver, which could attract more drivers to counter the shortage. Passenger advisory systems using GNSS can greatly improve a passengers travel experience by enabling them to plan their journeys according to real time conditions.

Moving toward emerging applications, GNSS is likely to be a critical technology for the navigation and positioning of autonomous road based public transport. As of 2023, autonomous road transport like shuttles remains experimental. Mobility as a Service on the other hand is also highly dependent on GNSS, fleet management requirements are even more demanding for multimodal transport MaaS offerings or bike/ride share programmes, meaning GNSS can greatly augment the efficiency of these.

For these reasons it can be said that EGNSS is highly coherent with several EU policies in this sector.

3.2.8.4.Drones

Drones: Coherence with EU Policies

GNSS use in drones and EU policies are highly coherent. Currently, there is work underway to regulate the u-space. UAS traffic management will be highly reliant on GNSS for the reasons discussed in the relevance section.

To reiterate, GNSS is used in geoawareness and e-conspicuity which ensures that drones and their operators are aware of restrictions in their use, and that other users of the air space are aware of the drones as they operate. Like the space sector, the drones sector is largely an “enabling” sector. This means that the benefits of drones are generally seen in the sectors that it enables. UTM is critical going forward, as the u-space is expected to support EU policy actions in numerous other sectors. Drones can perform surveying, search and rescue, agriculture and other sectors.

Drones: Synergies with other EU Space Programme Infrastructure

Data from drones used for remote sensing (enabled by GNSS) can be combined with Copernicus data to gather further insight. Similarly, drones can also be used in search and rescue, combining GNSS with EO to gain a better picture of the area of interest. In this last use case, GOVSATCOM would also be synergetic as secure communication would be beneficial in human safety and law enforcement applications.

3.2.8.5.Critical Infrastructure

Energy: Coherence with EU policies

In the context of the energy sector, GNSS plays an important role by primarily offering accurate timing and synchronization for Phasor Measurement Units (PMUs). PMUs play a critical role in enhancing the reliability of power systems by measuring voltage and current phasors and timestamping these measurements using a GPS receiver and a phase-lock oscillator. Consequently, the contribution of Galileo to PMUs is expected to impact the EU policy landscape.

Within the EU's strategic plans, the REPowerEU initiative stands out as a direct response to the disruption in the energy market due to Russia's invasion of Ukraine. Its primary objective is to transform EU's energy system and reduce dependence on Russian fossil fuels. Additionally, the Fit for 55 package encompasses a set of proposals designed to revise and

update EU legislation, aligning it with climate goals agreed upon by the Council and the European Parliament. These proposals aim to establish a framework that ensures a just and socially equitable transition, strengthens the competitiveness of EU industry, and reinforces the EU's leadership in the global fight against climate change.

While Earth Observation is a more direct service for addressing climate change, Galileo can play a crucial supporting role by providing precise timing and synchronization for PMUs. This, in turn, enhances the reliability and resilience of the energy system, aligning with the objectives and goals of these critical EU policies.

Energy: Synergies with the other EU Space Programme Components

Copernicus and Galileo collaborate in the segment of Renewable energy site selection, planning and monitoring. EO can provide support for the identification of the most suitable areas for the exploitation of the renewable sources, and GNSS can enable geomatics applications such as plant and construction surveying, mapping and GIS, photogrammetry, laser scanning and remote sensing, route planning and augmented reality visualization.

Infrastructure: Coherence with EU policies

The protection of critical infrastructures is of paramount importance, as these infrastructures support a wide range of sectors and enhance the quality of life for citizens. Recognizing this significance, the Commission introduced the European Programme for Critical Infrastructure Protection (EPCIP) in 2006, which establishes a European-level all-hazards framework for critical infrastructure protection (CIP). A key component of the EPCIP is Directive 2008/114, which outlines a procedure for identifying European Critical Infrastructures - infrastructures whose disruption or destruction would have a significant impact. Galileo is involved in bolstering the resilience of European Critical Infrastructures, particularly through services like the OSNMA, which provides timing and synchronization more secured and resilient services. Furthermore, efforts by standardization bodies are currently underway to standardize timing and synchronization receivers. This standardization will ensure an even higher quality of service and enhanced protection for critical infrastructures across the energy, telecommunications, and finance sectors. The commitment to these measures reflects the EU's dedication to safeguarding its vital infrastructure.

Infrastructure: Synergies with the other EU Space Programme Components

Galileo for infrastructure has two main uses, one related to infrastructure planning, construction and monitoring, while the other on timing and synchronisation of telecommunication networks. It is important to highlight that, especially in the realm of construction, Copernicus and Galileo work together, and their mutual contribution adds a lot of value. If GNSS contribute in both selection and planning of the sites, Copernicus on the other hand supports mainly the site selection phase through digital elevation models (DEMs), exploitation of SAR and optical imagery for land cover/use classification etc. In addition, one of the three domains covered by the secure communication that GOVSATCOM will provide is the one of key infrastructures. For this reason, Galileo and GOVSATCOM can potentially create and exploit synergies in the future both for crisis management and critical infrastructure protection.

Timing and Synchronization: Coherence with EU policies

Regulations pertaining to T&S are discussed in finance, infrastructure and energy sections.

3.2.8.6.High Precision Professional Applications

Finance: Coherence with EU policies

In the domain of Timing and Synchronization for financial transaction, the European Commission issued in December 2008 the 2008/114/EC Directive on the “identification and designation of European critical infrastructures and the assessment of the need to improve their protection”. The financial infrastructures are as of today considered critical, and the European Securities and Markets Authorities (ESMA) has published a set of Regulatory Technical Standards (RTS), among which different topics are touched, such as the accuracy of the business clock. For instance, some requirements such as 100% availability have been the driver for the development of new T&S network architectures. To meet the requirements and reassure regulators, financial operators need to implement different architectures solutions by using multiple timing sources, and GNSS is one of the essential ones for the aim.

Finance: Synergies with the other EU Space Programme Components

Cyber-attacks on critical infrastructure are an increasing issue, as demonstrated in this study when assessing the potential benefits of GOVSATCOM. GNSS is obviously subjected to these cybersecurity threats, including the Timing and Synchronization applications. The need for reliability and security is high and the regulations also require them, thus a future support of GOVSATCOM would create an important synergy with Galileo for the protection of critical infrastructures in the finance market.

Raw materials: Coherence with EU policies

The Action Plan for Critical Raw Materials stands out as a prominent EU policy geared towards mining, with the overarching goal of establishing a resilient value chain for the EU's industrial ecosystems. This multifaceted initiative includes a pillar dedicated to innovation, in tandem with efforts to bolster domestic sources of raw materials within the EU. In the realm of policy and regulation for mining, Earth Observation holds greater influence than GNSS, but Galileo also contributes significantly to enhancing innovation and sustainability within the EU segment.

As detailed in the relevance assessment Galileo plays an increasingly important role in the raw materials sector, particularly in applications like mining machinery control and mining vehicle tracking and asset management. These applications collectively render the mining process less disruptive to human environments, more cost-efficient with savings in fuel consumption, and notably innovative, resulting in greater speed and overall performance improvements. Galileo, in synergy with other technologies, contributes to the broader objectives of the EU Action Plan for Critical Raw Materials by advancing sustainability and resource efficiency in the mining sector.

Raw materials: Synergies with the other EU Space Programme Components

Most of the synergies in the raw materials' sector come from the mixed use of Copernicus and EGNSS in mining site exploration, planning and monitoring. When mining companies need to identify the most suitable areas for the extraction, plan their development and monitor their integrity and status (also after abandonment), Copernicus data complements and enhances traditional detection methods for studying the field characteristics, performing geological studies by reducing the location errors and being faster; on the other hand, Galileo (potentially with correction methods) supports on-site measurements and the whole mapping process, including the stability of the mines or potential oil spilling.

The main policy in agriculture is the Common Agricultural Policy. The objectives of the current (2023 to 2027) CAP are⁶⁷:

- Ensure fair income for farmers
- Increase competitiveness
- Improve the position of farmers in the value chain
- Climate change action
- Environmental care
- To Preserve Landscape and Biodiversity
- To support generational renewal
- Vibrant rural areas
- To protect food and health quality
- Fostering knowledge and innovation

GNSS can support on most of these policy objectives since it is a large boon to Precision Agriculture. PA is integral to most of these objectives as it increases the efficiency of the farming sector.

Regarding the first objective GNSS has the potential to improve farmer incomes by improving the productivity of the farm. PA can reduce the costs of agriculture while increasing the output, therein increasing farmer revenues.

The second objective refers to increasing the use of technology in the agricultural sector to ensure that EU farmers can remain competitive with the global industry. Precision agriculture would help farmers to make informed, data driven decisions, and to gain better insight into their production.

Similarly, regarding the third objective, GNSS can improve a farmer's position on the value chain. Due to improved insights and awareness of their costs, and due to better utilisation of inputs, farmers would have more information on buying inputs for their farms. These insights would also improve transparency along the value chain. Agri-logistic applications can also improve farmers positioning by improving their awareness of the value chain.

In terms of the fourth, fifth and sixth objectives, GNSS can improve the environmental and climate performance of agriculture by reducing consumption of both fuels and agricultural inputs. In the former case, precision agriculture can reduce the number of passes needed in agriculture, and in agri-logistics can improve the efficiency of the agri supply chain. The latter case addresses mainly mineral fertilisers and pesticides, where precision agriculture can significantly reduce their use by precisely dosing based on crop needs.

Several projects leverage Galileo that aim to directly support the implementation of the CAP. For example, the FaST project uses Galileo to support proper nutrient management, ensuring that farmers can comply with CAP regulation and receive their subsidies.

It should be noted, however, that many applications in precision agriculture require precision higher than what can be offered by Galileo or EGNOS, and generally would leverage instead

⁶⁷ European Commission : https://agriculture.ec.europa.eu/common-agricultural-policy/cap-overview/cap-2023-27/key-policy-objectives-cap-2023-27_en

commercial PPP or RTK. This, however, is not incoherent with EU objectives because the Union Space Programme is not meant to compete with industry.

Agriculture: Synergies with EU Space Programme Components

In the field of agriculture there are strong synergies between EO and GNSS. Copernicus and Galileo are both integral parts of various projects. For example, in the FaST project both Galileo and Copernicus are used in georeferencing data and identifying parcels.

In many commercial PA products, both EO and GNSS are used to estimate and map crop requirements, and to support farmers in applying the right amount of product efficiently.

3.2.8.7. Search and Rescue

Emergency Management and Humanitarian Aid: Coherence with EU policies

The Emergency Management and Humanitarian Aid sector benefits from GNSS utilization in multiple ways, from Search and Rescue (SAR) to NGO's assets management. The SAR/Galileo service, launched as part of Galileo Initial Services, contributes to these live-saving efforts by swiftly relaying radio beacon distress signals to the relevant SAR crews by means of dedicated payloads on-board Galileo satellites, supported by three ground stations strategically deployed across Europe. On January 21 2020, the SAR/Galileo Return Link Service (RLS) was declared operational. Now, Galileo not only locates people in distress and makes their position known to the relevant authorities, the SAR/Galileo RLS provides an automatic acknowledgement message back to the user informing them that their request for help has been received.

In doing that, Galileo helps the EU in achieving European Union Disaster Resilience Goals. In fact, the European Commission adopted the following objectives:

- Anticipate – To improve risk assessment, anticipation, and disaster risk management planning.
- Prepare - To increase risk awareness and preparedness of the population.
- Alert - To enhance early warning.
- Respond – To enhance the Union Civil Protection Mechanism response capacity.
- Secure - To ensure a robust civil protection system.

On the side of Humanitarian Aid, it is worth mentioning the Sendai Framework. Namely, “The Sendai Framework for Disaster Risk Reduction 2015-2030 outlines seven clear targets and four priorities for action to prevent new and reduce existing disaster risks: (i) Understanding disaster risk; (ii) Strengthening disaster risk governance to manage disaster risk; (iii) Investing in disaster reduction for resilience and; (iv) Enhancing disaster preparedness for effective response, and to "Build Back Better" in recovery, rehabilitation and reconstruction”. The framework was adopted at the Third UN World Conference on Disaster Risk Reduction in Sendai, Japan on March 2015. Through enabling NGO's assets management, for instance, Galileo allows civil protection bodies to be prepared and have a more precise understanding of an event, thus act more effectively.

Emergency Management and Humanitarian Aid: Synergies with the other EU Space Programme Components

The areas in which Copernicus and Galileo support each other in the field of emergency management are several. For example, in the cluster of preparedness, the monitoring of events such as landslides, tsunamis, earthquakes or volcanic activities is heavily helped by both the components of the EU Space Programme. At the same time, post-event recovery applications

such as damage assessment, building inspection and restoration of the infrastructure service benefit as well from the coordination of Copernicus services and Galileo services. Last but not least, in the humanitarian aid field, health and medicine response and coordination is an application in which Earth Observation is a very powerful tool for population counting in the case of a disaster, and GNSS allows geo-localization of people.

Crisis management is also one of the three application fields of the future GOVSATCOM component, which will support both humanitarian aid and civil protection interventions in case of disasters. As a consequence, Galileo and GOVSATCOM will create and exploit synergies in this field, allowing a more secure connectivity and thus a better support efficacy.

3.2.8.8. Takeaways on Policy Coherence of EGNSS

Galileo and EGNOS play an important role in supporting various EU policies by providing essential services and solutions. In promoting healthcare under the *EU4health initiative*, Galileo aids in emergency location services such as E112 calls, ensuring swift and accurate response during medical crises. Additionally, it aligns with the *EU Single European Sky initiative*, enhancing the efficiency and unity of European airspace management. In the realm of maritime safety, the Integrated Maritime Policy (IMP) and *EU Maritime Safety Strategy* benefit from Galileo's Open Service Navigation Message Authentication (OSNMA) to authenticate signals, contributing to safer European waters.

Furthermore, Galileo significantly contributes to *EU Disaster Resilience Goals* and supports the *Common Agricultural Policy*. Moreover, by bolstering the resilience of European Critical Infrastructures, particularly through the OSNMA service, Galileo strengthens the EU's disaster response capabilities and enhances agricultural policy implementation.

Galileo also supports in advancing the *EU Green Deal Initiative* for Sustainable and Smart Mobility, particularly in the European Rail Traffic Management System. Within the "*Europe on the Move*" package, Galileo's OSNMA and High Accuracy Service (HAS) ensure GNSS authenticity verification and decimeter accuracy, along with the future Galileo Emergency Warning, thus playing key roles in enhancing road segment safety and regulations.

Lastly, by addressing energy security in response to the energy market disruption caused by Russia's invasion of Ukraine, Galileo supports the *REPowerEU* plan by contributing to the transformation of Europe's energy system and reducing dependence on Russian fossil fuels.

Galileo serves as a crucial element in supporting various EU policies but also **demonstrates synergies with other space components** across multiple fields. In the consumer market, many applications blend Earth Observation data from Copernicus and Galileo data, fostering for instance sustainable tourism and geo-tagging. Collaboratively, Copernicus and Galileo play vital roles in the segment of renewable energy site selection, planning, and monitoring. Galileo assists in site selection and planning, while Copernicus, primarily through Digital Elevation Models (DEMs), contributes to the selection phase. Within the preparedness cluster, both components of the EU Space Programme greatly enhance event monitoring, such as of landslides, tsunamis, earthquakes, and volcanic activities. They work hand in hand, offering valuable support in post-event recovery applications, encompassing damage assessment, building inspection, and infrastructure restoration.

Finally, the synergy between GOVSATCOM and EGNSS comes to light in the context of marine search and rescue. GOVSATCOM lends its support to various critical infrastructures, including road-related ones, fostering mutual benefits between Galileo signals and secure communication. In the realm of crisis management, the future GOVSATCOM component aligns with humanitarian aid and civil protection interventions, potentially creating synergies with Galileo in this essential endeavor.

3.2.9. Additional insights to the EGNSS Component

The evolution of data and services offered by competitors

Galileo

Galileo is a GNSS that is comparable to other GNSS. There are currently three other operational GNSS; GPS, GLONASS, Beidou.

GPS

GPS is the first GNSS, and therefore has effectively become the standard for satellite navigation. All SBAS are built to augment GPS, and all GNSS receivers are GPS compatible. The system is currently being upgraded from the GPS Block II to GPS Block III. Block II satellites alone have accuracy levels of several meters, and function on the L1 band (which shares some bandwidth with the E1 band). This band is also the most commonly used band for navigation globally due to GPS heritage. Later models of Block II also broadcast on the L2 band, making GPS also multi frequency. L2, however, is not a civilian band and is reserved for the Precise Positioning Service (PPS) which is for authorized users only. Block III – which is currently being launched - is expected to be more accurate and add the L5 band, which shared bandwidth with the E5 band. Block III also will bring a civilian frequency on the L2 band.⁶⁸

Galileo performs at least as well as Block II GPS satellites, and also provides the PRS (public regulated service) which is similar to the PPS. Galileo provides dual frequencies on the E1 and E5 frequencies as standard, and is more accurate than GPS Block II⁶⁹ with an accuracy of 1 meter as compared with 3 meters for GPS. Galileo also has additional features that differentiate it from GPS⁷⁰:

- HAS: with the high accuracy service, Galileo broadcasts freely PPP corrections over the E6. This can make Galileo suitable for applications that require sub meter level accuracy without the need for any additional equipment.
- OS-NMA: on its open service (the civilian signal), Galileo signals can be authenticated which makes them significantly more robust against spoofing attacks. This sets it apart from GPS, as GPS does not provide any anti spoofing on the civilian service.
- RLS: Like GPS, Galileo contributes to the COSPAS SARSAT. Galileo, however, has the added ability to inform those in distress that their message was received and relayed to the authorities.

GLONASS

The GLONASS system was built by the Soviet Union, and was originally comparable to GPS, with accuracy in the order of several meters. The economic turmoil accompanying the dissolution of the Soviet Union meant that the system was neglected, but eventually modernized by Russia in the early 2000s.

⁶⁸ ESA : https://gssc.esa.int/navipedia/index.php?title=GPS_Signal_Plan ,
https://gssc.esa.int/navipedia/index.php/GNSS_signal ,

⁶⁹ <https://www.deingenieur.nl/artikel/after-13-years-galileo-satellite-navigation-complete-at-last>

⁷⁰ GPS World: <https://www.gpsworld.com/galileo-has-now-operational-with-20-cm-accuracy/>

Multi constellation receivers are widely the norm, since more satellites means higher availability. This means that most commercial devices that are multi constellation are GLONASS compatible. GLONASS also contributes to COSPAS SARSAT.

BeiDou

The Chinese BeiDou system is like Galileo in that it is a younger system aimed at being high performing. The system has more satellites than GPS and more monitoring stations, so BeiDou's accuracy is higher than that of GPS⁷¹. China has also been heavily promoting the uptake of BeiDou, particularly in the global south, partially driven by China's powerful tech sector and its heavy investment in infrastructure.

Beidou is also a multifrequency constellation that operates on similar bands to Galileo. The civilian signal is less accurate than Galileo, with a stated accuracy of 10 meters, although there is a military signal like PRS and PPS that is accurate to 10 cm.⁷² This signal has been granted only to the Chinese and Pakistani armed forces.

Beidou is also unique among GNSS in that it provides positioning based on both RDSS (Radio Determination Satellite Service) and RNSS (Radio Navigation Satellite Service) signals simultaneously, so it can provide accurate positioning with low dependence on satellite orbit accuracy⁷³.

While Beidou does not have an equivalent system to the OS NMA, as there is no authentication built into the system, Beidou does have other differentiators. Notably, Beidou has its own equivalent of the RLS which functions similarly to the RLS⁷⁴.

As with the HAS, Beidou also provides the "wide range differential service" which gives PPP corrections to users. Unlike the HAS, however, this service is not available to all users.

Concluding remarks on Galileo

While they provide similar services and target the same users, the four systems cannot be said to be in "competition." The use of Galileo would not reduce the use of GPS or Beidou or GLONASS, and vice versa. On the contrary, more satellites in orbit would be beneficial to the civilian end user, so the systems can be said to be complementary.

EGNOS and other SBAS

The SBAS systems are also not competitive, since they target different geographic areas. EGNOS covers Europe, WAAS covers North America, GAGAN covers South Asia, etc. They are fully interoperable and therefore complementary as the wider the coverage of SBAS, the more benefit there is to the end user.

As of October 2023, EGNOS, WAAS, MSAS and GAGAN all only can augment GPS. EGNOS v3 will also augment Galileo, the Japanese QZSS aims to also augment its own navigation satellites (but these are not MEO GNSS satellites but local navigation systems), the Russian SDCM aims to augment GLONASS but it is not yet certified for public aviation.

⁷¹ GPS World : <https://www.gpsworld.com/chinas-beidou-gps-and-great-power-competition/>

⁷² SHI Chuang, ZHAO QiLe, LI Min, TANG WeiMing, HU ZhiGang, LOU YiDong, ZHANG HongPing, NIU XiaoJi, LIU JingNan. Precise orbit determination of Beidou Satellites with precise positioning. SCIENCE CHINA Earth Sciences, 2012, 55(7): 1079-1086.

⁷³ Liu, W., Yuan, H., Ge, J. et al. Precise time and frequency transfer combined BeiDou's RDSS and RNSS signals. J Wireless Com Network 2019, 244 (2019). <https://doi.org/10.1186/s13638-019-1554-6>

⁷⁴ BeiDou: <http://www.beidou.gov.cn/xt/gfxz/202008/P020200803362068698004.pdf>

The SouthPAN initiative by Australia and New Zealand is a SBAS that augments GPS in Oceania, and it plans to become augment multiple constellations in the future and also provide PPP signals similar to the HAS.

3.3. SSA Components

3.3.1. Introduction to the SSA Component

The Space Situational Awareness (SSA) Programme is the initiative designed to support EU's independent space access and utilization through the timely and accurate information delivery regarding the space environment. Under the programme, the EU is acquiring the independent capability to monitor objects and natural phenomena that could harm satellites in orbit or infrastructure on the ground such as power grids. To achieve this, SSA focuses on three main areas:

- **Space Surveillance and Tracking (SST):** a system of networked sensors to survey and track space objects together with processing capabilities to provide data, information and services on objects that orbit the Earth
- **Near-Earth Objects (NEO):** capabilities to monitor the risk of natural space objects approaching the Earth, such as asteroids and comets
- **Space Weather Events (SWE):** capabilities to monitor space weather and solar activity.

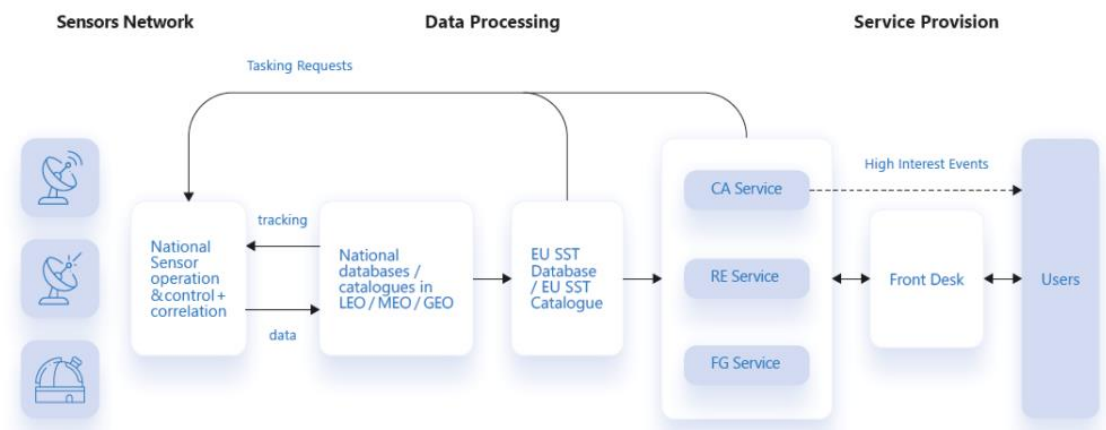
SST

For the implementation of the EU Space Surveillance and Tracking (SST), established in 2021 as a fully-fledged security subcomponent of the EU Space Programme, the SST Partnership of 15 EU Member States (Austria, Czech Republic, Denmark, Finland, France, Germany, Greece, Italy, Latvia, the Netherlands, Poland, Portugal, Romania, Spain and Sweden) together with the European Union Agency for the Space Programme (EUSPA) form the SST Cooperation.

Previously, EU SST was established as a Support Framework by the SST Decision (2014), which foresaw the creation of an SST Consortium of EU Member States. The Consortium and the European Union Satellite Centre (SatCen) cooperated to gradually develop the SST capability with the support of the European Union under different funding lines (i.e. H2020, Galileo & Copernicus). EU SST is now funded by the EU through the EU Space Programme and the Horizon Europe programmes.

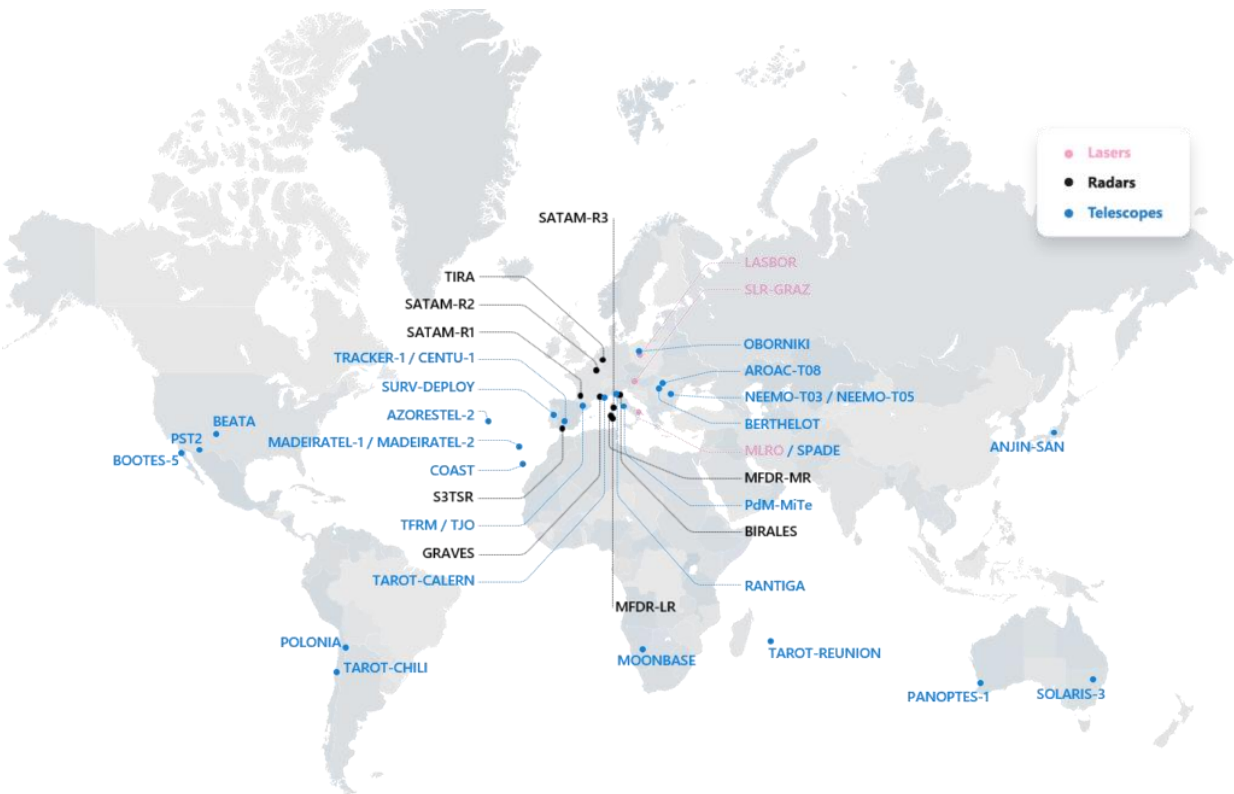
The SST capability consists of three main functions: sensor, processing and service provision. Sensors from Member States contribute data that is analysed in the processing function and feeds a joint database and ultimately a catalogue; from this, products are derived for three services, generated by the Operations Centres (OCs) and delivered to users via the SST Service Provision Portal (SST Portal).

Figure 77: EU SST Architecture⁷⁵



The Sensor function consists of a network of sensors to survey and track space objects in all orbital regimes (LEO, MEO, HEO and GEO). As of July 2022, the network comprises 40 sensors of the member states (incl. radars, telescopes and laser ranging stations). The network only comprised 38 sensors in October 2021.

Figure 78: EU SST Sensors Network (July 2022)⁷⁶



The Processing function aims to coordinate the data-sharing between the different OCs via a common database and to process thousands of daily measurements from the sensors contributing to EU SST. These data constitute the basis for a future EU SST Catalogue that

⁷⁵ Source : https://www.satcen.europa.eu/keydocuments/EUSST_Service_Portfolio622b4b653172450001cfa321.pdf

⁷⁶ Source : https://www.satcen.europa.eu/keydocuments/EUSST_Service_Portfolio622b4b653172450001cfa321.pdf

will be used for the SST services. Germany is responsible for hosting the EU SST Database and generating the future EU SST Catalogue.

The Service Provision function is in charge of providing three SST services – Collision Avoidance, Re-entry Analysis and Fragmentation Analysis – to entitled users through a secure portal, the SST Service Provision Portal, managed by EUSPA, which acts as Front Desk. More than 190 organisations are receiving these services and more than 400 satellites are safeguarded from the risk of collision. Currently, the French and Spanish OCs are responsible for the Collision Avoidance service, while the Italian OC is in charge of the Re-entry Analysis and Fragmentation Analysis services.

SWE

Space weather (SWE) encompasses the study, monitoring and analysis of the activities of the Sun and its effects on solar wind, and on Earth's magnetosphere, ionosphere, and neutral atmosphere. In particular, three solar events can manifest themselves on Earth in an impactful way:

- Coronal Mass Ejection (CME) – is a huge explosion of magnetic field and plasma from the Sun's corona (outer solar atmosphere). CMEs travel at an average speed of 300 km/s, although it can be as slow as 100 km/s or as fast as 3000 km/s. They are often accompanied by solar flares and can take as little as 14-17 hours to travel from the Sun to Earth (for faster CMEs). The size, speed, direction and density of a CME are all important parameters in the prediction of if/when it will impact Earth. They can be monitored utilizing a coronagraphs and X-rays.
- Solar Energetic Particles Event (SEPE) – are high-energy charged particles, released by shocks formed at the front of CMEs and solar flares. Since they are charged, they must follow the magnetic field lines that permeate the space between the Sun and Earth; hence, only those charged particles that follow the magnetic field lines intersecting with Earth will have an impact. The most important particles are protons, which can be accelerated to 1/3 the speed of light, travelling the distance between the Sun to Earth in around 30 minutes. They are monitored utilizing Gamma-ray, X-rays and radio observations.
- Solar Flares – are large eruptions of electromagnetic radiation from the Sun that can last between minutes and hours. Their effects impact the earth instantly as these electromagnetic outbursts travel at the speed of light and can reach the earth in 8 minutes. Solar flares are monitored utilizing x-rays and optical light.

These solar events can cause solar storms that can have significant impacts on operations in different industrial sectors.

From a capabilities and service perspective, space weather can utilize both ground-based and space-based sensors, which can acquire the relevant key information and data. This data is stored and processed in SWE data centres, and is analysed by specialists in order to provide forecasts, nowcasts, alerts and other essential services, as well as customized products to the end-user industries (e.g. satellite operators, power grids). Ground-based instruments are less expensive and easier to maintain and upgrade than space-based instruments mounted on satellites; however, it is vital to have data from instruments in space if real-time data for forecasting services is required.

NEO

From a scientific perspective, the subject of near-Earth objects (NEO) encompasses the study, monitoring, cataloguing and analysis of the evolution of the NEO population. NEO refers to natural objects in the solar system (e.g. meteoroids, asteroids), which travel in outer space in the proximity of the Earth (i.e. about 1 Astronomical Unit or about 150 million km from

Earth) but well beyond the regions of space (i.e. GEO, MEO and LEO) that are exploited for scientific and commercial purposes. NEOs travel typically at hypervelocity (about 17 km/s) and they can be on a trajectory leading to a collision with Earth, ranging from negligible damages (formation of small craters) to regional and European-wide devastations (e.g. formation of a Tsunami, destruction of a Europe-wide area), and up to the extinction of human civilization. The level of damage or destruction caused by a collision, for instance in terms of fatalities, injuries, and/or infrastructure damages, mostly depends upon the size of the NEO.

NEOs collide with the Earth quite frequently, ranging from 1 NEO every few months for small NEOs of a couple of meters in size, up to less frequent, larger NEOs, with impacts once every >500,000 years for NEOs greater than 1 km. Three main classifications of NEOs were identified based on current capability shortcomings in NEO surveys and follow-up systems, as well as the severity of potential impacts on Earth resulting from a collision. These classifications are:

- Uncatalogued: NEOs of 2-10 m are not yet discovered, but their impacts on Earth are typically negligible.
- Potentially catalogued: NEOs of 10 m - 1 km are poorly discovered; their impacts on Earth can be significant. Due the new NEO missions, such as NASA’s NEO survey and follow-up sensors, it is credible to expect an increase of discoveries of NEOs of this size in the future.
- Catalogued: NEOs of more than 1 km are largely discovered and their impacts can lead to the cataclysmic end of civilisation.

The SSA-NEO system is based on syndicating and federating observation and tracking data provided by a large number of European and international sources.

3.3.2. *The SSA component entrusted tasks and entrusted entities*

3.3.2.1.Entrusted tasks

As described in the introduction, the SSA Component aims at improving the knowledge of the space environment and encompasses 3 components: NEO, SWE and SST.

Under the 2021-2027 framework, the general objectives of the Component are:

- (a) To enhance space surveillance and tracking capabilities, based on those existing in Member States and networked thanks to the EU (SST sub-component);
- (b) To monitor, track and identify space objects and space debris with the aim to further increase the performance and autonomy of SST capabilities at Union level;
- (c) To provide space weather services (SWE sub-component) and to map and network Member States capacities related to near Earth objects (NEO sub-component).

In order to achieve these objectives, 2 entities have been entrusted with tasks related to these components, ESA for SWE and NEO and EUSPA for SST.

Following this logic, the Component can be segmented into 3 intervention groups corresponding to the 3 domains – SWE, NEO and SST -, and into several interventions, extracted from the documents made available to the team – The Annex to the Decision, the Work Programmes (2021, 2022, 2023-2024), the Procurement Work Plan and the Contribution Agreements – and confirmed during the calls with the entrusted entities.

The interventions per domain are summarized in the table below.

Table 212: Full list of interventions per domain

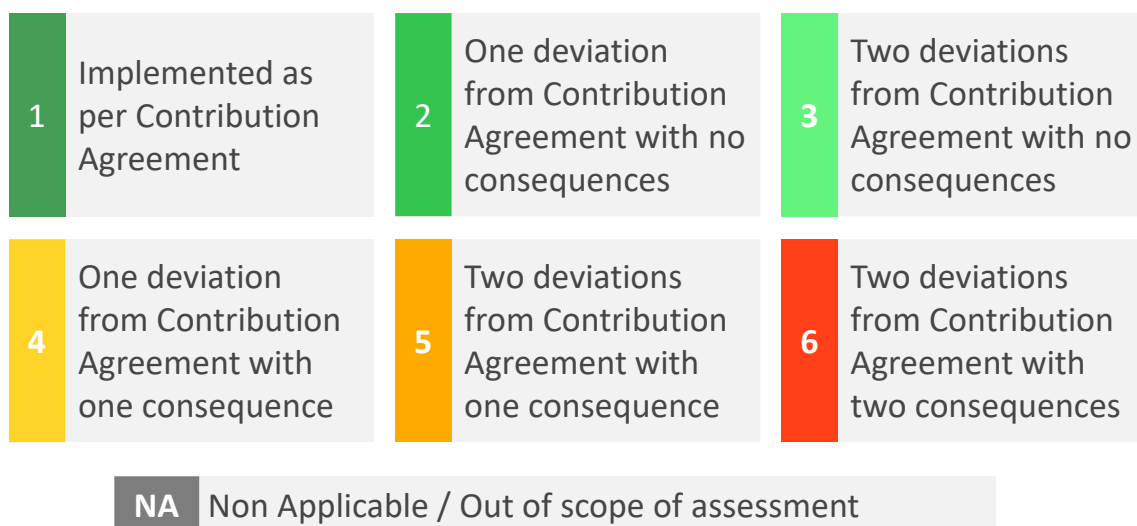
Intervention Group	Entrusted entity	Interventions

NEO	ESA	Mapping of Member States' capabilities for detecting and monitoring NEOs
NEO	ESA	Promotion of the networking of Member States facilities and research centres
NEO	ESA	Establishing and maintaining a European NEO catalogue
NEO	ESA	Development and provision of rapid expert response service in relation to new NEOs
SWE	ESA	Elaboration of user needs and service quality criteria
SWE	ESA	Pre-selection of space weather service for operational framework
SWE	ESA	Preparation of invitation for tender, publication, evaluation and contract placement
SST	EUSPA	User uptake, information and services (Front Desk)
SST	EUSPA	Support the Commission on security aspects in the implementation of SST
SST	EUSPA	Security Monitoring & Implementation
SST	EUSPA	Support tasks - General
SST	EUSPA	Support tasks - Security
SST	EUSPA	Support tasks - Technical

These interventions can be broken down into one or several activities which full list is provided in the appendix.

As described in the results assessment methodology section and reminded in the Copernicus part of this report, the specific outcome of each activity was determined based on its status, timeline, and budget *-when the information was available-*, that mapped to a numerical outcome on a scale of 1-6. As shown in the figure below, each number defines a different outcome within this scale and does not provide a score for the outcome.

Figure 86: Definition of scale to assess implementation of entrusted tasks



Any deviations or consequences in the implementation of the activities have been qualitatively explained in the results below. It is important to note that while the assessment was carried out at the activity level, the results shown below have been consolidated at the intervention level. A detailed view of the assessment at the activity level can be found in the Appendix.

3.3.2.2.SSA Budget

For the 2021-2027 timeline, the budget delegated for the SSA component was extracted from the Work Programmes⁷⁷ and is segmented as follows:

Table 213: SSA budget

No.	Entrusted Entity	2021	2022	2023	Total for 2021 – 2027
1	EUSPA (for SST)	€ 800 000	€ 800 000	€ 4.5M*	€ 1.6M (+ € 4.5 M)
2	ESA (For SWE and NEO)	€ 7.3M	€ 0	€ 1.2 (SWE) € 1M (NEO)	€ 9.5M

* An additional € 4 500 000 is expected in 2023/2024 for security monitoring systems related tasks – financing of the IT setup and maintenance of security monitoring activities and of capacities for the handling and exchange of EU classified information between EUSPA, the Commission, the EU SST Partnership and SST users as part of EUSPA’s role of the SST front desk for at least 4 years

3.3.3. Effectiveness of the Implementation of SSA

As for other components, the assessment of the effectiveness of implementation is divided into two interrelated sections.

- First, the extent to which the interventions outlined above were completed within the allocated time and budget, and the outcomes or severity of any delay or budget overrun that may have occurred.
- Second, the performance based on several KPIs as outlined in the contribution agreement.

3.3.3.1.Assessment of the implementation of the entrusted tasks by entrusted entities

As mentioned above, the interventions were extracted from the different documents made available to the team. The results assessment was conducted through consultations completed by information extracted from the AIR for SSA. For the SWE and NEO part, PwC discussed with the Commission and ESA and for the SST part, PwC discussed with EUSPA and EC.

Regarding the KPIs used to assess the implementation of the entrusted tasks, the methodology is the same as for the other Components, the effectiveness will be assessed at the intervention level.

NEO-related interventions entrusted to ESA

Intervention 1: Mapping of Member States’ capabilities for detecting and monitoring NEOs

The first intervention related to the NEO pillar under the Union Space Programme is the mapping of existing assets and capabilities in Europe within this domain. Indeed, the last assessment of mapping Member States detection and monitoring capabilities was done in 2010 and since then, many new capabilities have been developed while some players have disappeared. In addition to a full assessment exercise, current capabilities of the assets needed to be tested.

⁷⁷ Budget funded under Space Regulation

The target date for the completion of this task was Q4/2022 and the action has been completed in time.

Intervention 1 Qualification	Implemented as per Contribution Agreement

Intervention 2: Promotion of the networking of Member State facilities and research centres

After mapping the existing assets in EU Member States, the second intervention is the promotion of the networking of these facilities with an associated expected outcome of a yearly conference on NEOs.

This activity is on-going according to planned schedule (one conference per year until Q4/2027). Two such conferences have already been organized, one in 2022 and the other in 2023 - time of writing of this report.

Intervention 2 Qualification	Implemented as per Contribution Agreement

Intervention 3: Establishing and maintaining a European NEO catalogue

The third intervention is for ESA to establish and maintain a European NEO catalogue/database.

As opposed to the first 2 interventions, this activity requires expertise outside ESA, and shall thus in accordance with the Contribution Agreement be implemented through a public procurement. The Contribution agreement targeted the activity to be finalised in Q4/2027. According to the SIR S1 2023 the contract is expected to be signed in Q1/2024 with a 51-month long contract leading to the expected completion for the task in Q1/2028. Therefore, there's a slight delay in the planning leading the contract to be finalised after the end of the FFPA. However, this intervention is rather independent from others and the delay will not impact other tasks.

Intervention 3 Qualification	One deviation from Contribution Agreement with no consequences

Intervention 4: Development of provision of rapid expert response service in relation to new NEOs

The last intervention related to the NEO domain is to develop provision of rapid expert response service in relation to new NEOs including for potential ground impactors (>50 m), fast-response space missions for reconnaissance (to better understand the characteristics of the object) and/or deflection mission.

It will start in 2024 and the target for the completion of this intervention is Q4/2027 according to the Contribution Agreement.

Intervention 4 Qualification	To be implemented as per Contribution Agreement

Summary

Overall, ESA is effectively implementing its entrusted tasks under the NEO component. Its interventions have led to the mapping of Member States' capabilities for detecting and monitoring NEOs with a full list of institutions and assets. In addition, ESA's work contributes to the promotion of the networking of Member States facilities and research centres via the annual NEO conferences. Only one small delay can be noted however it does not impact implementation of the Contribution Agreement.

The interventions and timeline related to Space Weather domain were defined after a consultation with the Commission, ESA and additional desk research.

Intervention 1: Elaboration of user needs and service quality criteria

In the domain of Space Weather, the first intervention consists in defining service selection priorities by elaborating user needs and quality criteria for Space Weather Services, through a Space weather impact study of European Infrastructure and a Cost Benefit analysis ('CBA').

According to the Contribution Agreement, a first space weather impact study and a cost benefit analysis, external work done by European industry and institutes based on competitive tendering, should have been completed by 2023. The contract was however placed with a delay in Q3 2023 and will be finalized Q1 2025. There is therefore a 1-year delay in the completion of the CBA. However, the user needs assessment was done in 2023.

The CBA delay is due to procedural constraints. Indeed, ESA faced a timeline issue regarding the procurement set-up as the European Commission had to navigate in a very new environment: legal texts had to be prepared and some of the related legal questions were not straight to work, and thus, required more time.

Since the input from the CBA is needed for other SWE entrusted tasks (selection of the SWE service), a mitigation measure was put in place, whereby the contractor will deliver the elements needed for the foreseen 2025 SWE service in the middle of the contract. The delay is therefore not expected to have consequences for the implementation of the other tasks.

Intervention 1 Qualification

One deviation from Contribution Agreement with no consequences

Intervention 2: Pre-selection of space weather service for operational framework

The second intervention under the SWE segment will be based on ESA's work and pre-studies in the SWE field as well as on the priorities defined in the first intervention, which will allow ESA to propose the selection of components/elements to be part of an initial operational SWE-service framework.

The identification of such initial service elements will focus on the full data processing chain, ranging from raw measurement data to space weather products and combined end user services, considering timeliness, quality and reliability.

This activity has not started yet because the CBA needs to be done before. Indeed, as mentioned above, the results of the study will be used as an input in the selection of the service elements for the initial operational space weather services. However, this delay should not have an impact in the overall timeline due to the mitigation measure put in place in the CBA contract.

Intervention 2 Qualification

To be implemented as per Contribution Agreement

Intervention 3: Preparation of invitation for tender

The last intervention linked to SWE pillar under the Union Space Programme is the preparation of a tender related to the operation of the selected space weather service for the initial phase of the activities supported by the Union Space Programme.

This activity has not started, because the technical annexes of the tender will be based on the results of these previous interventions to be finally decided by Member States, with definitions of the requested contents of the service(s) and the quality criteria for their provision.

According to the Contribution Agreement, the target date for this intervention is 3 months after the adoption of the implementing Act requested by the Space Programme Regulation. Moreover, the contract for operational SWE services is foreseen to be kicked off in 2025 and to cover the service provision for 2.5 years.

The estimated date for the ITT was Q3/Q4 2024 according to the Work Programme of 2023-2024, and the contract for operational SWE services was foreseen to be kicked-off in 2025 and to cover the service provision for 2.5 years. In the current planning, the ITT is still set for release in Q4 2024.

Intervention 3 Qualification	To be implemented as per Contribution Agreement

Summary

For SWE related tasks, ESA ran into a timeline issue with the set-up of the procurement approach. This created a risk for the start of the procurement for the initial operational services. However, an approach to mitigate this risk has been put in place as explained above, whereby the contractor will deliver the elements needed for the foreseen 2025 SWE service in the middle of the contract. The delay is therefore not expected to have consequences on the initial service provision.

Overall, the delay has been effectively managed so as not to impact the timeline of the initial service provision and it can be stated that ESA is effectively managing its entrusted tasks and that their implementation is running smoothly.

SST-related interventions entrusted to EUSPA

SST-related tasks couldn't be assessed because at the time of this report, it was not yet EUSPA which was operating the SST front desk but still SatCen. Indeed, under the old MFF, this task was entrusted to SatCen and under the new one, it was entrusted to EUSPA. However, following consultations, at the time of writing of this report, SatCen was still effectively operating the Front Desk. This entrusted task has only recently effectively been transferred to EUSPA (1st of July of 2023). Thus, the implementation of the entrusted tasks to EUSPA for 2021 – 2023 under SST could not be effectively performed.

According to the information gathered during our consultations, the delay in transferring the front desk from SatCen to EUSPA, which was external to EUSPA, was mainly due to 3 reasons.

First, SatCen was responsible of the previous system (EU SST consortium) and the transfer of the Front Desk could be realised only when the partnership would be established according to the Space Regulation. Indeed, the signature (so the establishment) of the new EU SST Partnership, increasing the number of Member States from 7 to 15, was required to launch the grant. A 3-stage selection process was needed as well as the definition of the criteria to select Member States and the adoption of a very technical implementing act which delayed the transfer of the Front Desk.

Second, there were logistics requirements that needed to be addressed: qualified people, buildings and infrastructure for secure connectivity etc.

Third, there was a budget issue linked to the delay in the adoption of the MFF: it was late which impacted the transfer of the front desk.

Thus, it can be assumed that all EUSPA SST-entrusted tasks related to the operation of the Front Desk are delayed, however this might not impact the implementation of the component because it was still managed by SatCen. Moreover, EUSPA worked together with SatCen in order to ensure a smooth transition and in order to consolidate the relationship between the parties (through exchanges, meetings and workshops on a weekly basis). Moreover, the recruitment process related to the 11 temporary agent vacancy notices for the creation of the

technical team for the running of the SST Front Desk operations was successfully concluded in Q4/2022. Lastly, it should be noted that EUSPA worked in collaboration with the Commission for the set-up of the SSA General Security Requirement. The transition from SatCen to EUSPA was ensured smoothly and EUSPA's actions ensured continuity of the services provided.

3.3.3.2. Assessment of the performance of the SSA Component

Regarding SSA, two indicators were to be assessed under the Space Regulation: the number of users and the availability of services. The same indicators apply to the three segments of SSA: SST, NEO and SWE, however they cannot be assessed in a similar way due to the different maturity of levels of the components.

In addition to these 2 indicators, there is one more KPI relevant for SST, extracted from the Technical Annex to the Implementing Decision of the 15th of July of 2022, whose assessment is not required under the Space Regulation. We extracted only one KPI from this list because it was the only one where data was made available to use and was not confidential (detailed information about the performance of the SST service is sensitive and confidential so the associated KPIs results are not available).

The table below highlights the indicators adopted for SSA and their applicability.

Table 214: Indicators used to assess the performance of the SSA component

#	Component	Indicators	Comments
1	SST & NEO & SWE	Number of users of SSA component providing, where possible information such as the type of user, geographical distribution and sector of activity (including user satisfaction)	SWE is not operational yet therefore the indicator is not applicable yet. No service is planned for NEO. ⁷⁸
2	SST & NEO & SWE	Availability of Services (including analysis of the autonomy of the Space Surveillance and Tracking and of the level of independence of the Union in this area and networking for the activities of Near-Earth Objects)	SWE is not operational yet therefore the indicator is not applicable yet. No service is planned for NEO.
3	SST	Number of sensors (SST)	Extracted from the Annex to the Implementing Decision (not a KPI under the Space Regulation)

Indicator 1: Number of Users

The first indicator is related to the number of users of SSA component and their characteristics. SWE and NEO are not operational yet, therefore the indicator is not applicable at the time of writing of this report.

The SST sub-component is composed of 3 services: collision avoidance, re-entry analysis and fragmentation analysis.

There are 402 satellites registered, distributed as follows:

- LEO: 156
- MEO: 58
- GEO: 188

The repartition of the owners and/or operators is as follows.

⁷⁸ For the NEO sub-component, no service is planned, only the constitution of the database.

Table 215: Repartition of the owners and/or operators

Country	# operators	#owners	#operator owner	& #other	Total
Bulgaria			1		1
Finland	1	1	2		4
France	3	1	6		10
Germany	3		5	1	9
Greece			1	1	2
Italy		1	2		3
Luxembourg	1		1		2
Malaysia			1		1
Netherlands			2		2
Norway	1	1	1		3
Poland	1	1			2
Portugal				1	1
Slovenia			2		2
Spain	2		7		9
Sweden	1		1		2
United Kingdom			2		2
United States of America			2		2
Total	13	5	36	3	57

If we focus on Europe, we can note that the owners and/or operators are overall evenly distributed across the countries (1 to 4 operators and/or owners for each country), with France, Spain and Germany accounting twice as much.

As for details regarding the users, there is a total of 191 organizations registered and the number of registered users per service is divided as follows.

Table 216: Number of registered users per service (includes EU and non-Eu operators)

Service	# organizations	# accounts
Collision avoidance	57	111
Re-entry analysis	149	314
Fragmentation analysis	146	282

Their geographical distribution is as follows.

Table 217: Geographical distribution of the registered users

Country	# organizations
Austria	4
Begium	7
Bulgaria	5
Cyprus	3
Czech Republic	3
Denmark	3
Finland	11
France	27
Germany	23

Greece	8
Ireland	3
Italy	22
Luxembourg	7
Malaysia	1
Malta	1
Netherlands	6
Norway	3
Poland	15
Portugal	12
Romania	5
Slovakia	3
Slovenia	2
Spain	28
Sweden	5
United Kingdom	2
United States of America	4
Total	191

And finally, the types of users are summarized in the table below.

Table 218: Type of registered users

Service					
Scope	Category	CA	FG	RE	All services
International	EU Institution		3	4	4
	Intergovernmental Org.	3	3	3	4
	Private/Public Associations		2	2	2
National	Government	2	21	28	28
	Industry	34	55	55	83
	Media		1	1	1
	Military	4	21	19	21
	Research	2	10	10	11
	Space Agency	6	6	6	9
	University	6	23	20	27
Personal	Personal		1	1	1
Total		57	146	149	191

The SST service is delivered to EU users mainly operating at national or international scope (the personal scope being peculiar) with a strong focus on national entities and in particular on the industry sector. Indeed, for a total of 191 registered users, 83 are from the industry sector. Regarding the users registered per service, the majority of them are registered for re-entry and fragmentation services. A smaller number is registered for the collision avoidance service but this is because you need to operate a satellite to register to collision avoidance.

Since the 1st of January 2023, the scope of users has been widened. First, after the Brexit, negotiations have been carried out in order not to descope the UK satellites. Afterwards, 2 protocols have been signed and one in particular was covering the participation of the United

Kingdom to the SST with the possibility to add new satellites (and not only limit the involvement to not descoping the actual ones). Moreover, after the grant was signed and in accordance with the provision of the article 8 of the Space Regulation, third countries started to be granted access to the SST services (USA, Norway etc.).

Indicator 2: Availability of Services

As mentioned before, SWE and NEO are not operational yet, the indicator is therefore not applicable neither at the time of writing of study.

The SST sub-component is divided into 3 different services:

- **Collision avoidance** which provides risk assessment of collision between spacecraft and space debris, and generate collision avoidance alerts;
- **Re-entry analysis** which provides risk assessment of uncontrolled re-entry of manmade space objects into the Earth's atmosphere and generates related information;
- **Fragmentation analysis** which provides detection and characterisation of in-orbit fragmentations, break-ups and collisions and analyses all the available information regarding the object(s) involved in the event.

These services are provided upon request to all EU Member States, the European Council, the European Commission, the European Union's External Action Service, public and private spacecraft owners and operators, and public authorities concerned with civil protection.

Table 219: Key characteristics of SST services

Service	Key features	Products provided	Service provision mode
Collision avoidance	User-tailored service (The user can configure the thresholds for risk categorization) Hot-redundancy scheme with the French and Spanish OCs providing the services as a single service provider	Conjunction Data Message Collision Avoidance Report Monthly Report	Service provided via the SST Portal complemented, if needed, by direct dialogue between the OC and the O/O
Re-entry analysis	Long-term and short-term predictions Customized service (selection of areas of interest)	30 Days Re-entry List Re-entry Report	Service delivered via the SST Portal
Fragmentation analysis	Long, medium and short term analyses of information regarding in-orbit fragmentation	Short-term FG analysis notification Medium-term FG analysis report Long-term FG analysis report	Service carried out via the SST Portal

The SST service is available to all EU potential users which were until the 1st of January 2023, only EU users. As a result, for Collision avoidance, with the current number of users, SST has already reached more than 95% of all potential EU users.

More practically, the services are provided to the users through a secure portal with EUSPA (from 1st of July 2023) which operates the Front Desk. The end-users only have access to the data linked to their own assets. Indeed, as specified, only France and Spain have access to all the data which is necessary to ensure a hot redundancy in case a center shuts down.

An additional information regarding the services is that for the re-entry analysis, there's nearly 1 re-entry every month or month and a half, depending on the time of the re-entry (total of 8 to 12 per year). The re-entries to be followed are determined according to characteristics defined in a technical document regarding re-entries which may not degrade in the atmosphere.

The Fragmentation analysis is peculiar, handful a year.

Indicator 3

This indicator wasn't specifically mentioned in the Space Regulation but was extracted from the Technical Annex.

The number of sensors for the SST component was 38 in 2021 and 40 in July 2022. This positive trend⁷⁹ confirms a growing interest of the Member States for SSA, which is an essential component of the EU Space Programme and plays a key role in ensuring safety and security of the economies, societies, and citizens in Europe.⁸⁰ The Member States' involvement in the SSA domain contributes to the efficient development of this Component and is confirmed by this increasing number of sensors. In addition, yearly operational reviews have been held aiming to de-scope sensors which are not performing according to the agreed thresholds.

3.3.3.3. Takeaways on the effectiveness of SSA

Overall, the tasks entrusted to ESA related to the NEO segment **are running smoothly**. Only one delay was noted for one of the interventions, the creation of the NEO catalogue, but all the other tasks are going according to the schedule and are **implemented totally in line with the Contribution Agreement's provisions**.

For SWE related tasks, ESA faced a timeline issue regarding the procurement set-up due to procedural constraints. This initial delay **is not expected to have a cascading effect** on other activities because an approach to mitigate this risk has been put in place as explained above, whereby the contractor will deliver the elements needed for the foreseen 2025 SWE service in the middle of the contract. The delay is therefore **not expected to have consequences on the initial service provision**.

As specified, the SST Front Desk has only been transferred recently to EUSPA because of three reasons, external to EUSPA. However, SatCen was operating it before the 1st of July 2023. Even though the tasks entrusted to EUSPA can thus be said to be delayed, the agency **participated actively to ensure a smooth transition** between SatCen and them through regular workshops, meetings and exchanges, in addition of the recruitment process successfully conducted in order to set the technical team for the running of the SST Front Desk operations. Overall, **the transfer was performed smoothly and following the switch-over, the services are being provided as expected**.

The performance of the SSA component was evaluated through 2 KPIs – *the number of users and the availability of services* -, which were not applicable for all the SSA segments since some services are not operational yet. However, **SSA is an essential component of the EU Space Programme and the services that are already operational are performing very well**: the satisfaction rate for the SST segment according to the users' feedbacks gathered in March 2022 was very high: 8.4/10. Regarding the services currently under development (delivered under SWE and NEO components⁸¹), they will have a great **added value for the**

⁷⁹ Regarding the number of sensors, it must be underlined that a lot of sensors have been descope due to the rigorous selection criteria. This approach was taken to ensure that only high-quality sensors are included in the system.

⁸⁰ Decision No 541/2014/EU of the European Parliament and of the Council of 16 April 2014 establishing a Framework for Space Surveillance and Tracking Support

⁸¹ For NEO, only the constitution of the database.

enhancement of the space environment knowledge and will contribute to reinforce Europe's position in this domain.

3.3.4. Benefits assessment of the SSA component

3.3.4.1. Benefits assessment of the SST sub-component

The benefits assessment of SSA builds on research and evaluation from different sources. The analysed impacts come mainly from the 2018 study “An assessment of the possible EU space situational awareness initiative”. Some relevant quantitative impacts have been updated thanks to more recent data. This is the case of the number of satellites in orbit which is the main parameter impacting the probability of collisions. This was updated with recent data taking into account the presence of mega constellations. Other than this, it is expected that the benefits characterized in the 2018 study are still relevant and applicable, covering the full scope of the benefits of SSA today, because the system and service characteristics is the same. This section starts by the identification of impacts and the assessment of their benefits from 2020 to 2035. The last section is a summary of all the identified benefits.

1 Economic impacts

The two most important economic impacts expected to materialize from the SST service, as extracted from the previous SSA impact assessment done by PwC, are the following:

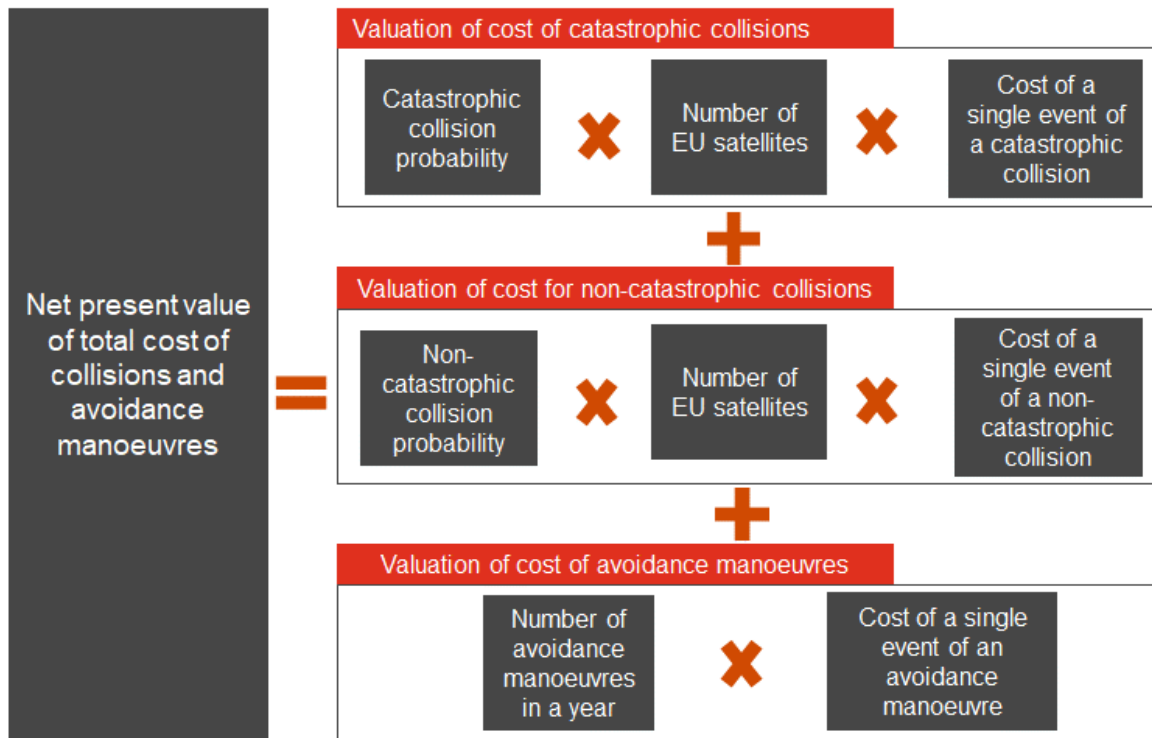
- Reduction in collisions between European spacecrafts and space debris, and in unnecessary collision avoidance manoeuvres (translated into reduction in lost revenue or costs). This impact is considered by far the main driver for SST therefore the largest focus of the IA is on this benefit. This benefit is assessed quantitatively by analysing the different costs linked to collisions and avoidance manoeuvres, and then evaluating the benefits that may be enabled thanks to the SST component. The same approach and modelling that was used in the 2018 study is adopted, however the parameters and the quantitative figures have been updated to account for the emerging trends in the space sector.
- The potential for emergence of new commercial markets for SST services as an indirect economic impact resulting from the evolution of EU SST. This impact is assessed qualitatively as it is still challenging to assess precisely the effects of the SST component on the market and the industry.

Impact 1: Reduced loss of revenues for spacecraft owners and operators (Updated)

Reduced loss of revenues is the main commercial driver for SST as it represents the largest impact. Its assessment is based on the SSA impact assessment study done in 2018. The focus was put in updating this impact thanks to more recent data concerning the projected number of satellites in orbit which takes into account the presence of mega constellations.

The first step of the assessment is based on the valuation of the costs of collisions and avoidance manoeuvres between 2020 and 2035 as shown in Figure 70 below. The collisions can be either lethal or non-lethal, each case having a different cost due to replacement of the satellite or lost revenue for service interruption, and a different probability of happening. Avoidance manoeuvres also have a significant cost to take into account as each manoeuvre reduce the lifespan of the satellite.

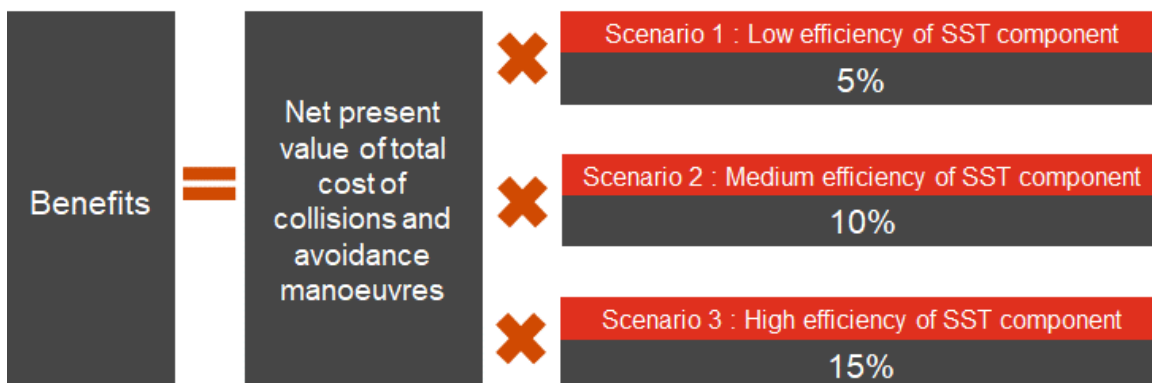
Figure 79: Costs calculation



Once all the costs are calculated, the next step is to evaluate how the SST component of the EC space programme can help in reducing these costs. This cost reduction is precisely the benefit of the SST component for this impact.

To assess this benefit, three scenarios were considered which translate the efficiency of the EC SST component as shown in the figure below.

Figure 80: Benefits calculation



Valuation of cost of catastrophic collisions

Considering the impact description that has been developed above, catastrophic collisions with electrically propelled and chemically propelled satellites in LEO and GEO have been quantified.

A catastrophic collision leads to two impacts:

- Revenue is lost from the interruption in services during the time in which a replacement satellite is built.
- The satellite is replaced sooner than anticipated, with additional investment required to maintain services up to the originally planned satellite lifetime.

In order to understand the baseline costs of catastrophic collisions in a given year, the cost of a single event is multiplied by the probability of this event happening to an EU satellite and

the number of EU satellites. These inputs to the impact valuation are detailed in the following paragraphs.

Cost of a single event: catastrophic collision

Lost revenue is calculated as the average annual revenue of a satellite (electric or chemical, GEO or LEO) multiplied by the number of years of lost revenue. It is assumed that if a satellite is destroyed, a replacement will be commissioned and launched into orbit after **2.5 years**, so that 2.5 years of revenue are lost.

The additional investment cost to replace the satellite is estimated as the annualised cost of satellite manufacture and launch multiplied by the years of life lost by the satellite due to the collision, discounted based on the year using the social discount rate⁸² (4%).

In all calculations, it is assumed that the catastrophic collision occurs at the midpoint of the lifespan of a satellite for those that are in LEO and GEO. The table below outlines the assumptions used for satellite lifespan and annualised costs and revenues.

The revenue assumptions and the satellite lifespan assumptions are provided from PwC analysis based on stakeholder consultation and other PwC studies.

Table 220: Assumed lifespan and annual revenue per satellite⁸³

	Chemical propulsion		Electric propulsion	
	GEO	LEO	GEO	LEO
Lifespan (years)	15	7.5	20	10
Annual revenue (million Euro)	63.84	25.01	43.68	25.01
Annualised investment cost	21.51	13.33	9.81	6.00

The table below shows the cost of a single catastrophic collision in present value terms.

The assumptions about the probability of catastrophic collisions and their extrapolation to 2040 are based on stakeholder consultation and PwC analysis.

Table 221 - Summary of cost of a single event catastrophic collision

(million Euro)	Chemical propulsion		Electric propulsion	
	GEO	LEO	GEO	LEO
Cost of revenue interruption	155	61	126	61
Cost of sooner replacement	140	46	82	27
Total benefit per avoided lethal	295	107	208	88

⁸² The social discount rate compares costs and benefits occurring in different time periods from the point of view of society. Such concept is taken from the European Commission Better Regulation "Toolbox".

⁸³Source: Space Traffic Management - <http://www.unoosa.org/pdf/pres/stsc2008/tech-05.pdf>

collision				

Baseline cost: catastrophic collision probability and number of satellites

The baseline cost is driven by the probability of satellite collision in each year and the number of Member States and Commission satellites in orbit in each year. It takes into account the cost of replacing the satellite and the revenue lost while the new satellite is rebuilt.

The probability of a collision varies between LEO and GEO, as the population of space debris is not evenly distributed among orbital regions. Therefore, it is assumed that the probability of collisions is higher in LEO at an altitude of roughly 800km, as this region has the highest concentration of space debris⁸⁴.

The probability of a collision occurring in an orbit evolves over time, as does the number of satellites in each orbit, and the mix of electric and chemical propelled satellites.

This probability was updated from the SSA Impact Assessment Study (2018) by taking into consideration a new forecast for the number of satellites in orbit between 2020 and 2035. This new forecast specially takes into account the presence of current and future mega constellations.

The following table provides the probability for an EU satellite to have a lethal collision in a given year.

Table 222 - Individual probability for a satellite of a lethal collision occurring in a given year⁸⁵

Orbital regime	2020	2035
LEO	0.000030	0.00033
GEO	0.00000061	0.00000129

Number of EU satellites

The number of EU satellites is expected to increase over time. In addition, the share of satellites with electric versus chemical propulsion is expected to change over time. Satellites with different types of propulsion system have different lifespans, annual revenues and costs, and therefore there is a different level of impact associated with their loss or damage.

The table below shows the assumed number of EU satellites in 2020 and 2035.

Table 223 - Number of EU satellites in orbit⁸⁶

Orbit – Propulsion type	2020	2035
GEO – chemical propelled	74	46
LEO – chemical propelled	106	158

⁸⁴ Source: Space Traffic Management - <http://www.unoosa.org/pdf/pres/stsc2008/tech-05.pdf>

⁸⁵ Equal to the probability of lethal collision divided by the number of satellites

⁸⁶ PwC analysis based on UCS Satellite Database

GEO – electric propelled	3	32
LEO – electric propelled	-	-

Baseline impact of catastrophic collisions

The baseline impact of catastrophic collisions is shown in the table below, in net present value terms. It is achieved by summing the annual cost of catastrophic collisions to EU satellites over the time period 2020-2035. The cost for each year is calculated by multiplying the cost of a single collision, the number of EU satellites in orbit, and the probability for a satellite to have a collision.

Table 224 - Baseline cost of catastrophic collisions between 2020 and 2035

(Million Euro)	Net present value of impact between 2020 and 2035
GEO – chemical propelled	0.24
LEO – chemical propelled	28.93
GEO – electric propelled	0.04
LEO – electric propelled	-
Total	29.22

Valuation of cost for non-catastrophic collisions in LEO and GEO

Some collisions between satellites and debris do not cause catastrophic damage. For the purpose of this exercise, this was modelled as damage occurring to the solar panels of an affected spacecraft. To quantify this impact, it is assumed that this external damage would not directly affect the satellite's ability to process data, but would to shorten the life of the satellite. It is estimated that damage to a solar panel would shorten a satellite's life by 70%. This assumption is based on the analysis of past non-catastrophic collisions events and stakeholder consultation.

The assessment covers two impacts from non-catastrophic collisions:

1. Revenue is lost from the interruption in services during the time that the replacement satellite is built. This is because the life of the satellite is shortened so drastically that even if construction of a new satellite occurs immediately, it will not be ready in time to replace the existing satellite.
2. The satellite is replaced sooner than anticipated, with additional investment required to replace the satellite and maintain service over the original planned satellite lifespan.

Impact 1 is not applicable to GEO electric satellites because the lifespan is longer than the other types of satellite, so the remaining 30% of the lifespan at time of impact is longer than the time taken to build a replacement satellite. Consequently, there is no impact on revenue.

In order to understand the baseline cost of non-catastrophic collisions in a given year, the cost of a single event is multiplied by the probability of this event happening to an EU satellite and the number of EU satellites. These inputs to the impact valuation are detailed in the following paragraphs.

Cost of a single event: non-catastrophic collision

The impact is calculated as the difference in the present value of replacing the satellite sooner versus at the end of its intended lifespan, plus any lost revenue.

Lost revenue is calculated as the average annual revenue of a satellite (electric or chemical, GEO or LEO) multiplied by the number of years of lost revenue. It is assumed that if a satellite is destroyed, a replacement will be commissioned and launched into orbit after 2.5 years, so that 2.5 years of revenue are lost.

The additional investment cost to replace the satellite is estimated as the annualised cost of satellite manufacture and launch multiplied by the years of life lost by the satellite due to the collision, discounted based on the year using the social discount rate (4%).

In all calculations, it is assumed that the non-catastrophic collision occurs at the midpoint of the lifespan of a satellite.

The costs associated with a single event are represented in the following table. These show the net present value of impacts occurring over time as result of a single discrete event.

Table 225 - Summary of cost of a single event non-catastrophic collision

(million Euro)	Chemical propulsion		Electric propulsion	
	GEO	LEO	GEO	LEO
Cost of revenue interruption	15	33	-	24
Replacement cost for lost years of operation	94	32	54	19
Total benefit per avoided non-lethal collision	109	55	54	42

Probability of an event in a given year: non- catastrophic collision

The baseline cost is driven by the probability of satellite collision in each year and the number of EU satellites in orbit in each year.

The probability of a non-catastrophic collision varies between LEO and GEO. It is assumed that collisions follow a random distribution and that therefore all satellites in each orbit have an equal probability of being involved in a catastrophic collision.

The probability of a non-catastrophic collision occurring in an orbit evolves over time, as does the number of satellites in each orbit, and the mix of electric and chemical propelled satellites. The tables below show the assumed probability of a collision occurring to an individual satellite, based on equal probability per satellite, which is applied to EU satellites.

This probability was updated from the SSA Impact Assessment Study (2018) by taking into consideration a new forecast for the number of satellites in orbit between 2020 and 2035. This new forecast specially takes into account the presence of current and future mega constellations.

The following table provides the probability for an EU satellite to have a non-lethal collision in a given year.

Table 226 - Individual probability for a satellite of a non-lethal collision occurring in a given year

Orbital regime	2020	2035
LEO	0.00018	0.00197
GEO	0.000018	0.000038

Baseline impact of non-catastrophic collisions on EU satellites

The baseline impact of non-catastrophic collisions is shown in the following table. It is calculated by summing the annual cost of non-catastrophic collisions to EU satellites between 2020 and 2035. The cost for each year is calculated by multiplying the cost of a single collision, the number of EU satellites in orbit, and the probability for a satellite to have a collision.

Table 227 - Baseline cost of non-catastrophic collisions between 2020 and 2035

(Million Euro)	NPV of impact between 2020 and 2035
GEO – chemical propelled	2.61
LEO – chemical propelled	89.23
GEO – electric propelled	0.34
LEO – electric propelled	-
Total	92.18

Valuation of cost of avoidance manoeuvres

Avoiding a collision by performing an avoidance manoeuvre has two identified impacts:

3. The use of fuel in order to perform the AM (Avoidance Manoeuvre) reduces the lifespan of the satellite, and therefore incremental investment is required to maintain spacecraft operations over the original lifespan of the satellite. This is only applicable for chemical propelled satellites. This is quantified by multiplying annualised investment cost of a satellite by the lost years of operation; and
4. Engineers spend time working on the avoidance manoeuvre, which has an opportunity cost.

In order to understand the baseline cost of avoidance manoeuvres in a given year, the cost of a single avoidance manoeuvre is multiplied by the number of avoidance numbers performed per year and the number of EU satellites. These inputs to the impact valuation are detailed in the following paragraphs.

Cost of a single event: avoidance manoeuvres

It is assumed that the lifespan of a chemical satellite is shortened by **1 day** and an electric satellite has no shortened lifespan.

The hourly rate of an engineer is assumed to be **600€** and the time spent on the preparation of an avoidance manoeuvre in LEO is **9 days**, while in GEO it is **1 day**⁸⁷.

The costs are represented in the following table. These are the net present value of impacts occurring over time as result of a single discrete event.

Table 228 - Summary of cost of a single event avoidance manoeuvre

(million Euro)	Chemical propulsion		Electric propulsion	
	GEO	LEO	GEO	LEO

⁸⁷ Source: Stakeholder consultation with satellite operators

Replacement cost for lost years of operation	0.044	0.032	-	-
Opportunity costs of engineer time spent elsewhere	0.001	0.011	0.001	0.011
Total costs per avoided non-lethal collision with solar panel	0.045	0.042	0.001	0.011

Number of avoidance manoeuvres performed in a given year

The assumed number of avoidance manoeuvres performed per satellite changes in GEO as the number of satellites increases.

This projection is based on an estimate of the current annual number of avoidance manoeuvres, projected to 2035 based on the expected evolution of the number of satellites in orbit and the 2018 SSA impact assessment study.

Table 229 - Number of avoidance manoeuvres per satellite performed in a given year

Orbital regime	2020	2035
LEO	1.75	19
GEO	1.01	2,1

Baseline impact of avoidance manoeuvres

The baseline impact of avoidance manoeuvre costs is shown in the following table. It is achieved by summing the annual cost of avoidance manoeuvres to EU satellites over the time period 2020-2035. The cost for each year is calculated by multiplying the cost of a single avoidance manoeuvre, the number of EU satellites in orbit, and the number of avoidance manoeuvres per satellite performed in a given year.

Table 230 - Baseline cost of avoidance manoeuvres between 2020 and 2040

(Million Euro)	NPV of impact between 2020 and 2035
GEO – chemical propelled	60,4
LEO – chemical propelled	662,5
GEO – electric propelled	1,3
LEO – electric propelled	-
Total	724,3

Monitoring of electric propelled satellites during their orbit-raising phase (Update)

Valuation of cost of potential catastrophic collision of electric propulsion satellites during their ascension toward their operational orbit

Catastrophic collisions with electrically propelled satellites that are on the journey to GEO are quantified in this section. A catastrophic collision has two identified impacts:

5. Revenue is lost from interruption in services during the time that the replacement satellite is built.
6. The satellite is replaced sooner than anticipated, with additional investment required to replace the satellite and maintain service over the original planned satellite lifespan.

In order to understand the baseline costs of catastrophic collisions in a given year, the cost of a single event is multiplied by the probability of this event happening to an EU satellite and the number of EU satellites. These inputs to the impact valuation are detailed in the following paragraphs.

Cost of a single event: catastrophic collision

It is assumed that it takes 2.5 years to build a replacement satellite and send this satellite into orbit. For electrically propelled satellites in GEO, there is an additional 6 months spent travelling to final orbit. While an electric propulsion satellite is journeying to GEO, it passes through LEO and therefore has an increased risk of being hit during this part of its journey.

It is assumed that a catastrophic collision could occur during the 6 months of orbit-raising operations that take place at the beginning of the lifetime of an electrically propelled satellite destined to join the GEO ring.

The benefits are represented in the following table. These are the net present value of impacts occurring over time as result of a single discrete event.

Table 231 - Summary of cost of a single event catastrophic collision during orbit-raising of electric propelled satellite (million Euro)

(Million Euro)	GEO electric on journey
Cost of revenue interruption	115
Replacement cost for lost years of operation	143
Total	258

Probability of an event in a given year: catastrophic collision

The probability of a collision occurring in the orbits that an electrically propelled satellite goes through on its journey towards its final orbit evolves over time. However, an electrically propelled satellite during its orbit-raising phase is mostly exposed to collisions with secondary objects when it passes LEO, as this is the orbital regime containing the most space objects.

This probability was updated from the SSA Impact Assessment Study (2018) by taking into consideration a new forecast for the number of satellites in orbit between 2020 and 2035. This new forecast specially takes into account the presence of current and future mega constellations.

The following table provides the probability for an electric satellite to have a catastrophic collision in its raising phase.

Table 232 - Individual probability for a satellite of a lethal collision occurring in a given year⁸⁸

Orbital regime	2020	2035

⁸⁸ Source: Stakeholder consultation and PwC analysis

GEO electric propelled satellite during orbit raising	0.000011	0.0000095

Number of EU satellites

The yearly number of EU satellites that are based on electric propulsion and sent to GEO will evolve. The estimations of the evolution comparison between 2020 and 2035 are provided in the following table.

Table 233 - Number of EU satellites

	2020	2035
Electric propelled satellites on journey to GEO	1	5

Baseline impact of catastrophic collisions

The baseline impact of catastrophic collisions is shown in the following table. It is achieved by summing the annual cost of catastrophic collisions to EU electrically propelled satellites on journey toward GEO. The cost for each year is calculated by multiplying the cost of a single collision, the number of EU electric propelled satellites in journey to GEO, and the probability for a satellite to have a collision.

Table 234 - Baseline cost of catastrophic collisions between 2020 and 2035

	Net present value of impact between 2020 and 2035
Electric propelled satellites on journey to GEO	EUR 0.10 M

Valuation of cost of potential non-catastrophic collision of electric propulsion satellites during their ascension toward their operational orbit

There is a possibility that a piece of debris damages only the solar panels of an electric propulsion satellite on its way to GEO. This external damage would not directly affect the satellite's ability to process data, but would be very likely to shorten the life of the satellite. It is estimated that damage to a solar panel would shorten a satellite's life by **70%**.

A non-catastrophic collision during an orbit-raising phase would lead to the satellite being replaced sooner than anticipated.

In order to understand the baseline cost of non-catastrophic collisions in a given year, the cost of a single event is multiplied by the probability of this event happening to an EU satellite and the number of EU satellites. These inputs to the impact valuation are detailed in the following paragraphs.

Cost of a single event: non-catastrophic collision

It has been assumed that the collision would occur during the electric propulsion satellite orbit-raising phase, which take place at the very beginning of the satellite's lifetime.

The costs associated with a single event are represented in the following table. These are the Net Present Value of impacts occurring over time as result of a single discrete event.

Table 235 - Summary of cost of a single event non-catastrophic collision for an electric propelled satellite during orbit-raising

	GEO electric on journey

Replacement cost for lost years of operation	EUR 86 M

Probability of an event for an individual satellite

The probability of a collision occurring in the orbits that an electric propulsion satellite goes through on its journey towards its final orbit evolves over time. However, an electric propelled satellite during its orbit-raising phase is mostly exposed to collide with a secondary object when it passes LEO, as this is the orbital regime containing the most space objects.

This probability was updated from the SSA Impact Assessment Study (2018) by taking into consideration a new forecast for the number of satellites in orbit between 2020 and 2035. This new forecast specially takes into account the presence of current and future mega constellations.

The following table provides the probability for an electric satellite to have a non-catastrophic collision in its raising phase.

Table 236 - Individual probability for a satellite of a non-lethal collision occurring during orbit-phase

Orbital regime	2020	2035
GEO electric propelled satellite during orbit raising	0.000058	0.000054

Baseline impact of non-catastrophic collisions

The baseline impact of non-catastrophic collisions is shown in the following table. It is calculated by summing the annual cost of non-catastrophic collisions to EU electrically propelled satellites on journey toward GEO. The cost for each year is calculated by multiplying the cost of a single collision, the number of EU electric propelled satellites in journey to GEO, and the probability for a satellite to have a collision.

Table 237 - Baseline cost of non-catastrophic collisions between 2020 and 2035

	Net present value of impact between 2020 and 2035
Electric propelled satellites on journey to GEO	EUR 0.19 M

Assessment of the impact benefits

As it appeared challenging to translate precisely the performance increase and difference brought by the EC SST segment, three scenarios assuming low, medium and high decreases in the probability of collision and reductions in the number of avoidance manoeuvres have been defined. It is important to note that these assumed scenarios intend to show what can be expected within three different degrees of performance increase. The following table summarises the key dimensions of the scenarios that have been analysed for improvements in SST.

Table 238 - Definition of scenarios

Scenario	Definition
Baseline	Business as usual
Low	5% decrease in probability of collision and 5% reduction in the number of avoidance manoeuvres required per year

Medium	10% decrease in probability of collision and 10% reduction in the number of avoidance manoeuvres required per year
High	15% decrease in probability of collision and 15% reduction in the number of avoidance manoeuvres required per year

The following tables show the benefits that could be achieved under these scenarios compared to the baseline.

Table 239 – Total Net present value of impacts

Scenario	NPV of total cost of collisions and avoidance manoeuvres between 2020 and 2035
Baseline	EUR 845.96 M

The following table provides the difference between the baseline and the three different scenarios that were assumed. In other terms, the benefit of each scenario is the difference in costs associated with each scenario and the baseline (money saved).

Table 240 - NPV of benefit of three scenarios between 2020 and 2035

Scenario	NPV of benefit of three scenarios between 2020 and 2035
Low (5% decrease)	EUR 42.3 M
Medium (10%)	EUR 84.6 M
High (15%)	EUR 126.9 M

Impact 2: Impact on the potential emergence of a commercial market for SST services (Not updated)

This section examines the impacts that the evolution of EU SST would have on the emergence of a commercial market of SST services through a set of three cases. It worth mentioning that the aim of this paragraph is to illustrate the point that the impact on the emergence of a commercial market for SST may vary depending on the implementation and set up of the EU SST initiative. Though giving some relevant inputs, the following analysis is not a comprehensive assessment of various governance approaches for EU SST, as it was not in the scope of this study.

The first case assumes that EU SST services are provided as they are today by the SST Consortium; the second case examines the impacts that would derive from having a first level service provided by EU SST that would be free of charge, and a second level service offering tailored solutions to satellite owners and operators that would be provided by the commercial sector and paid for by users. Finally the third case considers a service that would be fully provided by the private sector on behalf of the European Commission or through private-public partnership. This analysis aims to provide an overview of the different impacts that could potentially arise from these three cases.

The first case assumes that the status-quo is kept, and maintains the current involvement of the public sector in SST activities. The participating MS to the SST Consortium remain in charge of providing services to users, and undertake activities across the SST services' value chain. SST services would remain free of charge. Certain part of the process, service or maintenance of infrastructure could be even outsourced to private companies by the SST Consortium, fostering a market at an intermediate level (private sector works for the SST Consortium not for the end users), which is already the case for certain MS such as Spain,

which outsources activities to GMV and INDRA. Additional MS that may enter the SST Consortium would also outsource activities to private suppliers. In Poland, for example, the private sector acts on the sensor's development and delivery segments, as well as on the processing function and service delivery.

In terms of impact on the emergence of an SST commercial market targeting the end users (i.e. satellite operators), it is important to note that the provision of EU SST services fully assumed by the SST Consortium may jeopardise the development of EU private initiatives, especially for services concerning the GEO orbit where companies such as ArianeGroup have developed observation solutions that could be commercialised (GeoTracker). For this purpose, the DG DEFIS in close collaboration with the European Space Surveillance and Tracking (EU SST) Consortium organised the European Union Industry and Start-ups Forum on STM (EUISF)⁸⁹ in 2022 aiming to establish a Forum to foster the innovation and competitiveness of the SSA's commercial sector to achieve a higher level of strategic autonomy in Europe.

However, envisaging an ecosystem where the procurement of SST services would be fully based on the commercial sector only may appear unreasonable. First, because the willingness to pay for a service that has been so far provided for free is really low. Therefore, the service will have to offer a high added value, which could be one of reasons why for example ArianeGroup has chosen to develop its commercial services in GEO where the free offer (JSpoC) is less efficient. At the time of this report, it seems that ArianeGroup has sold its GeoTracker product to one customer: the French Joint Space Command⁹⁰. Second, in order to survive, commercial SST service providers will have to sell their product for a price, and small satellite operators may be unable to afford this kind of services and rather stay blind on their situation in space. That would be a threat for the whole safety of the space environment. Thirdly, some countries with already existing SST capabilities may not wish to go for private providers, and close their own capabilities. For these three reasons, relying purely on commercial offers for the procurement of SST services seems unlikely, as the market size would not be large enough to enable sufficient revenues for SST providers.

That is why a model with two level of services - a basic one for free, and a second one with high value added and where companies can be profitable - seems to be a promising alternative.

The second case examines an alternative to the first one by assuming that a more important role is given to the private sector. Since users would be reluctant to pay for services that have been so far been delivered free of charge, a clear definition of boundaries across the services' value chain, splitting services in two levels, would consolidate the provision of basic SST services such as Collision Avoidance, Re-entry and Fragmentation. This could allow the development of value added services that would be commercialised by private entities. In this case, the private market would remain open to new innovative actors.

Putting aside the potential reluctance of certain satellite operators to provide their data to private service providers (see above), it was suggested during stakeholder interviews that the demand for value-added SST services (second level) provided for a fee, could be driven by two needs:

⁸⁹ Link : https://defence-industry-space.ec.europa.eu/inaugural-event-european-union-industry-and-start-forum-stm-26-april-2022-09h00-12h15-brussels-2022-04-13_en

⁹⁰ <https://www.safran-group.com/media/arianegroup-becomes-key-player-space-surveillance-french-joint-space-command-20171218>

- Need for the monitoring of electrically propelled satellites during their orbit-raising operations. This kind of service has been proposed by AGI to support Boeing in the launch of two all-electric propulsion satellite⁹¹.
- Need for support to station-keeping operations and calibration. As mentioned earlier, it can be difficult for satellite operators to know exactly their absolute position in space.

Concerning the willingness to pay for value added services such as tracking system calibration for station-keeping operations, satellite operators have expressed that they would be ready to pay between USD \$1,000 and USD \$3,000 per satellite⁹² as one-off support (it has to be noted that such a tracking system calibration would only be required for new satellites).

The SDA adopted the same kind of model, by proposing to its members to have access to the JSpOC data and all the data of the other satellite operators, powered by a reliable software provided by AGI and in a service-oriented manner. The SDC 2.0 should provide added value to the SDA members as it can provide data on object smaller than 1m for example. However, the implementation of this new SDC has led to an increase in SDA price, which was not welcomed by all its members. The price to enter the SDA includes an entry fee depending on the level of membership and an additional fee depending on the size of the operator's fleet. The price list is presented below; the prices are per year.

Figure 81 – SDA annual membership fees⁹³

Membership fees		Cost per number of satellites	
Executive Director	\$ 30,000	1-5	\$ 5,775
Standard Member	\$ 7,500	6-10	\$ 17,325
Satellite Manufacturer/LV Provider	\$15,000	11-20	\$ 23,100
Civil Government Participant	\$15,000	21-30	\$ 28,875
Small Sat LEO Fleet (Uncontrolled)	\$ 7,500	31-40	\$ 34,650
		41-50	\$ 40,425
		51-60	\$ 46,200
		>60	\$ 57,750

Finally, the third case assumes that EU SST services would be fully supplied by the private sector, with the EU establishing direct partnerships with identified specialised companies. Such alternative could follow multiple schemes, from direct procurement to public-private partnership (PPP), and could help unleash new capabilities, technologies and methods to collect, process and manage SST data more rapidly than currently done by public actors. In any case, the services should be offered free of charge to final users, so small satellite operators could benefit for these services and large satellite operators benefit from value added services compared to the services already provided by SDA and JSpOC. However, the materialisation of this case would not be built upon the existing MS capabilities and capitalise on the investments and upgrade of capabilities made within EU SST. Private-public partnership could overcome these drawbacks but MS may be unwilling to enter in this kind of agreement as they own and control the EU SST assets.

The following figure summarises the different cases/alternatives considering the potential involvement of the private sector.

⁹¹ pacenews.com/boeing-is-customer-no-1-for-agis-comspoc-service/

⁹² Source: Stakeholder consultation

⁹³ Source: SDA Website

Figure 82: Summary of cases/alternatives considering the potential involvement of the private sector

Examined Cases/alternative	1st level service provision (CA, RE, and FA)	2nd level service provision (Value-Added-Services)	Service provision fees	Consequences on private sector initiatives
EU SST service provided as they are today	Provided by Consortium	Provided by Consortium	1st & 2nd level free of charge	Might be jeopardised
Service provision split into two levels	Provided by Consortium	Provided by private sector	1st level free of charge Commercialised 2 nd level	Might lead to the development VAS capabilities
Procurement of EU SST services from the private sector, possibly through a PPP	Private sector (full procurement, PPP, etc.)	Private sector (Full procurement, PPP, etc.)	1st level free of charge Commercialised 2 nd level	Might unleash new technologies, capabilities increasing efficiency

A sound development of EU SST capabilities will have to be formed with a relevant share of activities between public and private entities. Further investigation of the cases developed above will have to be considered and carefully addressed in order to avoid impeding the evolution of EU private entities on the SST solution market, whilst capitalising on past investments and efforts that have been made so far to support the development of existing EU SST capabilities. The right balance needs to be established between security and intelligence issues, and the maximisation of potential returns on investments reached from the commercial provision of SST services. Should this balance be found, business and scientific opportunities to cooperate with the EU SST would be extremely beneficial both for the quality of SST services and for the creation of an extra revenue stream. As previously discussed, such analysis merits particular attention and could be developed further in a dedicated governance analysis.

Impact 3: Impact on the risk of losing all the space assets (Kessler effect)

In a 2017 PwC study for the European Commission about the cost of no-Space, the impact on the economy of the EU-28 due to the loss of all assets in Space (EU assets and foreign assets) was estimated to be between **EUR 36.2 B (low estimation) and EUR 53.3 B (high estimation) of yearly GVA loss**. This estimation includes all the downstream sectors with direct dependence on space assets (GNSS, Space telecommunication, space EO) and indirect dependence (agriculture, forestry, transport....).

The exponential increase of the number of satellites and debris in orbit significantly increases the risk of the Kessler effect. The consequence of such an incident is the immediate shutdown of all the services depending on space assets. For the EU and UK, this will lead to a total GVA loss **EUR 36.2 B (low estimation) and EUR 53.3 B (high estimation)** per year.

An efficient and reliable SST service can be a strong way to help reducing the risk of a collision leading to a Kessler effect and thus avoiding the critical consequences on the EU GVA. Quantitatively, the SST subcomponent can help reducing the risk of losing between **EUR 36.2 B (low estimation) and EUR 53.3 B (high estimation)** per year of the total GVA in the EU and the UK.

Of course, SST can't alone make the EU avoid the losses due to the Kessler effect. Other mitigation scenarios are also tested such as debris cleaning missions for example.

2 Strategic impacts

Strategic impacts are mostly linked to EU leadership and strategic autonomy. There are two main impacts in this category: An increased safety of strategic EU owned space assets against both passive and active threats and a stronger role in the monitoring of international

guidelines on the safe use of space. These two impacts were assessed qualitatively as quantitative data regarding the SST components effects on these impacts isn't available.

Impact 1: Increased safety of strategic EU owned space assets against both passive and active threats (not updated)

Ensuring the safety of EU space infrastructure is one of the main drivers of the development of EU SST. Space infrastructure can be threatened in two ways:

- By space debris that cannot be controlled: their trajectory, velocity or size can be determined, however they cannot be manoeuvred to avoid a collision. With the number of debris increasing every year, space assets appear more at risk. An improved Space and Surveillance Tracking (SST) system can help protect space assets by giving precise information on the risk of collision, enabling satellite operators to take avoidance actions.
- By operated space objects that can act in an aggressive or unfriendly manner. Indeed, certain space assets fall within the domain of security and defence: navigation satellites such as the Galileo constellation or national military satellites for Earth Observation or intelligence activities. The development of EU SST capabilities should be considered to protect the strategic EU and national assets from potential risks, such as other satellites spying on or degrading EU satellites or their mission for example.

This second risk is particularly sensitive, but it has to be included in EU SST, given the important aspect of national sovereignty and the need of taking into account both civil and military interests in the SST domain. When considering the potential rise of geo-political tensions and the different gaps and ambiguities remaining in the legal framework of space activities, the risk of being confronted with controlled and voluntarily harmful satellites must not be excluded. As an example, French satellites have recently been approached in orbit for inspection by foreign governments⁹⁴. Therefore developing EU capability to detect and identify the suspect of an unfriendly act, and more generally, to track space activity, is an essential condition for the protection of infrastructures. This kind of information will not be provided by the US CDMs.

An increased EU autonomy in terms of surveillance capabilities to identify and detect voluntarily harmful threats can be perceived as an important strategic driver towards the protection of EU space assets. The European Union SST would therefore support this endeavour.

Impact 2: Stronger role in the monitoring of international guidelines on the safe use of space

The Space Strategy for Europe has clearly identified the proliferation of space debris as a serious threat to global and European space assets. In order to reduce the spread of debris, mitigation measures must be reinforced and their effective application must be controlled and verified. In that sense, a better knowledge of the nature and origin of space debris would be greatly supported by increased observation capabilities.

Even though best practices aimed at limiting the creation of additional space debris are encouraged among the global space community, the proliferation of space debris is still increasing as specified in section 4.3.4.1.1. The reasons explaining the difficulty to stem the global increase of space debris are twofold and cannot be exhaustively addressed with the current set of global SST capabilities. Firstly, even though measures aiming at limiting the creation of debris exist, these are not unanimously followed by the space community. The mitigation guidelines introduced by the Inter-Agency Space Debris Coordination Committee

⁹⁴ "Foreign governments are approaching French satellites in orbit", www.defencenews.com, January 2018.

(IADC), whose purpose is to promote best practices limiting the proliferation of space debris, are a set of standard mitigation measures that all major space agencies have recognised⁹⁵. These guidelines specifically provide best practices for space debris mitigation to be applied during all the milestones of a space mission's lifetime, from mission planning and design to satellite disposal. However, it sometimes appears that these best practices are not always followed due to technical reasons, or perhaps financial reasons. Indeed, satellite owners and operators might have an incentive to avoid performing certain activities that are recommended in order to avoid running the risk of creating additional debris, as these activities come with the set of costs detailed in the economic impacts that have been developed in the precedent section. On a side note, improved SST capabilities providing information that is more precise would support satellite operators in finding cheaper solutions that would be also compatible with mitigation guidelines. For instance, delivered in a timely manner, the information signalling a potential collision threat may enable satellite operators to synchronise secondary objects avoidance manoeuvres with station keeping operations that are regularly repeated during a satellite's lifetime in orbit. Debris mitigation guidelines are not strictly implemented and followed since none of them are legally binding. In other terms, it is currently difficult to issue any sort of sanctions against a satellite owner and operator who have voluntarily refused to apply debris mitigation measures. Secondly, the debris population increase in the three most exploited orbital regimes (LEO, MEO and GEO) are due to a growth of space activities. Such an upsurge is expected to be exacerbated in the coming years with the potential deployment of mega-constellations primarily instigated by commercial actors who benefit from cheaper and simplified access to space solutions⁹⁶. Such a trend highlights the fact that traditional barriers to entry, which until now have been characterized by the difficulties and constraints linked to initiating any type of space activity, are being diminished, opening the sector to new entrants that are not necessarily educated and sensitive to debris release mitigation best practices.

By developing stronger observation capabilities, the EU would be able to address the issues that have been developed in the paragraph above. The legal gap that make it difficult to require all space actors to strictly follow debris mitigation measures is created by the fact that with current global observation capabilities, it is difficult to collect proof that satellite owners and operators have intentionally tried to circumvent these measures. This is the main reason explaining the fact that these mitigation measures cannot be transformed into binding legal obligations. Furthermore, should certain trends, such as the deployment of mega-constellations and small-satellites, be confirmed, then there will be a strong need to put in place a robust legal regulation for space traffic management. Should the EU decide to play a prominent role in ensuring the safe use of space, then it should develop efficient observation capabilities that would be one of the main tools supporting the monitoring of sound and secured space activities.

3 Social Impacts

Social impacts relate to 3 main impacts: The spill over effect of knowledge investment, the job creation resulting from investments made to implement and develop EU SST, and the improved safety of people through better assessment of the land area in case of re-entry. These three impacts were assessed qualitatively as quantitative data regarding the SST components effects on these impacts isn't available.

95 IADC Members: ASI (Italy), CNES (France), CNSA (China), CSA (Canada), DLR (Germany), ESA (Europe), ISRO (India), JAXA (Japan), KARI (South-Korea), NASA (United States), ROSCOSMOS (Russia), SSAU (Ukraine), UKSA (United Kingdom). (Source: IADC website <https://www.iadc-online.org/>)

96 <https://www.satellitetoday.com/innovation/2018/05/07/space-situational-awareness-in-the-era-of-megaconstellations/>

The safety and security of EU citizens rely heavily on space-based applications such as communication, navigation, and Earth observation. The infrastructure that makes these activities possible are facing an increasing risk of collision with space objects. Developed EU SST will improve the information needed to avoid lethal collisions with strategic assets and will help provide on-time information to a variety of stakeholders in charge of the safety and security of people on Earth and in the space.

The fact that some objects could re-enter the atmosphere and collide with Earth also poses a threat to the safety of people. Most debris burns up entirely while entering the dense layer of the atmosphere at about an 80km altitude, but large debris such as rocket bodies and inactive satellites, and in some instances smaller debris such as titanium spheres and steel tanks, can survive re-entry and reach the Earth's surface.

Although some debris reaches the Earth's surface, the probability of debris hitting a person is extremely low. The chance is estimated at 1 in 1 trillion and the person involved in the only reported case in history (Mrs. Williams in 1997) was not injured⁹⁷. Until now, no fatalities or economic damages to infrastructure have been reported. This is mainly because around 75% of the Earth's surface is covered by water and only 25% of the Earth's land is inhabited.

Some debris weighing from a few tens of kilogrammes up to a few hundred kilogrammes each have been found on the Earth's surface, including in the vicinity of a nuclear power plant, a motorway, a village and inside the fields of a farm, but there was only one occasion where a debris item hit a property (based on study research). In March 2002, a 49 kg debris from the third stage of a European Ariane 3 launcher landed on a house in Uganda, but no damages or injuries were reported⁹⁸.

As suggested by the previous paragraph, the probabilities of fatalities happening are low, but not zero. This is one of the reasons why a team of experts, led by the International Association for the Advancement of Space Safety (IAASS), has launched a project called ADMIRE for Aviation – (Space) Debris and Meteorites Integrated Risk Evaluation⁹⁹. This project aims at becoming an integral part of aviation safety procedures that have been reassessed following the release of the final report of the CAIB (Columbia Accident Investigation Board) in 2004. This report released by the US Federal Aviation Administration (FAA) assumed that “any impact anywhere on a commercial transport by debris of mass above 300 grams would produce a catastrophic accident: all people on- board would be killed”¹⁰⁰.

The region of space is currently not surveyed as much as other parts of Earth's environment (oceans, sky, etc.). The more SST systems, and especially radar stations, are available at different sites around the globe, the more effectively re-entering objects can be tracked during descent, and better, more reasonable re-entry assessments can be made.

Thus, SST system information and data combined with trajectory predictions can lead in principle to proactive measures such as:

- **Controlled re-entry:** to evacuate a certain area of the ocean by stopping air and sea traffic along the calculated impact footprint for safety reasons.

97 Source: Aerospace corps, centre for orbital and re-entry debris website

98 Source: Aerospace Corporation, Summary of Recovered Re-entry Debris, 2014

99 Source : <http://www.spacesafetymagazine.com/space-on-earth/malaysia-flight-370/space-debris-meteorite-forecast-safer-aviation/>

100 Source : <http://www.spacesafetymagazine.com/space-debris/falling-satellite/aircraft-are-vulnerable-to-small-space-debris/>

- **Uncontrolled re-entry:** to alert local authorities over the impact footprint as necessary, or take extreme measures such as in the well-known case of USA 193, when in 2008 the US Department of Defence decided to shoot-down by missile its satellite at time of descent (about 250km altitude), in order to avoid risk of casualty from a re-entry that was calculated to exceed the probability threshold of human fatality of 1:10.000.

Moreover, the highest debris spatial density is in the LEO region where the International Space Station (ISS) is situated. The ISS is permanently inhabited, and periodically hosts EU astronauts. It is regularly threatened by debris and the ISS performs approximately 2 to 3 debris avoidance manoeuvres per year (5 avoidance manoeuvres were performed in 2014, a record year). SST systems will also enhanced the safety of the EU astronauts on board.

Impact 2: Knowledge investment (research and innovation)

EU funding for research and innovation is focused on strategic objectives, which include supporting an "Excellence science"¹⁰¹ and making EU a more attractive location to invest in research and innovation. The activities dedicated to the improvement of the surveillance and tracking of space debris in all scenarios are contributing to knowledge investment (R&D) in different degrees.

Safeguarding EU infrastructure will require not only scientific knowledge and understanding of the complex orbital environment, but also the development of the latest technological equipment that will be used to conduct research at the highest level.

The importance of knowledge investment is not limited to the scientific and technical progress to foster competitiveness. Although the German, French and UK national tracking sensors are capable of tracking objects in the order of 5 cm in LEO and of 50-70 cm in GEO and these capabilities could be considered as performant as US capabilities¹⁰², EU still has a wide technological gap with the US in survey capability due to sensors' performance limitations in LEO. This gap is also extended to the cataloguing capability and will be more pronounced once the second-generation space surveillance system Space Fence will be operational.

Knowledge investment could diminish EU dependence on US SST data. Currently, more research is needed to improve the knowledge in space objects population, develop mathematical models to understand the space objects behaviour and environment, and to supervise their evolution and fragmentation. Following the objectives expressed across the Space Strategy for EU, and in order to preserve the space environment and its future exploitation, it is essential that this knowledge be generated to support further space policy decision makers.

Moreover, it is well known that some of the benefits of knowledge investment are related to spillover effects resulting from being a world-renowned research cluster. In today's competitive environment, EU could benefit from an increased visibility of its SST technological developments, attracting an international skilled workforce willing to develop their research in an environment with technological and scientific dynamism. Talent attraction and labour market pooling are critical in developing synergies among the scientific community and are perhaps the main assets in the knowledge economy.

Impact 3: Job creation

A workforce encompassing the Science, Technology, Engineering and Mathematics (STEM) fields will be needed to apply the latest findings from science and research to projects of EU

101 Source: http://europa.eu/rapid/press-release_MEMO-11-848_en.htm?locale=en

102 Source: PwC, Strategy&. An ex-ante cost benefit analysis of the SSA program. Europe's SST technology/operational gap and strategic dependencies overview, 2016

SST. The establishment, operation and evolution of the three SST functions require scientists and technicians. Networking of ground-based or space-based sensors that collect data to survey and track space objects, processing and analysing this data to produce information and products and finally, providing SST services to the EU user community are all functions that require skilled employment.

The development of new sensor assets (radars, telescopes, laser stations) will trigger more job creation. The design, manufacturing and construction of these assets will support not only high-wage specialized jobs but also other jobs through the European Union due to indirect and induced economic demand.

In addition to the jobs directly created by the development of new sensors assets, there will be jobs created through the SST service value chain, which is broken down into: i) sensors and data centres manufacturers (industry), ii) sensors and data centres operators (institutions), iii) service providers (institutions) and iv) value-added-service (VAS) providers (typically institutions, although in the US a few industry players are emerging)¹⁰³.

4 Environmental impacts

Environmental impacts are mostly related to the reduction of fragmentation caused by the collision of two space objects in order to preserve the space environment and its usage and the protection of the environment against the risk of the re-entry of decaying satellites build potentially containing toxic components. These impacts were both assessed qualitatively as quantitative data regarding the SST component effects on these impacts isn't available.

Impact 1: Reduction of fragmentation

As depicted in the Kessler syndrome, once the amount of debris has attained critical mass, the number of debris will continue to increase exponentially without the possibility of taking any pre-emptive actions anymore. It is a chain reaction, as collisions will lead to an increase in the number of debris, itself leading to a rise in collision risk.

In 2016, a game theory based simulation estimated the population of debris in LEO to increase from the current 20,000 to 60,000 objects in the next 150 years due to the effects of fragmentation¹⁰⁴. As such, strong actions must be taken to reduce the speed of this debris increase, in order not to reach the point of no return. Indeed, the reliance on space activities has grown in the past decades, with more and more satellites being launched into space, resulting in the creation of a dependency from some sectors on space assets.

There are two main causes to the increase in the number of space debris:

- Collisions between two space debris (i.e. non-operational former satellites, thus that cannot be controlled anymore, or space rocks)
- Collisions between space debris and active spacecraft

Considering there currently exists no technique to remove debris from space or to displace them into further orbits, the only solution to have an impact on the evolution of the number of debris is to reduce the fragmentation resulting from the second type of collision; that is to say from space debris colliding with active spacecraft. This requires an improved Space and Surveillance Tracking (SST) in order to survey more debris and to warn spacecraft operators in enough time so that they can respond appropriately.

103 PwC, Strategy&. An ex-ante cost benefit analysis of the SSA program. SST Impacts, SST service value chain, 2016

104 Source: Klima, Richard et al. (2016): Space debris removal: A game theoretic analysis, Games, ISSN 2073-4336, Vol. 7, Iss. 3, pp 1-18.

The SST initiative should thus contribute to the control of the evolution in the number of space debris.

Impact 2: Environmental protection

Space objects pose a risk to Earth's environment when considering the re-entry of satellites, rocket stages, or other fragments. Those components that survive the re-entry process could potentially have a negative effect on the environment, including causing damage such as fires, or introducing toxic material.

Re-entry of space debris happens due to the natural decay of an orbit; all objects orbiting the Earth are attracted by the gravitational field and hence will re-enter the Earth's atmosphere given enough time (uncontrolled re-entry). This is not an uncommon occurrence - an average of two small (tracked) debris objects re-enter Earth's atmosphere each day, whilst those objects of around 1 m or above re-enter around once a week. Large items of debris, such as scientific satellites, only enter back into the atmosphere a few times per year. Furthermore, approximately 75% of all large objects ever launched into space have already re-entered, as they do not last nearly as long in orbit as smaller ones. Usually, space debris will burn up within the dense layers of the atmosphere, at an altitude of around 80km.

Approximately 10-40% of a satellite's mass will survive re-entry, although the specific percentage will depend on the shape, size and mass of the object, as well as the materials used in its manufacturing. The debris that survives will hit the surface within the 'impact footprint', which can be several hundred kilometres in length and around 20-40 km wide. It is difficult to predict where exactly this footprint will fall, and therefore how to mitigate the environmental impacts.

Most environmental damage from space debris re-entry has been considered negligible. However, there are eight known cases involving either the dispersal of radioactive (e.g. Uranium 235) or toxic (e.g. hydrazine) waste across the Earth's surface, as shown in the table below:

Table 241 - re-entry events causing potential environmental impacts

Re-entry Event	Country of Registration	Environmental Impact
Transit-5BN-3 April 1964	USA	~1kg plutonium-238 (17 kilocuries) vaporized, raining down on all continents for 10 years (latitudes: 25% northern, 75% southern)
Nimbus-B1 May 1968	USA	Contained 1.9kg plutonium-238 within two radioisotope thermoelectric generators (RTG), both were recovered intact
Apollo 13 April 1970	USA	RTG containing 3.8kg plutonium-238 sank intact to bottom of Tonga trench (Pacific, near New Zealand)
Kosmos 954 January 1978	USSR	Scattered 50kg of Uranium-235 in atmosphere and over 125,000 sq.km of northern Canada, prompting an extensive clean-up operation over 8 months (Jan.-Oct.1978) – only 1% recovered
Kosmos 1402 January 1983	USSR	Nuclear powered (31+kg Uranium-235), disintegrated – remains fell in Indian Ocean, no known debris
Mars 96 November	USSR	Four batteries containing 0.2kg Plutonium contaminated 26,000 sq.km in Chile, including

1996		watershed areas
USA-193 (NRO) February 2008	USA	Destroyed by missile at altitude of 246km. It possessed a 450kg tank of hydrazine and reported the spacecraft contained beryllium, a toxicity hazard when pulverized.
Phobos Grunt January 2012	Russia	7500kg of hydrazine and nitrogen tetroxide

The most severe environmental event was in 1977, when the Russian reconnaissance satellite Kosmos 954 deviated from its intended orbit and into an uncontrolled flightpath. The system designed to inject the on-board nuclear propulsion system, which used Uranium 253, into a safe disposal orbit failed. When the satellite re-entered the Earth's atmosphere, it left an impact footprint of over 125,000 square kilometres across northern Canada. Operation Morning Light was conducted between the US and Canada, taking over half a year to clear the highly radioactive material. Moreover, some of these debris pieces were lost to nature – they became embedded in the ice of the Great Slave Lake, and then sank to the bottom of the lake when the ice melted. Nuclear reactors such as the one in Kosmos 954 are no longer used for satellites in LEO however, and so the risk of a similar event occurring is low.

Mission failures can cause risk of pollution by toxic chemicals also, such as in the case of Phobos Grunt. This sample-return mission was stranded in LEO and subsequently crashed back on Earth, still carrying 7.5 metric tonnes of highly toxic hydrazine and nitrogen tetroxide. Whilst it was likely these compounds would burn up in re-entry, there was a risk that it could contaminate the impact area. In March 2018, there was a high concern over the Chinese Tiangong-1 space lab, which was expected to make an uncontrolled re-entry. The hydrazine on-board had the potential to survive re-entry and therefore scatter dangerous fragments across an unknown impact footprint until the very last hours prior to the station's re-entry.

Other environmental impacts include the potential to set off fires, such as in June 2017, when falling fragments from a rocket's discarded first stage, following a successful launch at the Baikonur Cosmodrome in Kazakhstan, set off a fire thanks especially to the weather conditions.

In general, re-entering objects pose a marginal risk to humans and infrastructure, considering the Earth's surface constitutes 75% water and much of the landmass is uninhabited. However, this does not take into account the potential for debris to land in conservation areas and other environmentally significant zones, which could then be at risk from contaminants or other damage. For example, in Canada there has been controversy over the dumping of a Rokot's second stage, which contained hydrazine-based fuel and was expected to impact in the North Water Polynya. This area is an important habitat for a vast array of bird and marine mammals, upon which the Inuit community rely on for food, and whilst it was unlikely the unspent fuel would survive re-entry, there was still concern over the unknown impact this type of debris could have after being dumped in the area.

Understanding the environmental impacts of space debris will hopefully lead to more spacecraft operators performing controlled re-entries, aiming to avoid most of these concerns. However, sometimes it is impossible to avoid an uncontrolled re-entry, in which case it is useful to be able to track the re-entry of any large debris, in order to understand where it will impact and what mitigation tactics need to be utilized if there is a danger to the environment. The more an object is tracked, the easier it is to have a clearer picture of its orbital movements and impact zone.

To this purpose, SSA has the potential to produce a positive effect. With an upgrade of current assets, the introduction of new tracking sensors and surveillance sensors, the EU will have the ability to track a particular debris and model the re-entry with more precision. Improved re-entry models would enable better preparedness in case of a re-entry of large and/or toxic space objects and therefore take adequate measures to protect the environment and mitigate the potential negative effects of such event.

3.3.4.2. Benefits assessment of the SWE component

This section aims at presenting the main sectors that would be affected in case of a space weather event. As previously defined, there are three types of events that could cause damages: ionospheric disturbances, geomagnetic storms and solar radiation storms. Several domains have been listed as being potentially directly or indirectly concerned by the impacts of SWE. Indeed, either the infrastructure, operations or service provision of an industrial domain are directly affected (e.g. degradation of navigation satellite signals, change in flight latitude, etc.); or the impact is indirect, meaning that, following direct disturbances of the functioning of operations or of service provision of some space activities, other domains reliant on these are affected (e.g. the degradation of navigation satellite signals affects maritime operations). The following figure presents the directly and indirectly impacted domains, with the priority ones in red, other domains affected in orange, and domains in grey that are negligibly affected and will therefore not be dealt with in the following sections.

The following table presents an overview of the main domains that could benefit from an operational and continuous SWE service at the EU level.

Whilst the impacts do have thematic results (e.g. strategic, economic), the methodology used for SWE differs from SST by instead grouping the impacts by the domains under which they fall. This is to be in line with the proposed services, which can be mapped to the specific industries analysed in the following sections.

Table 242 – List of domains impacted by SWE

Domains	Impact Category	Impacts
Aviation	Economic	Additional staff and other operational needs due to flights being delayed (quantified) Disruption to flight due to damages to aircraft and malfunctions
	Strategic	Delayed journeys due to flights being grounded (quantified)
	Social	Increase in morbidity due to exposure to radiation
	Environmental	Increased flight time causing environmental damages
Power grid operations	Economic	Increased cost due to need of equipment replacement Loss or damages on equipment due to power fluctuations across network Need of replacement for transformers (quantified)
	Strategic	Disruption to the running of the economy following loss of power in sectors dependent on electricity (quantified)
	Social	Disruption to the running of the economy following loss of power in sectors dependent on electricity (quantified)
	Environmental	Increase in fuel burnt due to use of fuel power energy generators to compensate loss of electricity
Space	Spacecraft operations	Economic Prolonged or permanent loss of satellite subsystems and of satellite

sector	and design	functionalities (quantified)	
		Complete loss of satellite/no longer functioning (quantified)	
	Strategic	Partial degradation of satellite/reduced functionality (quantified)	
		Reduced lifespan of specific services/satellites (quantified)	
	Launch operations	Economic	
		Waste of propellant due to defueling	
	Strategic	Complete loss of launcher (quantified)	
		Delays in launch	

1 Impact assessment on the Space Sector

Spacecraft operation and design

Several outcomes of space weather create impacts on spacecraft design and operation; these are detailed in the following sections.

Impact 1: Temporary disruption/loss of service

A Single Event Effect (SEE) is a general class of radiation effects on electronic devices. SEEs can be of two types: soft (non-destructive) and hard (potentially destructive).

Soft SEE are generally identified with Single Event Upsets (SEU) - temporarily failure or upsets of subsystems due to the effect of high-energy particle (SEP) impacts. As SEUs are soft errors and therefore non-destructive, the impact is that some part or all of the avionics is temporarily lost. These errors normally appear as transient pulses in logic or support circuitry, or as bit flips in memory cells or registers. An SEU can cause the payload or subsystem to switch automatically to “safe mode.” In this mode, the system is safe, but its activities are in idle and services can be disrupted. In case of commercial satellites, this can generate a loss of revenue for the operator; while in case of military satellites (high requirement in term of availability and continuity of service), an SEU can even result in loss of human lives.

Several types of hard errors, which are potentially destructive to avionics systems, can appear. Single Event Latch-up (SEL) results in a high operating current above device specifications, and must be cleared by a power reset. Other hard errors include Single Event Burnout (SEB) and noise in image sensors.

From the point of view of the operator, on-orbit anomalies generate major impacts either resulting from prolonged interruption of service provision (e.g. satellite telecommunication services), or from increased degradation of satellite operational life. This implies both a loss of revenue, and a shortening of operational life, which translates into a loss in the amortisation of satellite CAPEX (these are typically distributed through the entire operational life of the spacecraft).

The table below indicates the number of SEUs registered during Solar Cycle 23 for a specific satellite fleet, where a solar cycle is the periodic cycle the Sun goes through, of high and low activity that repeats every 11 years. Using this as an example snapshot, it is clear many SEUs can therefore occur. The majority of the observed (confirmed non man-made) SEUs are believed to be associated with space weather and cosmic radiation, but it is not confirmed.

Table 243 - SEU on INMARSAT fleet during Solar Cycle 23 (1996-2008)¹⁰⁵

¹⁰⁵ Whitney Q. Lohmeyer, Kerri Cahoy and Shiyang Liu, 2013, Causal Relationships between Solar Proton Events and Single Event Upsets for Communication Satellites

Single Event Upsets	Number
Total number of registered SEU	226
Number of SEU during solar maximum (1998-2002)	21
Total number of monitored satellites	8

Though mitigation actions can be taken by spacecraft operators to avoid anomalies generating the impacts mentioned above, these have a high cost: the impacts of SEE and of the charging effect could be countered by adapting the design of the spacecraft; however this would necessitate an increase in the cost of the satellite, which can be difficult to justify.

Currently, mitigations for SEUs are mainly achieved by design. In the case of a component or subsystem that might experience an SEU during space operation, the first mitigation layer usually consists of changing component/subsystem/technology provider in favour of technologies or providers with better records of handling SEUs.

Additionally, spacecraft architecture is consolidated and designed with no single points of failure. In case of an SEU in a critical subsystem with no back-up (single point of failure), on-board software triggers automatically a change to “Safe-Mode” and the temporary suspension of primary satellite activities. Elimination of single points of failure and increases of hot-redundancy between primary and secondary systems minimise this risk; a SEU will indeed trigger a reconfiguration to work on redundant or back-up systems, and not a reversion into Safe Mode. Redundancy and fault tolerance come at a price, and this price may fluctuate with the type and design of the subsystem being protected.

This sort of mitigation has proven to be effective so far; nevertheless in periods of high solar activity, multiple storms might impact the spacecraft and multiple point failures are very tough to protect against. The designed-in mitigations might not be sufficient to prevent (temporary) operation disruptions. It is also difficult sometimes to confirm the exact cause of a satellite anomaly; hence, space weather may be the cause yet the failure is not attributed to it.

Examples of SWE-caused anomalies occurring include during the Bastille Day Event in July 2000, where multiple satellites lost output from sensors, experienced power outages (some for several days), and attitude issues.¹⁰⁶ The Halloween storms of 2003 not only caused similar effects on satellites, including the complete loss of the Japanese ADEOS-II satellite, but forced several deep space missions to switch to safe mode or shutdown. The Martian radiation Environment Experiment on board NASA’s Mars Odyssey mission was destroyed.¹⁰⁷ In 2006, a large solar flare again forced satellite operators to respond to disruptions. The Cluster II ESA mission lost power in its attitude and orbit control unit, switching over to its redundant unit, whilst the payload module computer on Envisat was autonomously suspended¹⁰⁸. More recently, in 2012 the SkyTerra1 satellite lost power for around a month due to a solar storm, and had to undergo extensive reboots¹⁰⁹.

Impact 2: Reduced lifespan of specific services/satellites

Solar cells are degraded by solar particles during solar storms. This degradation is expected during the operational life of the satellite, and is factored in during the design phase, during which the expected efficiency of the solar panel at the end of its operational life is defined by

¹⁰⁶ http://swe.ssa.esa.int/TECEES/spweather/workshops/esww/proc/brekke_stoa5.pdf

¹⁰⁷ <https://www.ncei.noaa.gov/news/great-halloween-solar-storm-2003>

¹⁰⁸ [http://www.esa.int/Our_Activities/Operations/ESA_mission_controllers_react_to_solar_flare/\(print\)](http://www.esa.int/Our_Activities/Operations/ESA_mission_controllers_react_to_solar_flare/(print))

¹⁰⁹ https://www.seradata.com/skyterra_1_update_it_is_alive/

customer/user requirements. Solar panels are usually sized to ensure extra efficiency at the end of the mission with regards to the defined threshold. In order to mitigate risk of augmented degradation some manufacturers size the solar panels to allow for an extra 50% of efficiency at the end of the satellite operational life (as opposed to around 30%)¹¹⁰.

Operationally the degradation of the solar panel can be mitigated by turning the solar array away from the sun, leaving the satellites to operate on batteries. Procedures to do this have been designed for very extreme events (i.e. Carrington-level storm), but in reality have not been used. Operating a satellite on batteries, without solar panel charging, presents two kind of risks: reduction of satellite component temperatures (with an increased risk of component failure) and, in case of very low battery power, risk of losing the entire satellite (no possibility to operate the satellite from ground).

An example of this was on the SOHO spacecraft, which experienced significant permanent solar panel output degradation from the July 2000 storm and the Halloween 2003 storms.¹¹¹

Impact 3: Risk of complete loss/lack of functioning of satellite

Energetic particles, mainly from geomagnetic storms, can cause surface or internal charging, by charging one side of the spacecraft or internal components, with possible electric discharges that can result in malfunctions or even complete failure of the satellite. The charging may generate high voltage discharge through the structure of the satellite and the active subsystems, with risk of a Single Event Burnout (SEB) that could cause prolonged or permanent loss of satellite subsystems and therefore of its functionalities. Currently, the only mitigations for the charging effect are through passive mitigation design, by applying an appropriate coating on satellite surfaces that can potentially accumulate electronic charges.

An extreme space weather event may, if severe enough, cause permanent loss of the satellite, with the operator losing functionality and even control of the spacecraft. This has occurred in the past a handful of times; however, no recent failures due to SWE have been announced, and often it is difficult to confirm the precise cause of a satellite failure. The Equator-S satellite, for example, stopped sending data due to the failure of both its primary data processor in December 1997, followed by its redundant processor system in May 1998, and all attempts to command the spacecraft were unsuccessful. Both failures were attributed to latch-ups caused by penetrating particle radiation¹¹². A more recent example is the IMAGE spacecraft failure in December 2005, where contact was lost unexpectedly and permanently. The cause was determined most likely to be due to a SEU-induced “instant trip” of the Solid State Power Controller¹¹³.

Quantification for spacecraft operation and design

In order to calculate the benefit of investing in SWE on space operations, first a baseline cost per year was calculated. This baseline figure is the impact of single event upsets in LEO and GEO, and is calculated by multiplying the number of expected anomalies per year by the cost of an anomaly. These single event upsets are the results of several SWE: for the calculations,

¹¹⁰ Stakeholder interview

¹¹¹ Brekke, P. et al., 2003, Space weather effects on SOHO and its leading role in the early-warning system for space weather

¹¹² <http://www2011.mpe.mpg.de/EQS/eq-s-news.html>

¹¹³ https://image.gsfc.nasa.gov/publication/document/IMAGE_FRB_Final_Report.pdf

it has been assumed that an extreme SWE would happen between today and 2040. The number of expected anomalies per year depends on which point in solar cycle it is.

It is assumed that a certain number of anomalies are avoided as a result of investment in SWE. This reduction in anomalies is presented as two percentages. The first impact is the general reduction in anomalies, which is 10% of the baseline per year. The second impact is the percentage of anomalies avoided as a result of better design. This percentage is 0% in 2021 and grows to 40% in 2035, remaining at 40% thereafter.

The table below highlights the baseline impact amount, the anomaly percentages and the benefit of SWE.

Table 244 – Space operations impacts and benefits

	2021	2030	2040
Baseline Impact of critical and non-critical anomalies on LEO and GEO commercial satellites	EUR 5.84 M	EUR 7.57 M	EUR 14.15 M
Anomalies avoided (general)	10%	10%	10%
Anomalies avoided (design)	0%	23%	40%
Benefit of SWE	EUR 0.58 M	EUR 2.52 M	EUR 7.08 M

Launch Operations

Impact 1: Delays in launch

In the event that a class S3 or higher solar radiation storm occurs or might occur on the launch day of a Vega/Vega-C or a “sensitive” Ariane 5/6 mission, developments regarding the flux of high-energy protons will be closely monitored by Collecte Localisations Satellites (CLS), a subsidiary of CNES providing space weather forecasts. If the flux of high-energy protons exceeds the defined limit on the launch day, it means that a high intensity solar eruption is ongoing – an event also known as a Solar Energetic Particles Event (SEPE).

In such a case, the launch chronology is aborted and will restart only when favourable evolutions of space weather conditions are expected. If “sensitive missions” face some high intensity X-flares but the flux of high-energy protons remains limited, it means that space weather conditions remain uncertain. X-flares can induce strong ionospheric disturbance and radio blackouts, but these effects are not considered harmful to the launch. They can however be accompanied by a SEPE, leading to a solar radiation storm (S-class). Therefore, the intensity of the Sun’s activity must be observed continuously to eventually support the go/no-go decision.

Impact 2: Waste of propellant due to defueling

Some rockets are fuelled with cryogenic propellants, which are difficult to maintain in a liquid state due to their extremely low boiling points.

A no-go decision will naturally come with a price; operations will have to be aborted and, in some cases, reversed. This can affect the cryogenic fuelling of certain launch vehicle. Some rockets are fuelled with cryogenic propellants, which are difficult to maintain in a liquid state due to their extremely low boiling points. To minimize cooling efforts, cryogenic fuelling operations therefore usually start at just 5 hours before lift-off. When the decision to delay the launch is made after T-5hrs – that is, after the beginning of the fuelling sequence – fuelling

operations must be stopped and reversed. Defueling of the launch vehicle results in (partial) venting of the state-transitioned gaseous cryogenic propellants.

Impact 3: Orbit Injection Anomalies

Geomagnetic storms (G-storms) can induce issues with the orientation of the launch vehicle, thus causing a slight risk of an orbit injection anomaly. If a satellite is injected into the wrong orbit, there can be loss of satellite or service depending on the scale of the anomaly. This is the main risk to payload that the launch operator is trying to avoid by delaying the launch.

Quantification of launcher activities

In order to calculate the benefit of investing in SWE on launch operations, first a baseline cost per year was calculated. This baseline cost is the expected value of losing an EU launcher and satellites due to a space weather event. It is calculated by multiplying the probability of the loss of a launcher by the cost associated with losing the launcher and its payload. This cost includes potential revenue of EU satellites, and the time value of cost of replacing that satellite sooner than expected.

Table 245 - Launcher data

	Ariane 5	Vega	Ariane 6
Expected number of launches occurring simultaneously with scale a S5/S5+ SWE event	0.000373	0.000548	0.001369
Probability of scale a S5/S5+ SWE event impacting launcher and leading to complete loss	0.0100	0.01	0.01
Annual number of satellites lost	0.0000037	0.0000055	0.0000137
Estimated average cost of loss of Ariane V launch vehicle and payload	EUR 641 M	EUR 142 M	EUR 620 M
Number of launches per year	5	4	10

In addition, the lost revenue from delayed launch is calculated based on average revenue for EU satellites¹¹⁴. It is assumed that there is one EU satellite per launcher.

It is assumed that investment into SWE will mean that the probability of this event occurring reduces to zero; therefore the benefit associated with spending on SWE is equal to the full expected value of this event. The table below shows this impact figure.

Table 246 – Space Operations Impact and Benefit

	2021	2030	2040
Complete expected loss of EU launchers and payload	EUR 0.005 M	EUR 0.013 M	EUR 0.016 M

For Vega/Vega-C there is one impact scenario because of a no-go delay decision: loss in launch day operations. For Ariane 5/6 launches to LEO there are two impact scenarios: no-go decision between T-24hrs and T-5hrs, where only launch day operations are lost, and no-go decision after T-5hrs, with both launch day operations and some of the cryogenic propellant

¹¹⁴ For simplicity no distinction has been made between satellites, for example based on propulsion system or orbital regime, for this part of the analysis.

being lost. Although the loss of a launcher and its payload is a significant cost that is avoided, there is a very low probability of this occurring due to a solar storm, so the resulting impact is relatively low.

Table 247 - Estimated average costs of delay related to impact of space weather on launch operations

Launch vehicle	Estimated cost of loss of operations at day of launch	Estimated cost of wasted cryogenic propellant due to defueling
Ariane 5	EUR 100k	EUR 210k
Vega	EUR 50k	n/applicable
Ariane 6	EUR 100k	EUR 190k

2 Impact assessment on Aviation sector

Impacts resulting from geomagnetic storms and solar flares

Both geomagnetic storms (especially G3 and above over Polar Regions or G5+ in other regions) and solar flares (especially R5+ in the equatorial/mid-latitude) can generate ionospheric scintillation. Ionospheric scintillation can make it difficult for signals to travel through the ionosphere affecting the Global Navigation Satellite System (GNSS) and Satellite communications (satcom). High Frequency (HF) communications used for aviation will also struggle to function properly as they rely on using the ionosphere to allow signals to travel beyond the horizon.

Impact 1: Disruption to GNSS signals

Depending on the intensity of the SWE, GNSS signals can either be degraded or fully lost.

Functional **loss or degradation of GNSS** does not stop planes from flying, since aviation operators make use of augmentation systems to increase GNSS positioning performance. Both Satellite Based Augmentation Systems (SBAS) and AirBorn Augmentation System (ABAS) augmentation systems provide GNSS signal integrity used in all phases of flight. In case of loss of GNSS and augmentation, operations can continue without flight disruptions. Two other augmentation systems, that are ground-based, can be used as back up in landing operations: Ground Based Augmentation System (GBAS) and Instrument Landing System (ILS). These systems are mainly used in regional and smaller airports. If only one system is available at a regional airport, flights can be diverted and landed at different airports with multiple systems. **It should be noted that GNSS-based precision approaches** to airports are becoming more commonplace as traditional Instrument Landing Systems (ILS) are very expensive to install and to operate (20 times more expensive). Some regional airports may become critically dependent on GNSS-based approaches in the future, and many small airports will expand services with this technology too. Therefore, it is likely that there is an increased need for aircraft to divert from regional airports to major airport hubs in the event of space weather related disruptions to GNSS, or more importantly, SBAS satellites (which are less robust in terms of numbers), as these major hubs will probably retain ILS.

On the contrary, the intermittent or full loss of service, in line with the length of the scintillation, could lead to more damaging consequences for the aviation sector such as the re-routing of flights. Indeed, “back-up” operating procedures in the airspace, which are far less efficient, could be applied (e.g. from 15 nautical miles or 30nm flight envelopes to mandatory 60nm flight envelopes).

While Satellite Based Augmentation Systems, such as EGNOS, will decrease GNSS errors under most conditions, during extreme space weather conditions where the ionosphere is very

disturbed or scintillation is significant, SBAS will have no or very little impact, on improving positional accuracy. This can result in airlines having to spend extra on fuel, hence **higher expenditures and Green House Gases (GHGs) and air pollutants emissions**, and delays being created throughout the air traffic management system. The impacts induced by delays are twofold:

1. If it is decided whilst in-flight, this may necessitate an unplanned diversion for re-fuelling and thus will lead to delayed journeys for travellers as well as staffing issues for crew members. The requirement for additional staff is driven by the fact that delayed flights, longer flight times or landing for re-fuelling will cause employees not to be at their destination locations at the correct time, creating a need for extra staff to be deployed. Additional staff being needed means there will be more employment and more wages paid. When the total amount of additional staff needed is significant, it would lead to an increase in consumption by employees and an increase in tax revenue from all revenue streams.
2. If the re-routing is decided before take-off, it may be the case that some flights are delayed and in extreme cases cancelled, inducing similar issues as to staff management, or that routes are modified, implying similar needs for extra fuelling. All these impacts can potentially have a cascading economic effect, as for example, people miss business meetings because of delayed flights, affecting their company's revenues. Both delayed journey and increased flight time result in extra time being consumed, which is of value to individuals.

Impact 2: Disruption to HF communication

Though SATCOM on aircraft is becoming more prevalent (e.g. about 60% of the aircraft flying from the UK possess SATCOM equipment¹¹⁵), HF communication is still a mandatory requirement. HF communications are particularly key near the Earth's poles as satellite communications are not possible over 82 degrees North¹¹⁶. As such, all flights using the North Atlantic Tracks (NAT) between Europe and North America rely on HF radio signals used for 'over the horizon' communication between air traffic controllers and aircraft. During an extreme solar flare (that usually take 8 minutes to arrive to Earth¹¹⁷), there can be a total loss of HF communication across the Atlantic for 2 to 3 hours. ICAO has defined procedures in order for pilots to deal with this HF communication loss¹¹⁸. Any aircraft within the NAT will be expected to **continue to follow its flight plan** (potentially with larger, less-efficient, flight safety envelopes around the aircraft). For any other aircraft, Oceanic control centres will not permit them to enter the NAT; instead, they will be **put into holding patterns, be diverted or requested not to take-off**. However, no procedure is currently established as to the reopening of airspace when HF communications start working again. As for flights at low or mid altitudes, the impact of space weather is rather negligible: the impact lasts from 10 minutes to a few hours and consists mostly of fading or noise during HF communication, and

115 Royal Academy of Engineering, 2003, Extreme space weather: impacts on engineered systems and infrastructure. Available at: <https://www.raeng.org.uk/publications/reports/space-weather-full-report>

116 ICAO, Space Weather Effects in Regard to International Air Navigation. Available at: <https://www.icao.int/safety/meteorology/iavwopsg/Space%20Weather/Forms/AllItems.aspx>

117 ICAO, 2005 (edited in 2018), North Atlantic minimum navigation performance specification (MNPS) airspace operations manual. Available at: <http://publicapps.caa.co.uk/docs/33/InformationNotice2013089.pdf>

118 ICAO, 2005 (edited in 2018), North Atlantic minimum navigation performance specification (MNPS) airspace operations manual. Available at: <http://publicapps.caa.co.uk/docs/33/InformationNotice2013089.pdf>

a blackout in the worst-case scenario¹¹⁹. Moreover, flights utilizing these latitudes have well-established procedures that enable them to continue their flight plan as intended¹²⁰.

For the NAT, the aviation industry is now deploying space-based surveillance and other advanced technologies for improving aviation efficiency. As these capabilities come online, a major benefit is that controllers can **reduce the space between en route aeroplanes**, meaning more airplanes can use the flight paths simultaneously. Nevertheless, many of these new technologies could be susceptible to space weather. Therefore, although the aviation sector might improve efficiency, the potential impact from space weather may be increasing in parallel. Even when controllers are suddenly forced to increase the plane spacing again for contingency if the system becomes disrupted, this mitigation could potentially be improved by SWE services. EGNOS capabilities are being updated every 6 months or every year, and the impact from space weather is decreasing from year-to-year as these systems are continuously being improved. Therefore, it is difficult to model impacts over time as system performance is continuously changing.

Impacts resulting from solar radiation storms

Radiation that results from Coronal Mass Ejections (CMEs) can either directly impact humans, or can disturb the different avionics systems. Although the effects of a radiation storm can last several days, the high energy portion (energies of 300 MeV and greater) that creates the risk to avionics and humans is relatively short lived, at around a few hours in length, and the assumption is made here that it lasts for between 2 and 3 hours.

Impact 3: Human health risks

The high-energy radiation that hits planes during flight is assumed to cause **damage to human health**, as the radiation flux is about 300 times higher at flight altitude than down on Earth¹²¹. However, it is very difficult to obtain accurate data on the radiation levels of an incident due to the lack of on-board sensors. It is expected that the increased exposure to radiation for an extreme event on a typical London to Los Angeles flight that coincides with the peak in the high-energy portion of the storm, would produce an estimated increase of 1 in 1000 in the lifetime risk of contracting cancer, in all affected passengers and crew¹²². An extreme event could generate up to 20 mSv radiation dose, which is largely above the annual public exposure of 1mSv¹²³. This dose could increase lifetime fatal cancer risk by about 0.1%; however, this is in comparison with the risk of fatal cancer in the general population, which is of around 25%¹²⁴.

119 ICAO, Space Weather Effects in Regard to International Air Navigation. Available at: <https://www.icao.int/safety/meteorology/iavwopsg/Space%20Weather/Forms/AllItems.aspx>

120 CAA, 2016, Impacts of Space Weather on aviation (Online). Available at: <https://publicapps.caa.co.uk/docs/33/CAP%201428%20JUL16.pdf>

121 Royal Academy of Engineering, 2003, Extreme space weather: impacts on engineered systems and infrastructure. Available at: <https://www.raeng.org.uk/publications/reports/space-weather-full-report>

122 Royal Academy of Engineering, 2003, Extreme space weather: impacts on engineered systems and infrastructure. Available at: <https://www.raeng.org.uk/publications/reports/space-weather-full-report>

123 ONS, 2012, Leading Causes of Death in England and Wales, 2009. Available at: www.ons.gov.uk/ons/taxonomy/index.html?nscl=Causes+of+Death

124 CAA, 2016, Impacts of Space Weather on aviation (Online). Available at: <https://publicapps.caa.co.uk/docs/33/CAP%201428%20JUL16.pdf>

If such an event happens, advice on the level of radiation exposure or the necessity to do medical checks and recommendations on whether to take other flights would be needed. However, the lack of knowledge on the presence of radiation is likely to lead to incorrect judgements, either by raising false alarms or by failing to initiate correct mitigating actions (e.g. descending to lower altitudes to avoid radiation if permitted by air traffic control, grounding or re-routing flights). For radiation incidents, the principle of ‘as low as reasonably practicable’ (ALARP) is used - particularly with respect to public health protection.

There are no agreed procedures in the EU for coping with an extreme radiation event. Regulators and air traffic agencies do not close air space; instead, the risk is passed on to individual airlines who are permitted to fly within an approved safe operating environment, which is the same as the well-established procedures for operating in volcanic ash environments. It is believed that there are no agreed procedures for any airlines to operate under these extreme radiation environments. It is assumed that the action of one government to prevent take-off during a radiation risk will instigate similar action in other countries across Europe, effectively stopping any aircraft taking off across Europe. Aircraft en-route will continue their flight as per their filed flight plan. Flights will therefore be either delayed or cancelled. Once the intense, high-energy part of the storm has passed some three or so hours later, it is anticipated that aircraft will be allowed to take-off as normal. Such a scenario is complicated to anticipate, as there is no reliable source of data to provide necessary evidence for this decision-making. Current satellites measurements do not provide data covering such high-energy ranges and there is no routine monitoring of radiation levels/doses on board aircraft that would be available in real-time. The best source of information is from ground-based neutron monitors, but this is from a science-based network that does not provide the operational reliability or the spatial coverage required and therefore actions will need to be conservative.

Impact 4: Malfunction in avionics

The arrival of high-energy protons not only affect humans but can also cause **damage on avionics** induced by Single Event Effects (SEE) and **on ground systems** just 10 to 30 minutes after the CME happens¹²⁵; particles resulting from solar radiation disrupt the charge in semiconductor materials. Such malfunctions have an impact on the pilot’s workload, so that they must reorganise themselves during the flight in order to compensate for the disruption¹²⁶. There is no real mitigation to prevent this electronic damage in time but flights may be held at airports or rerouted until the event has passed. However, avionics are composed of redundant systems in order to mitigate such events. Studies in the 1990s looking at a particular autopilot system suggested an upset rate of one every 200 hours under background conditions which would rise to one every hour if scaled to the February 1956 radiation event. The future deployment of even more complex microelectronics and miniaturisation would most likely increase the risk of disruption¹²⁷.

Quantification for aviation

125 ICAO, 2005 (edited in 2018), North Atlantic minimum navigation performance specification (MNPS) airspace operations manual. Available at: <http://publicapps.caa.co.uk/docs/33/InformationNotice2013089.pdf>

126 CAA, 2016, Impacts of Space Weather on aviation (Online). Available at: <https://publicapps.caa.co.uk/docs/33/CAP%201428%20JUL16.pdf>

127 Civil Aviation Information Notice, 2013, Space Weather. Available at: <http://publicapps.caa.co.uk/docs/33/InformationNotice2013089.pdf>

In order to calculate the benefit of investing in SWE on aviation, first a baseline cost per year of the impact of space weather on delayed flights was calculated. The impact is quantified as the value of time to passengers that are delayed, and the financial cost of delayed flights.

The value of time is calculated as follows: value of an hour consumed (**42.07€¹²⁸**) multiplied by the number of passengers delayed and the average length of delay (**3 hours**).

The financial cost of delayed flights is calculated as follows: total flights delayed due to space weather * average cost of a 3 hour delayed flight (**46,638 €**).

It is assumed that investing in SWE will reduce the average flight delay time to 2 hours instead of 3 hours. Therefore, the average cost of a 2 hour delayed flight (**32,762 €**) is applied to the total flights delayed due to space weather to calculate a total cost of delays under an SWE scenario. The difference between these two values is therefore the benefit.

Table 248 – Aviation Impact and Benefit

	2021	2030	2040
Baseline: financial cost	EUR 0.047 M	EUR 0.084 M	EUR 0.148 M
Baseline: value of time	EUR 0.019 M	EUR 0.034 M	EUR 0.060 M
Investment in SWE: financial cost	EUR 0.033 M	EUR 0.059 M	EUR 0.104 M
Investment in SWE: value of time	EUR 0.013 M	EUR 0.023 M	EUR 0.040 M
Benefit of investing in SWE	EUR 0.020 M	EUR 0.036 M	EUR 0.064 M

3 Impact assessment on Power Grid Sector

Impacts resulting from geomagnetic storms

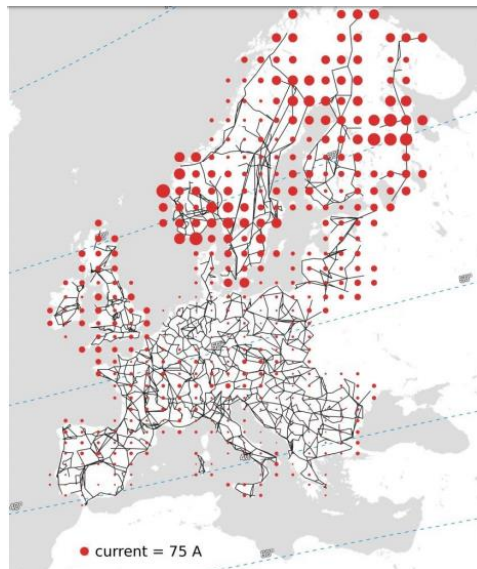
Geomagnetic storms deform the Earth's magnetic field and produce electric fields in the Earth's sub-surface layers. This leads to the creation of Geomagnetically Induced Currents (GICs) in power grid transmission lines, which cause transformer saturation and possible overheating, shutdown or, in some cases, destruction of the equipment, with potential long-term service outages¹²⁹. The most severe storms could result in multiple transformers failing in a given power grid network. However, geomagnetic storms of all grades and intensities represent a severe threat to the power grid infrastructure and operations, and to all the industry and people dependent on electrical network. The figure below presents the average of GICs in Europe between 1996 and 2008 per region.

Figure 83 – Average GICs in Europe between 1996 and 2008¹³⁰

128 "Standard Inputs for EUROCONTROL Cost-Benefit Analyses", Edition Number 7.0, Edition Date November 2015.

129 CAA, 2016, Impacts of Space Weather on aviation (Online). Available at: <https://publicapps.caa.co.uk/docs/33/CAP%201428%20JUL16.pdf>

130 FP7 EURISGIC



Impact 1: Failures of equipment

While single severe and extreme storms may generate high intensity and duration Geomagnetically Induced Currents, producing permanent damages to grid infrastructure, single lower intensity storms (i.e. G2 and G3 according to NOAA scale¹³¹) do not produce disruptive impacts but generate GICs that contribute to the wear of grid components. Irrespective of how frequently the lower intensity storms occur and generate GICs in the grid component, the impacts of the single storms cumulate over time with the final effect of **shortening the operational lifetime of the system**.

Awareness of the power grid community on the risk induced by geomagnetic storms is based on previous major occurrences such as the first major geomagnetic storm documented, the 1859 Carrington storm, which is also the most intense geomagnetic storm ever noted. As power grids did not exist at the time, impacts have only been witnessed on the telegraph lines in North America and Europe that were strongly disrupted, bringing the telegraph system-of-system to a complete halt for 8 hours. For instance, an extreme storm comparable to the Carrington storm would today put at risk of failure or permanent damage approximately 365 high-voltage transformers amongst the 2.000+ existing ones in the US¹³².

Another more recent event that caught the attention of power grid operators is the March 1989 extreme geomagnetic storm, also known as the Hydro-Quebec storm. Indeed, the power grid in Quebec, Canada system had a total failure. The storm caused a series of trip-outs; specifically five transmission lines from James Bay were tripped with a generation loss of 9.450MW. With a load of 21.350MW, the automatic voltage compensation system of Hydro-Quebec was unable to withstand the generation loss. This caused a cascade effect that brought the system to a complete shutdown in 90 seconds. It took 9 hours to restore normal operations¹³³. No storm as intense as the Hydro-Quebec 1989 storm impacted Europe in the last solar cycle (i.e. solar cycle 23 of 1996-2008); however, on October 30th 2003, an extreme

131 NOAA ale for geomagnetic storms : G1 = minor ; G2 = Moderate ; G3 = Strong ; G4 = Severe ; G5 = Extreme

132 Metatech Corporation, 2010, Geomagnetic Storms and Their Impacts on the U.S. Power Grid (Online). Available at: https://www.ferc.gov/industries/electric/indus-act/reliability/cybersecurity/ferc_meta-r-319.pdf

133 The National Academy of Sciences, 2008, Space Weather Impacts in retrospect, in 'Severe Space Weather Events- understanding societal and economic impacts'

G5 storm caused power distribution disruptions mainly in Sweden, leading to malfunctions of two transformers and a blackout that affected 50,000 people in the southern city of Malmö, Sweden. The power outage occurred around 9 p.m. and lasted between 20 minutes and half an hour, depending on the city area. The effects continued to be felt in the days following the storm, in the entire Nordic region particularly in Sweden where problems with transformers at a nuclear station and in the grid were observed¹³⁴.

For G3/G4 storms, the effects are more likely to be localised, with false alarms triggered on some protection devices. Voltage corrections may also be necessary and it is likely that there will be an increase in equipment failures, but these are most probably captured in Business As Usual (BAU) failures. All of these can lead to **potential equipment damage and cost of fixing or replacing**. In the more severe cases, there may be local intermittent loss of power but nothing comparable to the case of extreme events. The 2003 events, also known as the Halloween storm, provide evidence of the cumulative effects of lower intensity geomagnetic storms on power grids. A series of 12 geomagnetic storms occurred in the 20 days between the October 19th and the November 7th 2003. With the exception of 2 extreme and 1 severe storm registered on October 29th, 30th and 31st, the remaining 9 storms were all ranked as strong (G3) or moderate (G2). This sequence of storms in a very short period has been identified as the cause of a major power disruption in South Africa with the loss of 14 transformers in the period between mid-November 2003 and January 2004, and an indicative loss of energy distribution in the grid of 13% over that period of time. The South Africa disruption revealed some novel aspects of the threat to power grids and focused the attention of experts on the cumulated effect of multiple lower intensity storms¹³⁵. During the same October 2003 storm, no disruptions were reported in Europe on days of lower intensity storm. However, measurements made at three different locations in the UK (Lerwick, Eskdalemuir and Hartland) between 1983 and 1998 and including one full solar cycle (i.e. solar cycle 22) revealed that 18.9% of the geomagnetic storms generated relevant GICs phenomena in the monitored power grids. Considering that on the basis of the NOAA scale, indicatively only 10% of the geomagnetic storms should have an extreme and severe intensity (G4 and G5), this statistic indicates that lower intensity storms also cause GIC in Europe¹³⁶. This suggests the need to monitor low intensity storms as well and apply mitigation measures if needed, e.g. a threshold level of GICs of about 25A to 50A constitutes an approximate ‘concern threshold’ for the Scottish Power grid operators¹³⁷.

It therefore appears that G3 and above geomagnetic storms all impact power grid infrastructure.

Impact 2: Disruption of power grid networks leading to short power loss or longer blackout

The impact of failure or loss of multiple equipment such as transformers can range from short-term power loss to longer-term blackouts. A multitude of factors influence the order of magnitude of the impact: (i) the location of the transformer, (ii) the system design, (iii) the total number of transformers that fail or (iv) the extension of the power grids.

134 US Department of Commerce, 2003, NOAA Service Assessment – Intense Space Weather Storms October 19 – November 07, 2003

135 Lloyds 360 Risk Insight, 2007, Space Weather its impact on Earth and implications for business (Online). Available at: https://www.lloyds.com/~media/lloyds/reports/360/360-space-weather/7311_lloyds_360_space-weather_03.pdf

136 D. Beamish, T. D. G. Clark, E. Clarke and A. W. P. Thomson, 2000, Geomagnetically Induced Currents in the UK: Geomagnetic Variations and Surface Electric Fields (Online). Available at: http://nora.nerc.ac.uk/id/eprint/1100/1/JASTP_gic_180700_paper.pdf

137 A. W. P. Thomson, A. J. McKay, E. Clarke and S. J. Reay, Surface Electric Fields and Geomagnetic ally Induced Currents in the Scottish Power Grid: During the 30th October 2003 Geomagnetic Storm

- (i) Geomagnetic effects are naturally amplified in countries with a geomagnetic latitude higher than 30 degrees.

Figure 84 – Regions most impacted by geomagnetic storms



Analysis of historical data and stakeholder interviews confirmed that SWE-generated GICs are a constant concern for Northern European countries with UK and Sweden being historically the most affected countries.

- (ii) Power grid infrastructure can be designed in a way that enhances their resilience to geomagnetic storms.

As presented in the previous section, resilience to GICs can be amplified by adapting the design of the power grid. Indeed, countries at latitude similar to the ones most at risk such as Finland, Norway or Denmark have been less affected by GICs, mostly because of the implementation of different design solutions in the national power grids showing higher robustness to space weather induced phenomena. However, and as previously mentioned, it is not certain that this new design would protect power grids in the case of an extreme event.

- (iii) The total number of transformers that fail influence how long it takes to bring the whole grid back to full operation.

If only a few transformers encounter failures, then it is likely that power grids can compensate for it. They usually are designed in a way that enable back-up solutions, for instance by redistributing efforts. However, when failures affect several transformers simultaneously, back-up solutions are often not sufficient to cover the power loss. Hence, the higher the number of transformers that fail, the bigger the risk that the power grid will remain out of operation for a long duration.

- (iv) The extension of the power grids plays an important role.

Longer power grids present greater variation of electrical potential in the infrastructure and can generate larger GICs when hit by geomagnetic storms. This is particularly true in large countries at lower latitudes such as Germany or France. So far, literature shows no example of high GICs in European lower latitude countries. However, the US has the most extensive power grid in the world, extending over more than 120,000 km of transmission lines, often at even lower latitudes than European countries (e.g. the latitude of Paris is similar to the US-Canada border), and which has increased by 10 the total length of high-voltage power lines crisscrossing North America since the late 1950s-early 60s to respond to a constantly growing power demand. The potential impact would be considerable as power grids that were installed

quickly are designed in a complex manner and operate closer to their limits. This results in the grids being more and more vulnerable to the effects of geomagnetic storms.

Depending on the importance of the factors listed, the power loss will have varying intensities and thus varying impacts. Indeed, power blackouts have wide ranging impacts across multiple (if not all) sectors. The severity of this impact will often depend on the length of the outage; short outages although disruptive are comparatively less severe. Longer outages will have much larger economic and social implications. Indeed, an event similar to the Carrington storm would leave 130 million people without power in the US (presented here as an example since there is no current EU equivalent)¹³⁸. The crash of the power utility's grid of Hydro-Quebec in 1989 happened in less than two minutes, leaving no possibility to prepare backup solutions, and affected more than six million people in the Quebec province for approximately nine hours. As such, in the worst cases, power outages could pose **morbidity and mortality risks** predominantly among the already frail and infirm. Such a catastrophe had an economic cost estimated at CAD 13.2B¹³⁹. Considering today's enhanced reliance on electricity compared to 30 years ago, at the time of the Hydro-Quebec event, as underlined by the dependence of several and various activities such as banking, water supply or hospital services, the economic cost could reach trillions of dollars. In addition, it has been reported that in the aftermath of the 1989 events, the Canadian authorities had to spend USD 1.2B to upgrade the Hydro Quebec system¹⁴⁰.

Quantification for power grids

As elaborated, space weather has an impact on power grids. It is assumed that a G5 or G5+ storm leads to the following outcomes:

- 3 major European city blackouts for 3 days;
- 100% blackout outside major cities in Europe for 2 weeks, 50% blackout outside major cities in Europe for 3 weeks and 10% blackout outside major cities in Europe for 1 week;
- 68 European transformers damaged with a cost of 4.2M €.

Blackouts in major cities and outside major cities have an impact on GDP, morbidity and mortality.

If there is investment in SWE, it is assumed that a G5 or G5+ storm leads to the following outcomes:

- 2 major European city blackouts for 2 days;
- 33% decrease in blackouts outside major cities in Europe;
- 33% decrease in the number of European transformers damaged.

This therefore means that if there is investment in SWE, the associated impact as a result of a G5 or G5+ storm event reduces in terms of GDP, morbidity, mortality and damage to transformers.

See the following table for a summary of the impact on transformer cost, GDP, mortality and morbidity of space weather under the baseline, and the total benefit as a result of investment in space weather.

Table 249 – Power grids impact and benefit

138 Metatech Corporation, 2010, Geomagnetic Storms and Their Impacts on the U.S. Power Grid (Online). Available at: https://www.ferc.gov/industries/electric/indus-act/reliability/cybersecurity/ferc_meta-r-319.pdf

139 Lloyd's, 2013, Solar storm risk to the North American electric grid

140 The National Academy of Sciences, 2008, Space Weather Impacts in retrospect, in 'Severe Space Weather Events- understanding societal and economic impacts'

	2021	2030	2040
Baseline: major cities (GDP, mortality, morbidity)	EUR 204.7 M	EUR 234.1 M	EUR 267.7 M
Baseline: outside major cities (GDP, mortality, morbidity)	EUR 183.0 M	EUR 205.7 M	EUR 231.6 M
Baseline: loss of transformers	EUR 20.6 M	EUR 20.6 M	EUR 20.6 M
Benefit of SWE: major cities	EUR 113.7 M	EUR 130.0 M	EUR 148.7 M
Benefit of SWE: outside major cities	EUR 61.0 M	EUR 68.6 M	EUR 77.2 M
Benefit of SWE: loss of transformers	EUR 6.9 M	EUR 6.9 M	EUR 6.9 M

4 Other sectors that may benefit from SWE data and services

Other industries could suffer negative effects from space weather impacts also. Whilst there will not be any specific services introduced for end-users in these sectors, it may still be the case that thanks to the data collected, or indeed some of the tools available, the effects of space weather on these domains can be mitigated due to improved space weather services overall.

This section will explore at high-level four domains that could be significantly impacted directly or indirectly by SWE, and therefore an improvement of SWE services: space surveillance and tracking, human spaceflight, the natural resource exploitation sector, and the EU rail sector. It will then give an overview of several other sectors that are indirectly affected by perturbations in GNSS services or satellite communications.

Space Surveillance and Tracking

The negative effects space weather events could have on space surveillance and tracking are linked to the impacts mentioned in the section on spacecraft operation and design. This is because the impact from space weather may affect the spacecraft to the point where there is damage or even full loss of operations. Hence, it may be more complicated or even impossible to control the spacecraft after a space weather event, leading to a challenge in avoidance manoeuvres if the spacecraft is at risk of a collision, or the formation of more debris (uncontrolled spacecraft). In either situation, the risk of contributing to debris in orbit increases, which is both detrimental to any type of space activity in the long term, and puts more pressure on requiring space surveillance and tracking services.

Human spaceflight

Life on Earth is protected by the atmosphere and magnetosphere. The level of exposure to space radiation – mostly consisting of solar and cosmic radiation – rises with increasing altitude from the surface. Astronauts on board of the permanently inhabited International Space Station (ISS), annually receive doses ranging from 160 millisieverts (mSv) in the solar maximum to 320 mSv in the solar minimum¹⁴¹.

This inverse relationship with the solar cycle is due to the bulk of the radiation received coming from Galactic Cosmic Radiation (GCR) that is attenuated by an increase in solar

¹⁴¹ Source: <http://spaceflight.nasa.gov/spacenews/factsheets/pdfs/radiation.pdf>

activity. This is approximately 50 to 100 times more, respectively, than they would receive on Earth¹⁴².

However, some solar events (coronal mass ejections in particular) have the capability of sometimes suppressing cosmic rays (known as Forbush decrease), and in some cases that has lowered the radiation levels measured on board of the ISS¹⁴³. However, when an eruption is pointed in the direction of the Earth, the amount of received radiation heavily increases.

Despite the fact that the ISS is in a sufficiently low orbit to be (partly) protected by Earth's magnetic field, increased solar activity can still have a serious impact on the crew. Outside of the magnetosphere, crewed vehicles will be far more susceptible. A study of the potential impact of the Carrington solar event on astronauts situated beyond the protective magnetic field suggested that they would rapidly suffer a lethal dose of radiation with current shielding capabilities¹⁴⁴.

An improved service for monitoring radiation from space, such as solar radiation, would enable the inhabitants of the ISS to be better protected from the dangerous impacts of radiation on the human body. Data collected could also be utilized for furthering the understanding of radiation on astronauts and how to mitigate the effects, for future human space exploration expeditions.

Ionizing radiation, whether it originates from space weather or other sources, is harmful to the human body. The extent of its damaging effect depends on the radiation's flux and energy spectrum, and length of exposure. High doses of radiation can damage human tissue and destroy cells that play an important role in maintaining the immune system of a human being. Other reported impacts are damage to the brain and an increased risk of suffering from a decrease in vision (cataracts) and cancer.

On January 20, 2005, the Sun unleashed a strong solar flare of class X7. The CME that was accompanying this outburst caused the most powerful radiation storm since October 1989¹⁴⁵. The astronauts aboard the ISS took precautionary measures, temporarily decommissioned their daily operations and decided to weather the storm inside a section of the station better shielded from highly energetic radiation¹⁴⁶. In 2017, an X8.2 solar flare forced the ISS crew again to hide in a special shelter¹⁴⁷.

Noticeably, when the crew is forced to take shelter from a severe radiation storm and is hence hindered from their work, there is a loss of productivity on board the station.

In line with the Global Exploration Roadmap, drafted in 2013 by multiple space agencies across the globe, interplanetary robotic missions to the Moon and Mars will pave the road for eventual manned missions to these particular destinations (expected from 2030 onwards). However, since both bodies do not have a magnetic field nor an atmosphere worth mentioning, the exposure to space radiation and solar events will be extreme. The impact of space weather on humans will thus increase significantly.

142 Average annual radiation dose received on Earth is about 3 mSv. Source: http://www.unscear.org/docs/publications/2008/UNSCEAR_2008_Report_Vol.I.pdf

143 https://science.nasa.gov/science-news/science-at-nasa/2005/07oct_afraid/

144 Source: <https://www.newscientist.com/article/dn7142-superflares-could-kill-unprotected-astronauts/>

145 <http://spaceweather.com/archive.php?view=1&day=20&month=01&year=2005>

146 <https://www.space.com/2080-solar-flare-hits-earth-mars.html>

147 <https://www.rt.com/news/402946-iss-shelter-solar-flare/>

In order to mitigate the risk of exposure to a sickening or lethal dose of radiation for manned missions outside of the protective environment of the Earth, space agencies and other institutions are currently developing new shielding technologies and medication that would have the capability to counteract the malicious health effects¹⁴⁸.

SWE conditions during manned space missions are already monitored based on currently available systems and services. Since the safety and well-being of astronauts in outer space is of primary concern to agencies and/or operators, the awareness for space weather phenomena is obviously very high. For the ISS, there is a separate team within Mission Control monitoring near-Earth radiation environment. During nominal space weather conditions, members of the team are staffed for four hours per day to examine data and trends provided by forecasters, such as the National Oceanic and Atmospheric Administration (NOAA) in Boulder¹⁴⁹.

In the confirmed event of increasing solar activity and radiation exposure levels, the team will be operating continuously throughout the day and may recommend that astronauts cancel or reschedule any (extravehicular) activities and take shelter until radiation levels drop back to safe limits.

As human spaceflight missions are expected to go beyond LEO in the near future and would consequently be unprotected by Earth's magnetosphere, the demand for more accurate and timely information will definitely grow. This will allow the re-planning of the astronaut activities and proper taking of shelter to reduce any risk on human health.

Impact on the natural resource exploitation sector

The resource exploitation domain is particularly affected by GNSS anomalies, both direct and indirect. This is especially the case for the crude oil and gas domains, within activities such as survey, exploration, production, infrastructure development, and distribution of natural resources. These activities are conducted both in-shore (inland) and offshore (open sea).

The first stage of the resource exploitation process is to perform surveys, involving the survey and mapping of large in-shore and offshore areas to identify the presence of natural resource reservoirs underground. Once the survey step is completed, the exploration phase follows, where exploration wells are drilled, in order to confirm the existence of the reservoir and support the geological mapping of the underground area. This is based on (nominally) vertical drilling techniques, which are not intended for the extraction of the natural resources. Upon confirmation of the existence of a resource reservoir, production drilling starts. This is different from exploration drilling since it is based on horizontal well drilling techniques aiming to optimize the production of the natural resource.

At completion of the horizontal drilling campaign, the wells are connected to an extraction platform, which is connected to a pipeline for transportation of the extracted resources and further distribution. When an extraction platform is not available, such infrastructure is installed and connected to an existing or newly placed pipeline.

Survey activities not only suffer indirect impacts due to disruption of precise positioning services based on GNSS signals, but also from direct SWE impacts generated by geomagnetic storms.

Direct impacts derive from the utilisation of geomagnetic techniques for measuring distortions in the local gravity field as a method to survey the presence of resource reservoirs. This is a

148 <https://www.nasa.gov/feature/goddard/real-martians-how-to-protect-astronauts-from-space-radiation-on-mars>

149 <https://srag.jsc.nasa.gov/spaceradiation/how/how.cfm>

passive survey technique providing information about the geological characteristics of the surveyed areas. These campaigns provide necessary data, but are not sufficient for deciding whether to proceed with the drilling, and when successful they necessitate additional expensive and more focused survey campaigns.

Geomagnetic campaign measurements are usually compared and corrected against a set of measurements taken by networks of magnetometers in known (on-shore) positions. These allow for corrections to mitigate the risk of false-positive readings, and therefore help to minimise the additional costs of the follow-up survey campaigns. Corrections are effective when the reference magnetometers are at the same latitude of the surveyed areas; the more the difference in latitude increases the less effective and reliable the correction is. With the increase of distance from magnetometers (both north south and east west), geomagnetic storms can produce errors in either the campaign or the reference reading, thus increasing the risk of false-positive or false-negative readings.

Table 250 - indicative costs of survey equipment¹⁵⁰

Type of survey equipment	On-/Off-shore	Indicative cost (K\$/Day)
Marine vessel	Off-shore	50.000 to 200.000 depending on available survey sensors
Airplane	In- shore	3000

In cases of positive readings (i.e. expected presence of a reservoir), active seismic survey techniques usually follow the first geomagnetic survey. The technique consists of sending an acoustic pulse through the rocks and reading the echo. The readings, coupled with augmented GNSS precise positioning of the vessel are then used to generate 2D and 3D maps of the underground to support the drill/no-drill decision. A degradation of the GNSS positioning might influence the quality of the mapping and therefore the design of the subsequent drilling campaign.

Marine vessels are used to conduct offshore survey campaigns, while airplanes are used for in-shore surveys. As summarised in the table above, the cost of offshore survey vessels is much higher than the equivalent cost of inshore airplane. Therefore, the financial impact of space weather is expected to be higher for offshore survey activities.

Once the discovery is confirmed, production drilling is started, based on the technique of horizontal drilling. Horizontal drilling techniques are implemented for a variety of reasons, but above all are used to avoid areas that are non-geologically appropriate to support the well infrastructure. This is significant, as wells are drilled directly into the rocks and, with the exclusion of the first outward section, no metallic shell is installed to support the well infrastructure. Therefore, during the drilling activities, it is paramount to avoid areas of soft, crumbly or cracked rocks; these are likely to collapse under the high pressures present in underground reservoirs and in the wells during production activities. These critical horizontal drilling techniques depend on continuous acquisition of geomagnetic information, as errors in the geomagnetic readings can affect the result of the drilling operations.

A well blowout does not necessarily mean a release of oil in to the environment, and most blowouts are stopped quickly. Historically 94% of blowouts across the North Sea and the Gulf of Mexico have been stopped within 30 days after the introduction of capping devices. When it is not possible to intervene with a capping device, the only solution to a blowout is to

¹⁵⁰ Source: Stakeholder interview

drill a relief well within the blown-out well. A relief well drilling campaign usually lasts around 90 days.¹⁵¹

Therefore, continuous monitoring of the Earth's geomagnetic field during the drilling activities is necessary to make sure the drill is in the right position and to correct its orientation. Geomagnetic storms may reduce the integrity of the drill head positioning and orientation with the net effect of increasing the duration of the overall relief well drilling campaign. Besides the higher operational cost, longer campaigns have higher impacts on the environment and on related commercial activities (e.g. fisheries).

The shape and inclination of the horizontal well is defined based on the 2D or 3D mapping of the drilling area. Nevertheless, during the drilling activity it is fundamental to execute geomagnetic measurements to verify the geological characteristic of the rocks and verify the direction of the drilling as it progresses.

Geomagnetic storms have effects similar to the ones already described for the survey activities. The financial impacts are relevant considering that the hire cost of the drilling equipment can be up to 400-500 K\$ per day¹⁵². This excludes the additional operational cost of such a drilling rig, which can be in excess of 1 M\$ per day¹⁵³. Therefore, due to the very high daily cost of these production-drilling campaigns, a decision to stop the drilling has rarely been observed. Even in presence of confirmed wrong geomagnetic readings, operators often prefer to continue the drilling by applying a correction to the path, where possible. For an operator, stopping the drilling activities implies a loss of revenue. It is also in the interest of the commissioner to monitor the situation too, since a well drilled in the wrong area might cause damage to other existing wells or, in a worst-case scenario collapse during extraction operations.

In addition to positioning the drill, the exact position of the drilling rig must be continuously monitored and actively corrected, since it is necessary to prevent extreme structural stress in the riser due to an excessive shift of the rig on the surface of the sea. Offshore drilling rigs are not solidly anchored to the seabed, while the drill-head is solidly fixed to the seabed, creating a dynamic system with precision requirements. In the worst cases, an excessive shift of the rig could lead to a structural crisis and therefore to the loss of the drill and of the well. Emergency Quick Disconnect (EQD) systems are in place to seal the Blowout Preventer (BOP) and temporarily detach the drill to manage such crises.

Augmented, GNSS-based positioning is used to monitor and actively control the position of the rig. A prolonged degradation of the GNSS signal due to ionospheric disturbance, combined with other factors such as bad atmospheric weather conditions, might heavily affect production-drilling activities. This could increase the number of days necessary to complete the drilling campaign or, in a worst-case situation, lead to the fracture of the riser with the consequent loss of the drill.

Meanwhile, the building of the pipeline to transport the resources after extraction can suffer indirect space weather impacts because these activities depend on the utilisation of GNSS-based precise positioning techniques. These are used to ensure pipelines are placed within the 'corridor' agreed with the continental shelf authority. Operational costs for pipeline deployment are very high, with the need to hire vessels to place the pipes, and a limit to the number of kilometres of pipelines that can be placed per day. Depending on the seabed,

¹⁵¹ Source: Oil & Gas UK, 2012, Oil Spill Cost Study: OPOL financial limit

¹⁵² Source: <https://ihsmarkit.com/products/oil-gas-drilling-rigs-offshore-day-rates.html>

¹⁵³ Source: Stakeholder interview

dredging campaigns may be required to create the right corridor in which to place the pipe. Alongside this is the additional cost of a dredging vessel, and the limitation of whether sea conditions require operations to be halted temporarily.

A prolonged degradation of the augmented GNSS navigation signal might lead to a decision for idling operations and therefore, prolongation of the pipe laying campaign. This is particularly true in areas where the seabed is not flat and the corridor to place the pipes is very narrow or not straight.

In summary, offshore natural resource exploitation suffers direct and indirect space weather impacts mainly in the survey, exploration and infrastructure development activities.

The need to discover new resources in locations such as the North Sea will push exploration activities further away from the shore (beyond 200 km from the coast). This will reduce the effectiveness of the reference geomagnetic readings described earlier, resulting in an increase of dependency upon augmented GNSS positioning.

Similar to the inshore activities, industry shows a clear trend towards increasing the level of automation of mining and extraction operations. Such automation is believed to be able to increase productivity of mining sites by up to 15% in future. Automatization of mining sites is often heavily dependent upon precise GNSS positioning and local augmentation and re-transmission technologies. The latter allow the propagation of the GNSS navigation and timing signals to deep-dive caves.¹⁵⁴

Resource exploitation activities can benefit considerably from SWE information services. Nevertheless, because of the nature of the domain activities, operators require either large notice to re-plan vessel missions or real-time information to correct on-going drilling – which must be a high level of localisation and precision.

There is a medium-high level of awareness about space weather activities and its impact on their activities. Most of the current service demand focuses on reference geomagnetic readings to support the survey, exploration and production drilling campaigns. Companies commissioning the drilling of wells and construction of pipelines have showed interest in the definition of adverse space weather conditions and their impact on survey and construction activities.

As for the precise positioning, the demand for GNSS based positioning services is very high. Augmentation system providers already have networks of sensors and computational capabilities to detect the scintillation phenomena in real time, the degradation of GNSS positioning signal and to calculate GNSS correction signals. There is a moderate interest in SWE services, especially in the form of GNSS degradation forecasts, to improve performances of their service provision to resource exploration actors. Currently in Europe, TGO in Norway is providing geomagnetic measurement correction services in the form of now-cast and post-cast services to support survey activities. TGO currently bases its services on the reading of their own network of magnetometers. For precise GNSS positioning, the Fugro Corporation provides GNSS augmentation services and warning services in case of signal degradation.

Impact on the EU rail sector

There is historical evidence of space weather impacts on the rail sector in EU. These impacts have included signalling system anomalies during geomagnetic storms, and have been

¹⁵⁴ Acil Allen Consulting, 2013, Precise Positioning in the Mining sector.

recorded at high latitude locations such as Sweden and Russia, with errors such as false blockages (right-side failures) in sectors where there were no trains present¹⁵⁵.

Noticeable impacts are only expected to occur in extreme storm scenarios, i.e. 1 in 33 year storms or rarer. The largest potential impacts come from geomagnetic storms. Clearly, as in the power systems operator domain, a localised loss of power will have a direct impact on electrified sections of railway, since any power loss would have an effect on electrically-powered signalling systems and stations. Even where power failures do not occur, the GICs in track circuits can also produce anomalous train positions that would result in right-side failures, i.e. a green signal turning red. There is also concern about harmonics in the electricity supply to electric traction units, either causing protection devices to trip, shutting the locomotive down, or causing damage to on the on-board electric motor.

The view of the Rail Workshop¹⁵⁶ held in London in 2015 suggests the net effect could be large numbers of trains stopped across the rail network, many in remote locations. This will necessitate passenger evacuation, which will be a major undertaking for the responsible authorities. On-board batteries maintaining lighting, air conditioning/heating and toilets would last 90-120 minutes in the best case - many would lose this capability much sooner, which is likely to result in passengers choosing to self-evacuate. This means that even if the infrastructure can be quickly returned to normal operation, it will be some while before the network itself can resume normal operations. GICs also potentially present a safety risk to trackside maintenance staff due to the unexpected activation of protection systems.

Loss of GNSS through ionospheric scintillation, whilst not considered a safety issue, could also lead to disruption. Communication systems rely on GNSS timing and selective door opening (which can be overridden) and variable Traction Current Limiting rely on GNSS based positioning. SEEs from radiation storms may also cause upsets and potential malfunctions of both on-board and trackside electronic control equipment.

As rolling stock and infrastructure becomes increasingly electrified and operated using sophisticated electronic control systems, allied with an increase in the use of GNSS, it is anticipated that the sector could become more vulnerable to the effects of space weather, with the potential for large-scale, widespread disruption of the rail network.

Despite the potential impacts identified, awareness of space weather within the industry is very low. The accuracy and lead-time of current services, particularly geomagnetic storm warnings, are considered too poor for the sector to utilize for mitigating action at this current point in time. Improved services for other sectors could still have a positive impact on the rail networks if the end-users had more awareness of what data is needed.

3.3.4.3. Benefits assessment of the NEO component

Depending on its size, a NEO travelling in outer space and then impacting the Earth can cause anything from a negligible air-blast up to a massive crater, earthquake, and air-blast (on land) or tsunami (on water). Thus, a NEO can potentially cause societal (e.g. fatalities, injuries), economic (e.g. property damages) and environmental (e.g. hectares of land degradation) damages. Mapping of existing NEO capabilities and networking global NEO capabilities are activities aimed at supporting the discovery and surveillance of more NEOs, while defining coordinated action plans with national civil protection authorities is aimed at better handling and mitigating risks related to a potential impact to Earth. These actions are directly related,

¹⁵⁵ http://publications.jrc.ec.europa.eu/repository/bitstream/JRC98155/sw&rail_eur27523en.pdf

¹⁵⁶ Lloyds 360 Risk Insight, Space Weather its impact on Earth and implications for business; Gaunt, Coetzee, transformer failures in regions incorrectly considered to have low GIC –risk, 2007

as the more NEOs are discovered, the more collision warnings can be issued, and the better the evacuation plans can be executed.

All the activities dedicated to support NEO can help to limit the impacts of a non-large NEO in terms of fatalities and injuries, by enabling timely evacuation.

This analysis identifies four categories of impacts from un-mitigated events such as NEO collisions: strategic, economic, social and environmental. These are measured quantitatively or qualitatively, depending on data availability and materiality. There are two types of impacts identified in this section.

1 *Strategic impacts*

Strategic impacts of NEO are linked to the EU stance on the international stage and can be listed as the following:

- Demonstrating leadership of EU in mapping and networking existing capabilities,
- Fostering international cooperation,
- Becoming a stronger partner for the US,
- Demonstrating EU's ability to protect its own territory and citizens.

2 *Economic impacts*

Economic impacts are related not only to the economic return of the EU NEO service value chain, but also to the economic damage reduction (particularly affected industry or infrastructure damages).

In order to better exemplify the economic impacts on the NEO service value chain, a brief description of this is provided in the following paragraphs:

- The **upstream** (NEO sensor and centre manufacturers) is characterised by manufacturing industry. These organisations design and develop NEO assets such as ground-based and/or space-based sensors (telescopes), as well as tasking and data centres.
- The **midstream** (NEO sensor and data centre operators) is characterised by institutions or national observatories that operate the telescopes and their tasking centres, acquire, pre-process and archive NEO data (e.g. US NASA MPC archive NEO positioning data for the international community), and maintain up-to-date NEO discoveries lists and statistics.
- The **downstream** (NEO service providers) is characterised by institutions that produce (in-house and/or in cooperation with companies acting as contractors to such institutions on a de facto exclusive basis¹⁵⁷) NEO services, by analysing data in order to: elaborate estimates of NEO population, discover NEOs and assess their physical properties such as size and material, determine NEO orbits and elaborate predictions, assess collision risk with Earth, and report findings to institutions that decide on issuing a collision warning to take appropriate steps for evacuation and/or for planning a deflection mission. NEO downstream value-added services are inherent in the activities of the NEO service providers (any differentiation among the two would be artificial).

It is assumed that the current situation will remain in the coming years. In other words, EC investment actions that will require the performing of architecture studies to define and consolidate the pooling and sharing of information processes will strengthen the service value chain (from midstream to downstream) but will not generate an impact on the upstream market or any downstream commercial market related to VAS.

¹⁵⁷ There is no evidence of any emerging commercial activity beyond this point.

3 Social impacts

Social impacts mostly relate to the number of lives saved (avoided fatalities) as a result of an evacuation plan or a deflection mission triggered by on-time NEO discoveries and on-time warnings. Concerning the timeliness of discovery, it is assumed that EC actions will improve the global percentage of NEOs discovered on time for an evacuation (i.e. >3weeks ahead) compared to current global performances.

As already mentioned, the characterisation of NEO impacts indicates that a NEO can cause anything from a negligible air blast (<10 m NEO) up to the end of civilisation (>1km NEO), and these impacts vary mostly based on NEO size. However, NEO impacts should be seen in light of their probabilities. NEO impacts are rare events (for example on the order of 1 in 70 years up to 1 in 15,000 years for the NEO family of 20-140 m); past NEO impact events have occurred but are few (the three main ones being: Chelyabinsk, Tunguska, and Barringer) and most of them ancient (the latter two are from 1908 and 50,000 years ago respectively). The following figure provides quantitative figures from these past NEOs ($\geq 20\text{m}$) events that caused severe consequences to people and property. In order to exemplify economic and social impacts, potential consequences to modern society are mentioned.

Figure 85: NEO event and description of its consequences¹⁵⁸

NEO event	NEO size	Description of consequences	Potential consequences to modern society
Chelyabinsk (year 2013)	NEO ~17-20 m at re-entry	- Air explosion (~500 TNT KT), airburst caused damages - People: No fatalities, ~1500 people injured Property: ~4000 buildings damaged (USD >30 Mln)	No or few fatalities, thousands injured, City damages
Tunguska (year 1908)	NEO ~40 m at re-entry	- Air explosion (4 TNT MT) airburst caused damages - People: No fatalities (unpopulated area of Siberia) Property: 2600 km² of forest flattened/devastated	Destroy a city and urban area (incl. population)
Barringer (~50.000 years ago)	NEO ~50 m at re-entry	- Ground collision (25 TNT MT), caused damages - Crater 1.2 km wide, 170 m deep Burned-down everything within 19 km from crater - Large animal killed or wounded within 24 km from crater - Hurricane force wind for 40 Km from impact crater	Destroy a city and urban area (incl. population)

Need of "Analogous Cases" (e.g. Earthquakes, Tsunamis) for case studies of modelling economic impacts

Fatalities

To determine the fatalities associated with a NEO that enters the Earth's atmosphere over land, we developed a modelling technique combining data on air-blast wind speeds from the Purdue Impact Earth database with data on tornados from the NOAA Storm Events database as well as data from other relevant literature. We used the Purdue Impact Earth database to map the wind speeds at different distances from the centre of an air-blast. We then mapped these different wind speeds to levels of the tornado Enhanced Fujitsu scale. Once this mapping was complete, we were able to use relevant academic literature to determine a relationship between wind speeds and mortality rates. For example for a "typical" 50m NEO, a wind speed of 276 km/h occurs at a radius of 5km from the centre of the air-blast and is mapped to an 85% mortality rate, whereas at a wind speed of 143km/h occurs at a 20km radius from the centre of the same air-blast and is mapped to a 2.2% mortality rate. The result

¹⁵⁸ Source: SWF "NEO responding to the International challenge" 2014, NASA/Fema "Pierweg charter" 2015, ESA; Strategy& analysis

is a series of concentric circles with decreasing mortality rates as a function of distance from the centre of the air-blast. The width of the concentric circles and their corresponding mortality rates both vary by NEO size.

The mortality rate for the 1km NEO size was inflated from the rate that was associated with wind speed alone. This is because the Purdue Impact Earth database indicates that NEO of 1km will also generate thermal radiation which will cause further harm to the exposed population. Evidence suggests that once a second or third degree burn is sustained on 70% of more of the body, the mortality rate of the exposed individual reaches approximately 69%. Therefore, we proportionately increased the mortality rate, based on the assumption that in the case of a 1km NEO impact, the majority of infrastructure would be destroyed and therefore the majority of the population would be exposed to full-body thermal radiation. This is a conservative assumption given that the 69% burn mortality rate is based on situations in which a victim has access to proper health treatment, which is unlikely to be unavailable in the case of a 1km NEO impact.

Once mortality rates at various distances from the centre of the air-blast were determined for all the modelled NEO sizes, we used average global land population¹⁸⁷ in order to derive an actual number of expected fatalities for an air-blast event at each NEO size. Fatalities were then valued using Value of Statistical Life (VSL) valuation methodology, which accounts for willingness to pay (WTP) to avoid death, treatment costs associated with fatalities and lost output associated with one fatality, an established technique grounded in welfare economics. Further background on valuation of statistical life methodology is available in APPENDIX A. We used an international weighted average value of a statistical life due to the global nature of the NEO threat.

Injuries

In order to determine the number of injuries, we extrapolated the fatalities numbers using the ratio of injuries to fatalities during historical tornado events from the NOAA Storm Events database¹⁸⁸. We selected tornados during the period 1950 to 1959 (the earliest decade of data available in the database) in order to best simulate an “unprepared” population, as would be the case with a NEO impact under the “Do Nothing” scenario. In order to do this, we took a sample of 4,759 tornados during this tenyear period and calculated the ratio of injuries to fatalities for each level of the Fujitsu scale. We applied this ratio to the fatalities number in order to determine the number of injuries for each NEO size modelled. It should be noted that for this extrapolation, the original Fujitsu scale, as opposed to Enhanced Fujitsu scale was used because the Enhanced Fujitsu scale was not introduced until 2007 and therefore was not in use during the period 1950 to 1959. Furthermore, due to the high number of fatalities associated with a 1km NEO impact, a lower injury to fatality ratio was used such that the total population impacted did not exceed 100%.

Injuries were then valued using the VSL approach noted previously. This methodology categorises injuries into the following groups: major 1, major 2, major 3 and moderate. We have taken an average of these based on the assumption that all of these categories of injuries would be equally prevalent during an Earthquake event. As with fatalities, we have also used an international weighted average value due to the global nature of the NEO threat. This same injury valuation coefficient was also applied to the injuries extrapolated from the Chelyabinsk event to determine the value of the injuries associated with a 20m NEO.

The resulting numbers of injuries were extrapolated for each size of NEO analysed and a few outliers within the overall damage curve (e.g. injuries for a 140m NEO) have been subsequently smoothed to achieve a more logical relationship between NEO sizes and estimated injuries/damages that was assumed to be most representative within the scope of this study. Such final estimated injuries/damages are reported in table 42.

Table 251: Impact assessment and valuation for selected NEO sizes 20m, 50m, 140m and 1Km

NEO Size	Impact Type	Societal Outcome	Raw Number	Raw Value (EUR Mln)	Average Event Value (EUR M)
20m	Air Blast	Fatalities	0 persons	0	0
		Injuries	1,217 persons	57	17
		Infrastructure Damage	EUR 23Mln	23	6,8
		Land Damage	10 km sq	8,2	2,5
	Tsunami	Fatalities	3 persons	3,4	0,4
		Injuries	0 persons	0	0
		Infrastructure Damage	EUR 0.7 Mln	0,7	0,1
50m	Air Blast	Fatalities	6 712 persons	7 125	2 137
		Injuries	100 211 persons	4 681	1 404
		Infrastructure Damage	EUR 528Mln	528	158
		Land Damage	376 km sq	310	93
	Tsunami	Fatalities	3 persons	3,6	0,43
		Injuries	2 persons	0,1	0,01
		Infrastructure Damage	EUR 1.2Mln	1,2	0,14
140M	Air Blast & Crater	Fatalities	51.8K persons	55 028	16 508
		Injuries	1.7M persons	78 500	23 550
		Land Damage	7468 km sq	6 145	1 843
	Earthquake	Infrastructure Damage	EUR 2,867Mln	2,867	860
	Tsunami	Fatalities	85 persons	90,2	11
		Injuries	69 persons	3,2	0,4
		Infrastructure Damage	EUR 12.1Mln	12,1	1,5
1km	Air Blast & Crater	Fatalities	9.3M persons	9 849 638	2 954 891
		Injuries	18.2M persons	851 923	255 577
		Land Damage	90,996 km sq	74 874	22 462
	Earthquake	Infrastructure Damage	EUR24,841Mln	24 841	7 452
	Tsunami	Fatalities	467 persons	496	60

Injuries	155 persons	7,2	0,9
Infrastructure Damage	EUR 160Mln	161	19

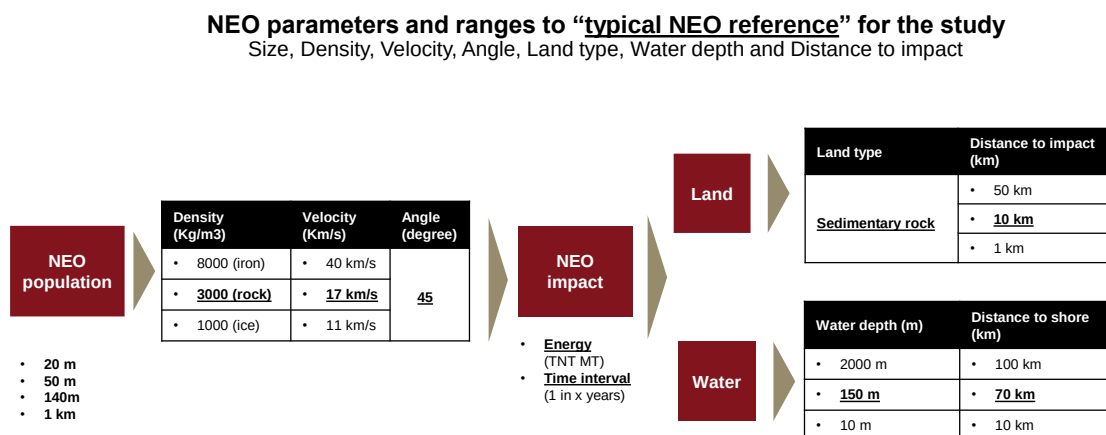
4 Environmental impacts

Environmental impacts are mostly related to the saving in environmental damages that a NEO can cause (e.g. hectares of land degradation) and that a deflection mission can avoid. NEOs that enter the Earth's atmosphere can impact land (30% of the globe) or water (70% of the globe) and can cause, inter alia, earthquakes and tsunamis. Thus, to measure NEO impacts and overcome the lack of past NEO impact statistics this study proceeded thus:

- Firstly, by characterising a 'typical reference' NEO impact through the usage of pre-defined NEO sizes (e.g. 50m, 140m) and reference parameters such as NEO density (e.g. 3000kg/m3) or velocity (e.g. 17km/sec) that can be representative of a NEO impact on land or on water.
 - This analysis gives as output a characterisation of the impact from a certain NEO size. For instance, the size of the crater, the level of earthquake on a Richter scale, or the height of the resulting tsunami wave. This analysis has been performed using the publicly available NEO model of the Purdue University/Imperial College of London, and is reported in this document.
- Subsequently, by using "analogous cases" (e.g. statistics of past earthquakes and tsunamis not caused by NEO but comparable) to quantify the impact in terms of fatalities, injuries and economic damages.

The characterisation of a 'typical reference' NEO has been made using the following parameters, which are visible in the figure below.

Figure 86: NEO parameters for typical reference of a NEO impact on Earth¹⁵⁹



The parameters are applied to a NEO of a given size (e.g. 50m, 140m) and are set to the following variable ranges: a NEO density in kg/m3 (set of values: 1000, 3000, 8000), a NEO velocity in km/s (set of values: 11, 17, 40) and an impact angle fixed at 45°. As a result, a representative reference value in terms of: i) energy impact in Megatons at entry in the atmosphere (TNT MT) and ii) time interval (i.e. 1 NEO every x years) is obtained. Afterwards, the reference value of energy impact in megatons is used to characterise further the impact on land and water (using a typical value of the ocean floor). Finally, the model considers sedimentary rock as a fixed land type and uses an impact distance variable in km (set of values: 1, 10, 50); for water, it uses water depth in meters (m) (set of values: 10, 150, 2000) and impact distance to shore in kilometres (km) (set of values: 10, 70, 100).

¹⁵⁹ Source: SWF "NEO responding to the International challenge" 2014, NASA/Fema "Pierweg charter" 2015, ESA; Strategy& analysis

The results of applying the above-mentioned parameters for a typical reference NEO has led to the characterisation of a potential NEO impact on Earth, both for an impact on land and on water by NEO size as summarized in the table below.

Figure 87 - Typical NEO impact on Earth, Summary table¹⁶⁰

NEOs potential impact to Earth – Summary table					
Time interval, Energy, Land analogous (Crater km, Earthquake Richer scale, Air-blast), Water analogous (Tsunamis)					
Near Earth Objects – Potential Impact to Earth					
NEO families (size/diameter)	Time interval to impact* (1 Neo every x Years)	NEO impact to Earth (high-level description)	Energy* (TNT, MT)	Land analogous* (Crater km, Earthquake R)**	Water analogous* (Tsunami)
• ~ 10 to 20 m	• 12 to ~70 yrs	• Air blasts causing alarm to local damages (city) Chelyabinsk	• 0.05 to ~0.3	• No crater • No Earthquake • Air-blast (Ab) only	• 0.1 to 0.3 m wave
• ~20 to 140 m • 20 m • 50 m • 100 m • 140 m	• 70 to 15.000 yrs • ~70 yrs • ~870 yrs • ~6000 yrs • ~15.000 yrs	• Air blasts/local damages (city) to Tunguska alike impacts up to regional destruction (many fatalities, buildings collapse, damage to economy)	• 0.3 to 150 • ~0.3 • ~7 • ~55 • ~150	• 0 to 2.5/5.8 • 0/0/Ab • 0/0/Ab • 1.5/5.2/Ab • 2.5/5.8/Ab	• 0.2 to 7m • 0.2 to 0.5m • ~0.5 to 1 m • ~1 to 3.5 m • ~1.5 to 7m
• 140m to 1km • 140 m • 250m • 500 m • 1km	• 15.000/500.000 • ~15.000 yrs • ~ 63000 yrs • ~140.000 yrs • ~500.000 yrs	• Regional to continental to global damages (NEOs >1km)	• Up to 50000 • ~150 • ~850 • ~ 6700 • ~ 50.000	• Up to 15/7.8 • 2.5/5.8/Ab • 4/6.5/Ab • 8/7.2/Ab • 15/7.8/Ab	• Up to 200m • 1.5 to 7 m • 2.8 to 20m • 5 to 65 m • 18 to 200

It should be noted that the characterisation of the impact of a ‘typical reference’ NEO and all values in terms of energy, impact on land, impact on water and the frequency/time interval in the summary table above should be viewed as indicative. They represent an approximation given the limited knowledge of the NEO population and the very limited sample of past events that inevitably affect the reliability of any theoretical model, including the highly regarded Purdue University model used in this study. In particular, concerning the estimates of the frequency/interval of time that a typical NEO of a given size would collide with Earth, there is significant uncertainty in such models. As a result, estimates of collision probabilities for NEOs >100m could be imprecise by around a factor 10¹⁶¹.

3.3.4.4. Employment Impact

Employment impact was assessed in the 2018 SSA IA utilizing an Input output modelling. However for the scope of this study, the calculation of this benefits will not be done from scratch. Instead, the team will take the hypothesis that the same multipliers from the previous study to measure employment supported remains constant, and will reutilize the multiplier with the new spending values to get the updated value for employment.

Spending on the SSA initiative will directly support employment in the space industry (within the companies receiving the spending), in addition to further employment that will be supported indirectly or induced, particularly in the further supply chain industry and the wider goods and services industries enabled by employees spending their incomes.

The assessment of the employment impact is based on the SSA Impact Assessment of 2018. In this former study, the employment impact was done utilizing an input output matrix (same approach described in the Copernicus chapter) that modelled the spending across different sectors, combined with wages etc. to extract the employment supported. However for this

160 Note (*): Neo parameters for typical NEO reference: Neo Velocity 17 km/s, Neo density 3000 kg/m³, Impact angle 45°

161 Source: NEO experts at Purdue University

study, the team will utilize the employment ratio calculated in the 2018 study, and assume it remains constant in order to extract the updated supported employment from the new spending under scope. The assessment of the employment spillovers is based on the SSA Impact Assessment of 2018. In this former study, the employment spillovers were assessed on the basis of an assumption of the spendings. The approach suggested is to use the global multiplier observed in the former study between the spendings and the spillovers benefit expressed as an annualised Person-year of employment supported, and to apply this multiplier to updated intended spendings between 2014-2027 to calculate an updated employment benefit.

The ratio to be calculated is demonstrated via the following equation:

$$\text{Multiplier} = \frac{\text{Employment Impact (Person Years)}}{\text{Total spendings}}$$

Person – years of employment supported = Multiplier × Expected spendings
Where:

$$\text{Multiplier} = \frac{\text{Employment Impact (Person Years)}}{\text{Total spendings}}$$

The 2018 study assessed the estimated employment that would be supported as a result of 20 years (2020 – 2040) of spending on the SSA component which would amount to 1143,8 M EUR in 2016 constant prices, which is 1 505,2 M EUR in 2023 constant prices. The table below shows the results of the 2018 SSA IA study:

Table 252: Employment impact and multiplier calculated in the 2018 SSA IA

Total spendings (2020-2040)	Employment Supported	Multiplier
EUR 1 505,2 M (2023 constant prices)	17 800 person-year of total employment supported (direct, indirect and induced)	1 million spent supports 11,8 person years of employment

The objective thereof is to utilize the 2018 study and assess the expected employment impact due to the 2014 – 2027 spending. By using this same multiplier with the hypothesis that it remains constant and computing the spending of 2014 – 2027 whose impact is being evaluated, the employment impact resulting from the new spending can be calculated.

The employment impact is assessed for the spending of the 2014 – 2027 period where the 2021-2027 budget for SSA was extracted from the Work Programmes (to be validated by the commission) The spending values utilized are listed in the table below.

Table 253: 2014-2027 SSA expected spending

Period	SSA Budget (millions)
2014-2020	EUR 52,3 M
2021-2027	EUR 208,2 M
Total	EUR 260,5 M

Applying the following formula:

$$\text{Employment Supported (Person Years)} = \text{Multiplier} \times \text{Updated spendings}$$

The updated employment impact due to the 2014 – 2027 spending is computed and presented in the table below.

Table 254: Employment impact due to the 2014 – 2027 spending

Total Budget	Multiplier	Employment supported

EUR 260,5 million	1 million spent supports 11,8 person years of employment	3 074 Person-years of employment supported

3.3.4.5. Summary table of benefits

For the 3 sub-components of the SSA component (SST, SWE, NEO), employment was assessed as transversal impact expressed in “Person-year of employment supported”. The assessment shows that for the total budget spent on SSA over the period 2014-2027, 3 074 Person-years of employment will be supported.

The following table summarizes the different benefits evaluated from the 3 segments of the SSA component (SST, SWE and NEO)

Table 255: Summary table for the benefits of SSA

Component	Impact category	Impact	Valuation of Benefits between 2020 and 2035
SST	Economic impact	Reduced loss of revenues for spacecraft owners and operators (Updated)	EUR 84.6 M (Neutral scenario)
		Impact on the potential emergence of a commercial market for SST services (Not updated)	Qualitative - Business and scientific opportunities to cooperate with the EU SST would be extremely beneficial both for the quality of SST services and for the creation of an extra revenue stream.
		Impact on the risk of losing all the space assets (Kessler effect)	Qualitative - Role in mitigating the risks of a Kessler effect which can cost up to EUR 52.3 B in GVA loss per year for the EU and the UK.
	Strategic impact	Increased safety of strategic EU owned space assets against both passive and active threats (not updated)	Qualitative - An increased EU autonomy in terms of surveillance capabilities to identify and detect voluntarily harmful threats can be perceived as an important strategic driver towards the protection of EU space assets.
		Stronger role in the monitoring of international guidelines on the safe use of space	Qualitative - By developing stronger observation capabilities, the EU would be able to play a prominent role in ensuring the safe use of space.
	Social Impact	Safety of people	Qualitative - SST system information and data combined with trajectory predictions can lead in principle to proactive measures to evacuate certain areas on earth and enhance the safety of the astronauts on board of the ISS.
		Knowledge investment (research and innovation)	Qualitative - Knowledge investment could diminish EU dependence on US SST data. Moreover, it is well known that some of the benefits of knowledge investment are related to spillover effects resulting from being a world-renowned research cluster
		Job creation	Qualitative - The development of new sensor assets (radars, telescopes, laser stations) will trigger more job creation. There will also be jobs created through the SST service value chain, which is broken down into: i) sensors and data centres manufacturers (industry), ii) sensors and data centres operators (institutions), iii) service providers (institutions) and iv) value-added-service (VAS) providers (institutions)

Component	Impact category	Impact	Valuation of Benefits between 2020 and 2035
	Environmental impact	Reduction of fragmentation	Qualitative - The SST initiative should thus contribute to the control of the evolution in the number of space debris.
		Environmental protection	Qualitative - The EU will have the ability to track a particular debris and model the re-entry with more precision. Improved re-entry models would enable better preparedness in case of a re-entry of large and/or toxic space objects and therefore take adequate measures to protect the environment and mitigate the potential negative effects of such event.
SWE	Impact on Space sector - Spacecraft operation and design	Temporary disruption/loss of service	Estimated to be: EUR 0.88 M in 2020
		Reduced lifespan of specific services/satellites	EUR 2.52 M in 2030
		Risk of complete loss/lack of functioning of satellite	EUR 7.08 M in 2040
	Impact on Space sector - Launch Operations	Delays in launch	Estimated to be:
		Waste of propellant due to defueling	EUR 0.005 M in 2020
		Orbit Injection Anomalies	EUR 0.013 M in 2030 EUR 0.016 M in 2040
	Impact on Aviation sector	Disruption to GNSS signals	Estimated to be:
		Disruption to HF communication	EUR 0.020 M in 2020
		Human health risks	EUR 0.036 M in 2030
		Malfunction in avionics	EUR 0.064 M in 2040
	Impact on Power grid sector	Failures of equipment	Estimated to be:
		Disruption of power grid networks leading to short power loss or longer blackout	EUR 181.6 M in 2020 EUR 205.5 M in 2030 EUR 232.8 M in 2040
NEO	Strategic impact	Demonstrating leadership of EU in mapping and networking existing capabilities	Qualitative - Improvement of the EU stance on the international stage
		Fostering international cooperation	Qualitative - Improvement of the EU stance on the international stage
		Becoming a stronger partner for the US	Qualitative - Improvement of the EU stance on the international stage
		Demonstrating Europe's ability to protect its own European territory and citizens	Qualitative - Improvement of the EU stance on the international stage
	Economic impact	Increased economic return of the EU NEO service value chain	Qualitative - EC investment actions to define and consolidate the pooling and sharing of information processes will strengthen the service value chain, particularly from midstream (NEO sensor and data center operators) to downstream (NEO service providers).
	Social Impact	Saving lives	Through deviation missions, up to 9.3 million people can be saved in the case of a NEO of 1km in size.

Component	Impact category	Impact	Valuation of Benefits between 2020 and 2035
		Preventing injuries	Through deviation missions, up to 18.2 million injuries can be avoided in the case of a NEO of 1km in size.
		Preventing infrastructure damages	Through deviation missions, up to EUR 161 M can be saved in the case of a NEO of 1km in size.
	Environmental impact	Preventing Land damage	Up to EUR 74 874 M can be saved in the case of a NEO of 1km in size.

3.3.5. Efficiency and Cost Benefit Assessment of SSA

The following cost-benefit analysis is based on the benefit assessment in the previous section which and the costs provided by the European commission related to the SSA component. A comparison of these two factors is developed in order to understand to what extent are the costs involved justified and proportionate to the benefits achieved.

Benefits of SSA

The benefits of the SSA component were assessed in the previous section. Each sub-component (SST, NEO, SWE) was analysed separately to quantify as much as possible the related quantitative benefits and to describe the qualitative ones. The assessment was largely based on the 2018 Impact Assessment study of the possible EU SSA initiative, done by PwC for the European Commission.

The results of the benefit assessment are summarized in the above section which contains the quantitative and qualitative benefits. For the cost benefit assessment, only the quantitative benefits can be compared to the costs, but as shown in the previous section, the benefits assessed qualitatively are also very impactful and should also be taken into account while questioning the efficiency and relevance of the SSA component.

The table below shows the cumulative benefits for the SSA component:

Table 256: Employment impact due to the 2014 – 2027 spending

Total Budget	Multiplier	Employment supported
EUR 260,5 million	1 million spent supports 11,8 person years of employment	3 074 Person-years of employment supported

Table 257: Cumulative quantified benefits for SSA sub-components

Sub-component	Time Frame	Quantifiable Cumulated benefit*
SST	2014 - 2027	EUR 14,46 M
SWE	2020 - 2027	EUR 1 528,38 M
NEO	2020 - 2027	Not quantified
Total	2020 - 2027	EUR 1 542,84 M

**Only specific use cases could be quantified for the benefits*

To be noted that the SST sub-component also has a major role in mitigating the risks of a Kessler effect which can be highly critical for all the sectors with services depending on space assets. This role can't be quantitatively assessed as there are other strategies being tested to help mitigating the Kessler effect.

The benefits for SST were assessed up to 2035 with the assumption that they be enabled thanks to the current programme. However, in the scope of this cost-benefit assessment, only the benefits between 2014 and 2027 are taken into consideration for the purpose of keeping the consistency with the cost's timeframes. This assessment is therefore very conservative and shows that the actual benefits can be more important.

Costs of SSA

The costs related to the SSA component are provided by the European Commission. In the table below, the cumulative spending at entrusted entity level for SSA is segmented into Contract Value (budget spent in the industry layer) and Workforce Value (budget spent for salaries) for the time frames 2014-2020 and 2021-2027. This last time frame is further subdivided in what has been committed up to 2022 and what is the planned commitment for the remaining years (2023-2027).

Table 258: Spending segmentation per time frame and spending type of SSA

Spending type	Time Frame	Amount in M€
Old MFF		
Total Commitment	2014-2020	52,3
New MFF		
Total Commitment	2021-2027	208,16
Total Spending (2014-2027)		260,5

Cost-benefit assessment outcome

The cost benefit assessment (CBA) of the SSA component will assess the ratio and the difference between the benefits generated by SSA and the costs it takes to develop and operate its tree sub-components.

Therefore, the cost considered in this CBA are all the costs that have accumulated from the beginning of the component and that are expected till the end of this MFF. This is because, the benefits from the exploitation of SST are the consequences of all the investments made to develop the programme, including the investments made before the programme became operational.

On the benefit side, the CBA will account for also all the benefits accumulated since the beginning of the programme. In the previous ex-ante Impact assessment performed by PwC in 2018 (from which the benefits were extracted and updated), the benefits were assessed starting 2020, assuming that the component will only be at a mature stage of development in 2020. This leads to a total cumulative benefit of EUR 1 542,84 M for a total cost of EUR 260,5 M.

Over the timeframe 2014 – 2027:

Between 2014 and 2020, the SSA component had a total cost of 52,3 million euros. However, this component wasn't mature enough yet to enable significant benefits.

The benefits quantified for this cost benefit assessment (CBA) are mainly generated between 2020 and 2027. The table below outlines the Benefit To Cost Ratio :

Table 259: Cost Benefit ratio for SSA component

Costs	Benefits	Benefits Cost Ratio (BCR)
EUR 260,5 M	EUR 1 542,84 M	5,92

As shown in the table above, the benefit to cost ratio (BCR) of SSA for the period of 2014 – 2027 is 5.92. This means that the downstream socio-economic benefits experienced by the SSA end-users and beneficiaries over the timeframe 2014-2020 largely outweigh the costs and spending that went into SSA over the same period by 5.92 times

Furthermore, the investments in the SSA component also generate many benefits that were only assessed qualitatively and could not be included in the cost-benefit assessment. These benefits correspond to thousands of lives saved; to a better positioning of the EU in the international stage; to reduce EU dependence on other countries; to important knowledge creation... (more details in the “Benefits assessment of SSA” section). All these benefits increase the usefulness of the SSA component and shows that the investments in this component are justified and coherent.

Post 2027

Naturally, the benefits of the SSA component are expected to continue growing post 2027 due to the continuity and evolution of the service and the investment made before. Costs are also expected to continue being incurred for the same reason. However, as the budget for 2027 – 2035 has not been allocated yet, it will not be covered in the assessment. On the other hand, one caveat has to be made regarding the fact that a good portion of the benefits expected post 2027 are linked to the costs that have been incurred over 2014 – 2027, and not just due to the costs that will be incurred in 2027 – 2035. However, it is not possible to extract that portion of the benefits to incorporate it in the Benefit Cost Ratio.

It is possible to conclude that the expected SSA societal, environmental and economic benefits largely outweigh its costs and spending.

3.3.6. Relevance assessment of SSA

As explained previously, the relevance assessment section aims at ensuring that the component is in line with current and emerging needs. However, for NEO and SWE the **services are not yet operational**. Therefore, the methodology is slightly different as it's not feasible to make direct comparisons between the service and the user needs, as it was done for Galileo/EGNOS and Copernicus. Instead, the focus is placed on examining the link between user needs and service definition. The data in this section was gathered through desk research and consultations with EC, EUSPA (for SST) and ESA (for NEO & SWE).

SWE

The SWE sub-component aims at implementing and funding a number of space weather services to users that are potentially affected by this threat (satellite and launcher operators, telecommunication and navigation actors etc.). As specified, the **service is not operational yet**, the initial service provision being expected in **2025**. However, to ensure that the forthcoming features will be aligned with current and emerging needs, several tasks are ongoing.

A **Customer Requirements Document** has been established by ESA and shared with the Commission, even though ESA's S2P and the SWE sub-component are two different programmes. It highlights the high-level user requirements and identifies the **services of this segment** as part of the applicable baseline for all SWE segment design definition and development activities.

The CRD will **serve as an input for the SEIA of SWE**, which has been kicked-off recently and which outputs aim at helping for the selection of the 2025 EU SWE service(s). Regarding user needs, the ongoing study will assess the user domains considering their impacted

economic activities as well as the sensitivity and vulnerability of their infrastructure to space weather events. The result will thus be a **priority list of individual services**.

The final choice regarding **the scope of the initial service** will be decided by the **Member States** by means of **implementing acts**, taking into account the **guidelines** provided by the **results of the SEIA**, the **Commission's additional inputs** on this subject and the directions given by the **article 60 of the Space Regulation**, namely (a) prioritize SWE services to be provided at Union level according to the needs of SWE users, the technological readiness of the services and the result of a risk assessment and (b) Services which may contribute to civil protection activities and to the protection of a wide range of sectors such as space, transport, GNSS, electric power grids and communications. The costs associated with the development of the future service as well as the technical feasibility will also be taken into account for the final choice.

The exact number of services is **not determined yet** however, it was understood from the consultation with EC that one service is foreseen, considering the current budget allocated to the SWE sub-component.

NEO

Regarding the NEO sub-component, it was understood through the consultations that **no user needs assessment has been conducted for NEO**. The chosen topics are described in article 61 of the Space Regulation and involve for instance the mapping of Member States' capacities for detecting and monitoring NEOs and the creation of a European catalogue of NEOs.

These topics were selected in order to strike a **balance between the interest for the community and the budget constraints**. In this context, for example, the development of a NEO catalogue holds substantial importance. Indeed, understanding the physical properties of NEOs such as the composition and the internal structure are crucial as different type of NEOs require distinct approaches and strategies. This carries significant implication for both science and impact mitigation as physical properties might determine if the NEO will burn up in the Earth's atmosphere or make it to the surface, potentially creating an impact crater.

SST

For SST, **SatCen worked on the user needs and this work is now continued by EUSPA**. The task is nearly consolidated, resulting in a documentation of **roughly 100 user needs** (not requirements) collected through feedback campaigns, meetings or more recently with EUSPA tools (UCP) according to stakeholder consultation. However, this document is not publicly available and is only shared with EC and the partnership due to the sensitive nature of the SST services.

Since the documentation of user needs cannot be accessed, it was not possible to compare the services with these needs to draw conclusions. However, based on consultations with EUSPA, It was communicated that overall, **around 80% of the identified needs are currently being covered** with the service. The remaining 20% present a varied coverage rate – roughly, an estimated 10% of the needs are partially covered and the remaining 10% are not covered at all (however, this is not the exact repartition). For these, either it is **not possible to fulfil them with the current system**, because of technical – impossible to detect extremely small objects - or financial limitations. Or these needs are **considered for future services**, as it will be developed below.

For example, one of the needs could be to **avoid receiving false alerts**. Indeed, an initial alert is received by the user 10 days prior to a supposed collision. However, during this period, the collision risk can fluctuate, potentially decreasing. If this happens, which is plausible, the initial alert might be considered as a false one by the user. However, this is due to system's

limitations as it's impossible currently to predict this outcome in advance. Thus, it would not be feasible to meet this need due to the **inherent constraints of the system**.

Another example could be that users want to know the exact timing of when the information will be updated. SST operates through tasking a network of sensors however, technical limitations or even adverse weather conditions can prevent to provide an exact timing of these updates as desired by users.

Thus, these limitations stem mainly from **technical constraints**. However, these gaps can be potentially bridged by **leveraging more powerful assets**, which would however require more **significant budget allocation**. Additionally, to address some of the gaps, there's an initiative today to focus on **innovative technologies**. The overarching goal is to enhance the performance of existing assets, to develop new ones and deploy them in strategic areas or to develop new technologies i.e space-based assets. Grants such as Horizon Europe with primary emphasis on R&D as well as calls of interest aimed at providing solutions are clear illustrations of this trend. Regarding Space Traffic Management, recent initiatives include the establishment of industry and startups forums aimed at supporting the development of operational capabilities alongside specific tenders.

It can be anticipated that **user needs will evolve**, with **Space Traffic Management** being the central axis of this transformation. As the need might arise to enhance the system, one aspect could involve **augmenting system's current capability to effectively coordinate events involving two operational satellites**. Currently, even though the service provides support in these cases, a clear framework is lacking and establishing one would be highly beneficial. Indeed, in general, operators have their own information and sometimes the information provided through the SST services complete this information. However, in scenarios when they don't have planned manoeuvres or if their information is inconsistent with the information provided by the SST services, then a mediation process is necessary to determine the appropriate course of action (i.e., which satellite should move). Large constellations often manoeuvre themselves in order to mitigate the risks promptly. But for standard satellites, a case-by-case analysis is essential to ascertain whether an operator has planned manoeuvres and more generally, to determine the most suitable operator for any required adjustments. In these cases, **having a structured framework outlining how to process would be helpful**. Once the rules will be defined, it would also be possible to think about **standardizing the process**. EU SST could recommend the optimal operator for manoeuvres based on predefined factors, and EUSPA could afterwards facilitate the coordination, follow through and effectively close the loop.

Additionally, **further automatization will be needed with STM** to answer the needs which will be associated with the development of large constellations – a current trend. For collision avoidance for instance, which is a key service delivered by SST, there will be a topic on how it will operate for these **constellations**.

Among the upcoming priorities for the users, one topic is expected to gain in importance and become of high priority: the **support to critical operations**. Users require additional assistance in accurately tracking satellite positions and additional support through the early orbit phase as well as the management of the end-of-life process (e.g to avoid collision in the process of transferring to graveyard orbit or in case of a forced re-entry, to ensure a seamless and secured way to do so). This will be added on top of collision avoidance service, **extending the coverage from nominal operation to the entire satellite life cycle**. Currently, the existing system would allow to handle such requests in a **punctual way** however, if this type of requirements become more systematic and extends to Space Traffic Management, it could require additional resources, the exact quantum of which is yet to be determined.

3.3.7. EU Added Value

This section analyses the added value of an action at the Union level compared to what would have been the results of actions by Member States acting alone. This analysis is crucial for designing new policy measures and for evaluating existing initiatives. The data in this section was gathered through desk research and consultations with EC, EUSPA (for SST) and ESA (for NEO & SWE).

SWE

Space weather events have the potential to impact both technologies in space and on Earth. In its severe manifestations, it could pose risks to astronauts, interfere with communications systems, and can even lead to temporary power grid outages. Hence, understanding how space weather events affect Earth, our assets and human well-being is crucial for effectively managing the associated risks.

These events pose a **global threat necessitating a global response**. Relying solely on national initiatives would be insufficient because national capabilities, if not mutualised, would experience **significant limitations**. A good understanding and forecasting of SWE events, indeed, rely on the availability of diverse data sets – mainly scientific – which must be combined in order to have a full picture of the event. For this purpose, the ground-based observation systems, which are based in several Member States, need to be used together, the data they provide with shared and the expertise in various areas available (services in different countries) put together for this common goal.

This cooperation has the potential to **enhance Member States' capacity in addressing SWE risks** and foster **active participation in ongoing global SWE efforts**. By collaborating with international partners, especially those working with diverse funding structures and opportunities, the EU can create synergies, contributing to and benefiting from parallel worldwide initiatives led by global organizations such as the United Nations.

A **flexible approach** would be interesting, allowing each institution and country to engage to the best of their abilities. This approach could integrate scientific and interpretative expertise from various institutions. This would facilitate the swift incorporation of emerging capabilities and knowledge and support informed decision-making based on a comprehensive understanding of current possibilities and emerging trends within the research community.

However, addressing the issues covered by SWE also calls for **regional and cross-regional strategies, because it is necessary to tackle national specificities for space weather events**, mandating coordinated efforts at all levels¹⁶². Indeed, the landscape and risks associated with SWE events are diverse and have to be taken into account, which calls for a **coordinated EU assessment of national and regional risks** and consequent potential socio-economic impacts of a variety of SWE events, both for extreme and average daily solar activity. Looking at these SWE events' potential impacts could lead to an uniformization in safety matters (for example through a regulation covering transportation safety in aviation) and this requires **the backing of the EU** to enable and oversee these initiatives.

Space weather represents a domain where scientific knowledge, economic interests and societal implications are inherently linked and **a fragmented approach would be insufficient** to satisfy the growing societal needs, for both advancement of knowledge and the provision of services.

¹⁶² ESWACC, Assessment and Recommendations for a Consolidated European Approach to Space Weather, 30th of August of 2019

The topic being addressed by the NEO sub-component is also a **topic of global scale** – planetary defence – which necessitates a **concerted global effort**. Given the extensive repercussions of a NEO impact and the substantial resources needed to prevent such a collision, it is crucial to raise awareness and promote global cooperation. An action at a Member State level would not be sufficient in this field because this sub-component deals with a cross-border issue which thus requires cross-border data flows in order to ensure that all Member States, especially those with limited capacities in predicting and mitigating a NEO impact are aware of potential threats.

Effectively dealing with this hazard, which includes identifying objects posing a threat of impact to Earth and planning suitable mitigation strategies require cooperative action in the interest of public safety by the EU community.

It is indeed crucial to **study the physical properties of the NEOs** to understand their composition and structure. Regarding this, ground-based observations play an important role in investigating the physical and dynamic properties of the NEO population, significantly augmenting the scientific yields of missions. This is necessary for judiciously selecting NEO targets for space missions, ensuring both technical feasibility and maximizing the scientific outcome. This is also essential to establish an effective emergency response and disaster management protocols in case of a NEO impact.

Substantial resources are required to do so and to achieve these objectives. Firstly, an extensive instrument deployment across EU is needed to have the observation time necessary with the appropriate tools to determine the NEO's physical properties. Secondly, getting a complete picture requires a synergy of diverse capabilities, including sensors, telescopes, and related technologies. An action at EU level is thus not only justified but necessary to obtain the most reliable and precise information. Indeed, even with substantial resources, there's no assurance of achieving the set objectives due to the inherent uncertainties in this domain and in order to be the most accurate possible, a cohesive effort is thus imperative, pooling together the diverse resources all across Europe in the **most effective way possible**.

Moreover, implementing an initiative at EU level **enhance its efficiency by preventing duplication of assets** across Member States.

Overall, tackling this problem at a national level would neither be efficient nor effective and the costs incurred by this initiative would be unreasonably high. The Space Regulation even highlights the need for an **international cooperation** in this field (and for the SSA component in general), in particular with the United States, international organizations and other third parties, particularly to increase preparedness for the effects of near-Earth objects (as well as to avoid collisions in space, to prevent the proliferation of space debris -SST- and to increase preparedness for the effects of extreme space weather events -SWE-).

The services delivered by the SST sub-component play a key role in ensuring the safety and security of the economies, societies, and citizens in Europe by safeguarding the space assets of the EU, especially the satellites involved in the EU Space Programme, its Member States and other space operators.

Undertaking this initiative at the Union level has a lot of clear benefits. Indeed, SST deals with a **cross-border issue involving all Member States** and it would not be feasible to tackle this challenge at a national level, mostly because of **the costs induced** as well as the need for a lot of **capabilities** currently not available for most of the Member States.

Moreover, SST sub-component delivers a public service which is free of charge and if the users don't receive it, they will probably rely on other sources, which will impact Europe's

positioning on the international scene in this sector. On that note, currently, the **EU SST value is acknowledged at an international level**. For example, the United States are developing their STM system and in this process, a lot of operators have been referencing EU SST. This allows Europe to have a strategic position in this field and a presence on the international stage alongside the USA and other players in this domain. Yet, the challenges regarding the autonomy of Europe in this sector are to be taken into account. Any kind of dependance would ultimately lead to certain limitations. Thus, if we want to aim for **a EU leadership in this domain**, the level of investment should be substantially greater.

Furthermore, if the EU intervention was withdrawn, a pragmatic question would remain unanswered regarding **who would protect the EU assets**.

Regarding the services delivered, they aim at developing the EU assets/companies and therefore EU data as well as constituting a European catalogue according to the provisions of the Space Regulation. The service is not aimed at becoming independent from the US Programme or competing with it; mostly because the US invest more money (nearly 1 billion per year for Hubble for example). Accordingly, it is rather designed on a **cooperative basis**: the system is thought out more in terms of **added value** - the data from the US is supplemented by additional **EU expertise** (to refine the data, check the calculation etc.) and more accurate data using **Member States sensors**.

Although coherence is evident in the current mechanism, some stakeholders pointed out that SST sub-component would benefit from **enhanced coordination** in its governance which would help efficiently determining the long-term objectives and desired evolution in provided services in order to maximize the benefits that can be achieved.

3.3.8. Policy Coherence

The policy coherence assessment aims at underlining how well or not different interventions, EU/international policies or national/local policy elements work together. The objective is to highlight areas where there are synergies which improve overall performance or on the contrary, point tensions with potentially contradictory objectives or overlapping approaches, which are causing inefficiencies. The data in this section was gathered through desk research and consultations with EC, EUSPA (for SST) and ESA (for NEO & SWE).

SWE

Overall, within the SSA component, regarding policy coherence, discussions are more oriented towards the SST sub-component. However, some synergies can be found for SWE, mainly with other components of the Space Programme.

First, **synergies with Galileo could be explored**. Some Galileo satellites currently host SWE instruments which measure radiation around the satellites. The Sun poses several potential impacts which can affect the satellites directly. Electromagnetic radiation and charged particles resulting from solar flares have the potential to interfere with satellite electronics, create potentially hazardous electrostatic charging, and cause damage to onboard materials.

While all satellites are susceptible to these risks, this is even more the case for satellite navigation constellations. Positioned at relatively high altitude, Galileo's medium orbit is less protected by the geomagnetic field than other orbit regimes, like low orbit. Moreover, this orbit also takes satellites through the outer Van Allen radiation belt where incoming charged particles are funneled by the magnetosphere. These instruments already collect data however,

the prolonged **security clearance** process results in **outdated data by the time it becomes available**.¹⁶³

Second, **synergies could also be fostered with Copernicus**. Indeed, currently, Sentinel-6A hosts space weather applicable instrument, a Radiation Environment Monitor sensor, among the supporting instruments, in order to measure in-situ the space radiation environment. This existing coherence between Copernicus and SWE could be further promoted by multiplying similar **hosting payloads initiatives** or by **further collaboration in flight mutualization efforts**. The Copernicus LEO missions could for instance, offer a favorable environment for additional magnetic field measurements, observing the plasma environment, and studying radiation conditions. Technical limitations to bear in mind would include factors such as the available additional mass and power required to host these instruments. There could be two potential approaches: the first involves proactive planning, where synergies could be integrated into the mission design from the start. The second approach would entail introducing SWE instruments at a later stage in the mission implementation, once margins are assessed and confirmed to be sufficient. In any case, it would be interesting to conduct joint planning to ensure a seamless integration.

More generally, SWE sub-component is coherent with other EU initiatives such as National risk registers - to the extent possible. Indeed, severe space weather events are included in the **National Risk Register of some of the Member States**. As an example, the 2023 Finish NRR mentions extremely strong space weather storm as one of the risks faced by Finland. Among the consequences are listed disturbance in satellites functioning as well as potential damage to transformers due to voltage fluctuations in the national power supply grid¹⁶⁴. Other countries such as Belgium or Sweden also include space weather events in their national risk assessment, highlighting once again that the sub-component is coherent with other EU initiatives.

Lastly, in order to **avoid duplication of assets**, the SWE sub-component should be coherent with the ESA's Space Safety Programme. Indeed, under the Contribution Agreement, for the tasks entrusted to ESA under Horizon Europe¹⁶⁵ and the related activity which is the development of certain technology elements for precursor services, it is specified that these developments will "*complement the existing European space weather assets and will not overlap or duplicate assets transitioned into the operational framework*". Thus, although those are two different programmes, it would be beneficial to ensure the coherence of one programme with the other to **prevent unnecessary duplication of efforts and to enhance the overall efficiency**.

NEO

Similarly, to SWE sub-component, NEO topics are mentioned in the **national risk assessment** carried out by some Member States. As an example, among the risks listed in the large-scale risk assessment for Belgium for the period 2018-2023, carried out in 2018 by the National Crisis Center, the "risks from outer space" section includes meteorite impacts, which were assessed as having a low probability but with a catastrophic impact. Moreover, in a more

¹⁶³ Obsolete data for operational process but might be used for scientific research.

¹⁶⁴ Even if it is mentioned that Finland's national grid is relatively resilient against changes in space weather, problems in the neighboring countries can also be reflected in Finland via the joint Nordic power grid and the need for importing electric power.

¹⁶⁵ Tasks under Horizon Europe are not under the scope of this study. This was to underline the need for overall coherence between the ESA S2P and EC SWE - which remain 2 different programmes.

practical way, Belgium has developed a **general emergency and intervention plan** which is also operational in the event of a meteorite impact. These types of plans, containing measures and procedures in case of an emergency situation, can be drawn up at local or national level. This underlines that NEO topics are as well considered in **some local and national policies**.

On a more global scale, NEO sub-component should be coherent with external policies, recommendations and must align with the worldwide efforts in this sector in order to nourish international collaboration. Indeed, NEO-related subjects are a matter of international concern and several initiatives already exist. The **United Nations Committee on the peaceful uses of outer space-endorsed recommendations for building an international response to the NEO-impact threat**. These recommendations were centered on facilitating international information sharing in discovering, monitoring and physically characterizing potentially hazardous NEOs. They aimed at raising **awareness** among all nations about potential NEO impact risks and underlined the importance of establishing efficient **emergency response** and disaster management protocols in the event of an identified NEO impact threat. Two of the NEO sub-component objectives perfectly align with this. The first one is to build a **European Catalogue of NEOs** in order to monitor them, obtain insights about their physical properties and facilitate the sharing of these information. The second one is to develop **provision of rapid expert response service** in relation to new NEOs including for potential ground impactors (>50 m), fast-response space missions for reconnaissance (to better understand the characteristics of the object) and/or deflection mission.

Additionally, the **IAWN** and the **SMPAG** are two entities established in 2014 as a result of these recommendations and which serve as significant mechanisms on a global scale contributing to **enhanced coordination** in the realm of planetary defense. As the overall goal is to protect human beings and the ecosystem in its globality, a collaboration with these two organizations would be highly beneficial in order to increase the effectiveness and efficiency of the NEO sub-component. This would align, more generally, with the **aspiration for collaboration** from European countries, as demonstrated by the efforts of various entities and organizations to actively participate in **international initiatives** in this field and offer precious contributions. As an example, ESA is a member of IAWN and NEOROCKS study has provided valuable inputs to the IAWN.

SST

The SST sub-component was initially created in order to contribute to ensuring long-term availability of EU and national **space infrastructure, facilities and services** which are essential for the safety and security of the economies, societies and citizens in Member States.¹⁶⁶

SST therefore aligns cohesively with all other components of the Programme as it prevents damages to EU Space infrastructure, which **is essential for the continuity of the services provided by the other components**. Indeed, space assets are now integral to European economy and it is crucial to guarantee their security, mainly by **leveraging existing national assets** to develop a EU monitoring and surveillance capacity. By safeguarding these assets, SST plays a crucial role in ensuring that the essential services are delivered efficiently to the end users.

According to the Decision establishing the framework of SST, and in addition to the **Union's flagship space components Galileo and Copernicus**, the SST services were also thought to be complementary to **wider EU initiatives** such as **research activities related to the protection of space-based infrastructure** carried out under Horizon 2020, **the Digital**

¹⁶⁶ Decision n°541/2014 of the European Parliament and of the Council of 16 April 2014, art. 3.

Agenda initiative and more generally other **telecommunication infrastructures** which aid the realization of the information society, **security-related initiatives**¹⁶⁷ as well as to **ESA activities**¹⁶⁸.

On a larger scale, it is also essential to consider **cooperation** with international partners, especially the US, international organizations and other third parties to enhance coherence among the initiatives particularly to avoid collisions in space and to prevent the proliferation of space debris. The SST sub-component should indeed **complement existing mitigation measures** such as the United Nations guidelines for space debris mitigation or other relevant initiatives, ultimately promoting safety, security and sustainability of outer space activities.

Regarding upcoming challenges, there are two points where coherence will be essential. Firstly, with **constellations**, which are a current trend, especially in the context of the Union Secure Connectivity Programme (IRIS²). Addressing how this sub-component will function effectively and navigate coherently through these types of constellations will be one of the essential next steps.

Secondly, with the development of STM, as SST will represent its operational branch. An **enhancement of the EU SST capabilities** will surely be needed to effectively tackle the **challenges associated with STM**.

3.3.9. Additional insights to the SSA component

Two further aspects were assessed for this component: the **pricing policy** and the **evolution of the available capacities for pooling and sharing**. The data in this section was gathered through desk research and consultations with EUSPA, ESA and EC.

Pricing policy

The pricing policy for the SSA component covers the pricing policy for SWE, NEO and SST sub-components.

Regarding NEO, the service is currently under construction so assessing the pricing policy at this early stage **would not be relevant**. However, NEO will be a **predominantly institutional service** and there are **no short or medium-term expectations of commercializing future services**. But in the future, if asteroids mining activities advance, there could be an opportunity for commercialization by providing information on the physical properties of the asteroids. Yet, this is not a current focus or topic of discussion.

Regarding SWE, the service will be free of charge. While commercial services may be proposed, it is important to note that presently, meteorological services are primarily considered public services. Customized services could then be added for various sectors such as transportation or defense, **tailoring the service to specific needs** within these sectors. However, for now, and due to the objectives of SWE future service – mitigate the risks associated with extreme space weather events and safeguard systems and technologies in orbit and on Earth – the service is expected to be a public service, free of charges.

Regarding SST, the service has been **free of charges** from the beginning. It was decided so not based on an impact assessment nor a political choice but in order to furnish a **fundamental safety service**, particularly ensuring the **safety of EU Space Programme's satellites**. This approach is similar to Member States providing accident/roadwork information at no cost for highways and streets, ultimately enhancing traffic safety at a marginal cost compared to the expenses incurred from accidents. **In economic terms**, the SST

¹⁶⁷ Such as coherence with EDF to avoid unnecessary duplication.

¹⁶⁸ Regarding ESA, the cooperation is more based on a dialogue in order to inform on ongoing initiatives but is not meant to be complementary. To avoid duplication of assets in this case refers to the R&D only.

service proves significantly more economical than destroyed satellites. Moreover, the **quality of the service delivered** might be impacted if private entities are involved since a competition to provide them at lower cost can appear. **In governance terms**, implementing a pricing mechanism could pose great challenges given that SST uses national assets to deliver its services – which is distinct from all the other EU Space Programme services.

However, this doesn't exclude the **possibility of additional commercial layers** being provided by the industry in the future. For this, it would be essential to understand the **potential offer**, exploring the likelihood of additional added-value services (some users could be interested in additional features, statistical analysis etc.). Simultaneously, understanding the **potential demand** from the satellite operators' perspective would also be crucial – for example about the potential market size - as well as bearing in mind that if institutional welfare is sufficient to deliver a good service, additional commercial services might not be necessary. A **balance** can be found between what is necessary and what could constitute an additional added-value service, however, in any case, it is certain that the **fundamental service level will remain free of charges** for the reasons previously mentioned.

Evolution of available capacities for pooling and sharing

Regarding the SSA component, the evolution of available capacities for pooling and sharing referred to the SST sub-component. However, it was understood from the consultations that there was **not really a pooling and sharing mechanism** such as the one for the GOVSATCOM component but rather **an aggregation of the resources available at EU level**. This system is based on **Member states capabilities**, allowing them to use available assets (and avoid their unnecessary duplication) under defined framework conditions with the Commission covering the costs.

Currently several assets are already in place and the transition from the SST consortium to the SST partnership with an increase from 7 to 15 members anticipates **the inclusion of additional sensors** in the pool with **additional enhanced capabilities**. Ensuring that these assets perform as expected is one of the responsibilities of the Front Desk, which oversees KPIs to guarantee the effectiveness of the system.

The **capacities are expected to expand with additional assets from new Member States, extending the geographical coverage**, as well as the **improvement of the existing ones**. Furthermore, the **industry involvement is growing**, as evidenced by calls for tenders aimed at developing sensors for example.

In summary, there's an **overall growth expected** for the available capacities, both from the **institutional** and **commercial** side but the key focus and main challenge would remain on ensuring that these assets **meet their expected performance standards and on guaranteeing the continuity of the service**.

3.4. GOVSATCOM Component

3.4.1. Introduction to the GOVSATCOM Component

In a highly fragmented landscape, with telecommunications services being offered by both nationally owned and commercial satellite infrastructures, a mismatch currently exists between governmental satellite communications needs and available solutions. As a result, key missions, operations and infrastructures of the Union and its Member States are exposed to security risks. Access to secure SatCom services is key in case of network interruptions (e.g., in case of natural or man-made disasters), unavailability (e.g., in maritime areas or in the Arctic region), humanitarian missions in hostile territories and operations of critical infrastructure. Secure satellite communications that can be timely and efficiently deployed are critical for governmental security actors such as police, border guards, firefighters, civilian and military crisis forces. SatCom services can assist in securely operating response missions, which may not be able to rely on the traditional networks or may be subject to cyber threats.

To address existing challenges and ensure an appropriate level of European non-dependence on third party technology, the European Council on its 19-20 December 2013 meeting welcomed the preparations for the next generation of Governmental Satellite Communication (GOVSATCOM) through close cooperation between the Member States, the European Commission and the European Space Agency. Moreover, in April 2021, the Council and the European Parliament adopted a regulation establishing the new EU space programme for the years 2021 to 2027. The objectives include ensuring secure space data and services, and enhance EU security and autonomy: GOVSATCOM is well-aligned with these goals.

The European Union Governmental Satellite Communications initiative aims to provide secured communication capacity to EU governmental stakeholders performing various missions in the fields of emergency response, security and defense. Executed at the crossroad between three EU policy areas - space, defense and security - it is being considered to bridge the gap between the growing EU governmental needs for communication capacity and existing satcom systems. The initiative is fully relevant for the Global Strategy of the European Union's Foreign and Security Policy, as it would enhance the Union's capacity and capability in strengthening its position as a global security actor.

GOVSATCOM should:

- overcome the fragmentation of GOVSATCOM on EU scale (from the demand side, from the supply side for nationally owned SatCom systems), and seek synergies between civilian and military domains;
- ensure the critical security needs of EU and MS governmental users are met by appropriate guarantee of access; and by ensuring that solutions are secure and sufficiently robust to ill-intentioned acts;
- ensure that the solutions provide an appropriate level of EU non-dependence in terms of technologies, assets, operations and services.

Moreover, as mentioned above, GOVSATCOM will ensure the long-term availability of reliable, secure and cost-effective satellite communications services for GOVSATCOM users. Three main use cases have been identified:

- Crisis management, which may include civilian and military by Common Security and Defence missions and operations, natural and man-made disasters, humanitarian crisis, and maritime emergencies;
- Surveillance, such as border and maritime surveillance, or surveillance of illegal trafficking;
- Key infrastructures, including EU space infrastructures such as Galileo and EGNOS.

3.4.2. *The GOVSATCOM component entrusted tasks and entrusted entities*

3.4.2.1. Entrusted tasks

Under the 2021-2027 framework, the tasks related to the objectives of the Component have been entrusted to 2 entities: ESA and EUSPA. For the timeframe of the study, the general objectives, directly extracted from the Work Programmes, were the following.

2021 Objectives

In 2021, the main objective was to continue to prepare the implementation of the GOVSATCOM component. This encompassed several sub-objectives:

- (a) Drafting the implementing acts for the GOVSATCOM service portfolio, the operational requirements, the general security requirements, the location of the Hub(s) and the sharing and prioritisation of resources

- (b) Supervising and supporting the implementation of the GOVSATCOM preparatory action for the procurement of GOVSATCOM Hubs
- (c) Supervising the preparation and implementation of downstream research for GOVSATCOM service uptake
- (d) Supervise the entrusted tasks for research on upstream technology related to GOVSATCOM
- (e) Prepare the adoption of GOVSATCOM services through outreach activities
- (f) Define the security aspects of GOVSATCOM and supervise its implementation across the different development and service uptake activities.

2022 Objectives

In 2022, 2 general objectives have been defined regarding GOVSATCOM component:

- (a) Prepare the grounds for a timely and appropriate level of adoption of the GOVSATCOM services when they will start to be provided; and
- (b) Continue the procurement of the GOVSATCOM ground segment infrastructure.

2023-2024 Objectives

3 general objectives were set in the Work Programme for 2023-2024 regarding GOVSATCOM component:

- (a) Finalise the development of the GOVSATCOM ground segment infrastructure
- (b) Set the conditions for allowing Member States to pool resources accessible to GOVSATCOM users
- (c) Prepare the conditions for a timely and appropriate level of adoption of the GOVSATCOM services when operational

These objectives were further broken down into several intervention groups, extracted via desk research in the documentation made available to the team, namely: the Work Programmes, the Annex to the Decision on entrusting budget implementation tasks to the EUSPA and ESA and the two Contribution Agreement (one between EUSPA and the Commission and one between ESA and the Commission).

The table below provides an overview of the different intervention groups and associated interventions extracted from the documentation.

Table 260: Full list of GOVSATCOM-related interventions

Intervention group	Entrusted entity	Interventions
Procurement of GOVSATCOM Hubs	EUSPA	Procurement of the GOVSATCOM Hubs
Procurement of GOVSATCOM Hubs	EUSPA	Tender and procurement for the GOVSATCOM ground infrastructure
Procurement of GOVSATCOM Hubs	EUSPA	Development and running of the GOVSATCOM ground infrastructure
Procurement of GOVSATCOM Hubs	EUSPA	Set the conditions for allowing Member States to pool resources accessible to GOVSATCOM users
Operation of GOVSATCOM Hubs	EUSPA	Preparation of the Hubs operator
Operation of GOVSATCOM Hubs	EUSPA	Operation of the GOVSATCOM Hubs
Market uptake & User needs	EUSPA	Preparation of the User Equipment
Market uptake & User needs	EUSPA	User-related aspects of GOVSATCOM

Market uptake & User needs	EUSPA	Downstream activities
Support and implementation of SLAs	EUSPA	SLAs
Support to system and services evolution	EUSPA	Support to system and services evolution
Support to system and services evolution	EUSPA	Security support
Support to system and services evolution	EUSPA	Security support related to GOVSATCOM Hubs
EuroQCI	EUSPA	Security aspects of the EuroQCI
Support to space and ground segment	ESA	Ensure the appropriate and timely preparation and design of any future GOVSATCOM space segment and its related ground segment
Support to space and ground segment	ESA	Implement the development and deployment of end-to-end demonstrators of future GOVSATCOM space segment and related ground segment
Support to space and ground segment	ESA	Contribute to assess the need for an additional GOVSATCOM space component and some innovative system features and identify relevant design options for GOVSATCOM evolutions responding to this need
Technical coordination activities	ESA	Contribution to the preparation of Horizon Europe Work Programme
Implementation of demonstration activities	ESA	Execution of end-to-end demonstrations
Provision of technical input	ESA	Provision of technical input to the Commission for the relevant Commission Programme Committee configurations (including those stemming from the Horizon Europe programme or the EU space programme), sub-groups or experts groups, task forces, workshops, or stakeholder consultations organised by the Commission in relation to the GOVSATCOM entrusted tasks
Provision of technical input	ESA	Coordination by ESA of EU national research institutes and national space agencies for the consolidation of an upstream GOVSATCOM R&D roadmap
Provision of technical input	ESA	Participation of ESA as full member in the integrated project teams set-up for the implementation of studies launched by the Commission towards the European space-based secure connectivity initiative, especially as focal point for space segment and ground segment
Provision of technical input	ESA	Identification and assessment of relevant options for EuroQCI space segment and related ground segment, in accordance with ESA role in EuroQCI
EUCI	ESA	Distribution of EUCI
EUCI	ESA	Management of the classified network

These interventions can be further broken down into one or several activities, whose evaluation, through KPIs, will constitute the effectiveness impact basis (detailed list of activities is available in the appendix).

3.4.2.2.GOVSAATCOM budget

For the 2021-2027 timeline, the budget delegated for the GOVSATCOM component has been extracted for the Work Programmes¹⁶⁹ and is segmented as follow:

¹⁶⁹ Budget funded under Space Regulation, excluding the budget under Horizon Europe.

Table 261: Budget of the GOVSATCOM component

No	Intervention Group	2021	2022	2023	2024	Total 2021 – 2027 ¹⁷⁰
1	EUSPA					€165 000 000
1.1	Procurement of the Hubs, the preparation of the Hubs operator and the preparation of the User Equipment	€ 15 708 560				
1.2	Procurement of GOVSATCOM Hubs		€ 18 400 000			
1.3	Development of the ground segment infrastructure			€ 34 133 580	€ 34 245 000	
2	ESA					€10 000 000
2.1	Support to demonstration activities and technical assistance	€ 1 000 000	€ 4 000 000			
2.2	Implementation of demonstrations			€ 1 000 000	€ 2 000 000	

3.4.3. Effectiveness of the Implementation of GOVSATCOM

As for other components, the assessment of the effectiveness of implementation is divided into two interrelated sections.

- First, the extent to which the interventions outlined above were completed within the allocated time and budget, and the outcomes or severity of any delay or budget overrun that may have occurred.
- Second, the performance based on several KPIs as outlined in the contribution agreement.

3.4.3.1. Assessment of the implementation of the entrusted tasks and entrusted entities

As underlined before, several interventions have been split between ESA and EUSPA. Those interventions encompass one or several activities, which are tasks entrusted for a certain timeframe.

As for other components, a set of KPIs and criteria have been defined to assess if the objectives and the targets set have been met and to what extent. The assessment will be done at the intervention level but the full list of activities and associated KPIs is available in the appendix.

As described in the results assessment methodology section and reminded in the Copernicus part of this report, the specific outcome of each activity was determined based on its status, timeline, and budget *-when the information was available-*, that mapped to a numerical

¹⁷⁰ Please note that the total 2021-2027 refers to the maximum amount and was extracted from the Work Programme. It doesn't correspond to the addition of years 2021-2024 because there are still years 2025, 2026 and 2027 to be determined, no precise information was available for the expected distribution for years 2025-2027.

outcome on a scale of 1-6. As shown in the figure below, each number defines a different outcome within this scale and does not provide a score for the outcome.

Table 262: Definition of scale to assess implementation of entrusted tasks

1	Implemented as per Contribution Agreement	2	One deviation from Contribution Agreement with no consequences	3	Two deviations from Contribution Agreement with no consequences
4	One deviation from Contribution Agreement with one consequence	5	Two deviations from Contribution Agreement with one consequence	6	Two deviations from Contribution Agreement with two consequences
NA Non Applicable / Out of scope of assessment					

Any deviations or consequences in the implementation of the activities have been qualitatively explained in the results below. It is important to note that while the assessment was carried out at the activity level, the results shown below have been consolidated at the intervention level. A detailed view of the assessment at the activity level can be found in the Appendix.

GOVSATCOM entrusted tasks to EUSPA

Intervention 1: Tender and procurement for the GOVSATCOM ground infrastructure

This intervention covers 2 activities, the preparation of the specifications for the tendering and the running and concluding of the procurement process for the development of GOVSATCOM Hubs.

According to the 2021-2027 Work Programme, EUSPA was tasked in 2021 with the preparation of the specifications for the tendering and the running and concluding of the procurement process for the development of GOVSATCOM Hubs. However, this activity did not have a precise timeline in the Contribution Agreement. In practice this activity started in 2020 and the tender is foreseen to be concluded in the next few months, as there was a delay linked to legal implications in the procurement set up which took some time because the Commission had first to determine the conditions of participation (which countries may participate etc.) in a really new environment with a lot of stakes linked to the sensitive nature of the GOVSATCOM component. Regarding the current situation, EUSPA received the tenders on March 15th and immediately started their evaluation. This delay is propagating across certain other interventions that depend on its completion, however despite these delays, it is expected that EUSPA remains within the timeline for service provision and therefore remains in coherence with the Contribution agreement (despite the deviation from the WP)

The second activity is on-going according to planned schedule over the 2021 – to date period. The conclusion of the tendering process is foreseen in 2023 with a planned 5-years contract after.

Intervention 1 Qualification	2 out of 2 (i.e. 100%) of the activities were Implemented as per the Contribution Agreement

Intervention 2: Procurement of the GOVSATCOM Hubs

This intervention is linked to the development of specific remote communication systems.

According to the 2021-2027 Work Programme, EUSPA was tasked in 2021 with the development of specific remote communication systems, however this task has no specific timeline assigned under the Contribution Agreement. It is ongoing but has been delayed because the initial procurement set up took some time as explained. Moreover, it was first planned that new terminals had to be created for the GOVSATCOM component however, the related activities couldn't be financed within the budget which was allocated to the component. This risk has been effectively communicated to the European Commission and mitigation actions were suggested which led to the decision to pool from existing satellites which already had terminals. Despite the delays in this intervention, it is expected that EUSPA remains within the timeline for service provision and therefore remains in coherence with the Contribution Agreement (despite the deviation from the WP)

Intervention 2 Qualification

Implemented as per Contribution Agreement

Intervention 3: Development and running of the GOVSATCOM ground infrastructure

The development and running of the GOVSATCOM ground infrastructure has two target dates in the Work Programmes (no precise timeline in the Contribution Agreement): the award and management of the contracts awarded (2022) and the management of the contracts and the validation of the deliverables (2023-2024). This has been delayed due to the same reasons as above. Despite the delays in this intervention, it is expected that EUSPA remains within the timeline for service provision and therefore remains in coherence with the Regulation and Contribution Agreement (despite the deviation from the WP)

Intervention 3 Qualification

Implemented as per Contribution Agreement

Intervention 4: Set the conditions for allowing Member States to pool resources accessible to GOVSATCOM users

This intervention encompasses 2 activities, one aiming at providing support to the Commission in the definition of the contracts with Member States and providers and the other one related to the implementation of the contracts upon request of the Commission, including the management of contractual interfaces with GOVSATCOM Hubs infrastructure provider/s and operator/s.

These 2 activities have not started yet, however the timeline associated to them starts in 2023 in the Work Programmes and they are only defined to be support activities for the Commission when needed. Indeed, the Commission will contact the Member States and negotiate and EUSPA will support by providing the content/technical part of the contracts. Thus, there is no deviation from the Contribution Agreement.

Intervention 4 Qualification

2 out of 2 activities (i.e 100%) implemented as per Contribution Agreement

Intervention 5: Preparation of the Hubs operator

This intervention covers the support in the preparation of the contractual aspects of the service contracts with the GOVSATCOM operators.

According to the 2021-2027 Work Programme, EUSPA was tasked in 2021 with the support in the preparation of the contractual aspects of the service. However, this activity had no precise timeline assigned under the Contribution Agreement. This activity is a support activity for the Commission in the preparation of the contractual aspects of the service contracts with the operators. It has not started yet because 90% of it will depend on the result of the

procurement which is ongoing (regarding for instance when and how will the contracts be organized with resources providers/satcom operators).

Intervention 5 Qualification

Implemented as per Contribution Agreement

Intervention 6: Operation of the GOVSATCOM Hubs

This intervention covers 2 activities linked to the management (directly or through contractual and financial scheme) of the hosting infrastructures made available for GOVSATCOM Hubs deployment and the communication links among these infrastructures as well as the operation of the Hubs.

These activities have not started yet but they have no precise timeline assigned under the Contribution Agreement, except the fact that they have to begin between 2021 and 2027, which means the timeline is in line with the Contribution Agreement.

Intervention 6 Qualification

2 out of 2 activities (i.e 100%) implemented as per Contribution Agreement

Intervention 7: Preparation of the User Equipment

The activity linked to this intervention is related to the launch of a study on the technical requirements and specifications for User Equipment interoperability, roadmap for standardization and development activities.

The activity was planned for 2021 in the Work Programmes but has not started yet because further assessment is needed mainly through the output of the procurement which is still ongoing. However, this activity is not among emergencies and the delay only has a minor to no consequence.

Intervention 7 Qualification

Implemented as per Contribution Agreement

Intervention 8: User-related aspects of GOVSATCOM

This intervention encompasses 6 activities linked to the user-related aspects of GOVSATCOM, with no particular timeline except the 2021-2027 interval.

The first activity is linked to the identification of user needs in the design of the GOVSATCOM component. This activity is ongoing and is on time, a survey aimed at identifying user requirements and use cases was launched within the ENTRUSTED project and the permission requirement document has been approved recently by the Member States.

The second activity is related to the monitoring of the use, demand and compliance with the operational user requirement. This activity is ongoing and in on time, one study has been done which encompasses the objectives (user demand etc.) and the monitoring and compliance part will follow after.

The third activity is related to the identification of the needs for service evolutions but as mentioned previously, it has not precise timeline associated (except 2021-2027) and its assessment would not be accurate at the moment since it concerns service evolutions and there's no service yet.

The fourth activity covers analyses associated to the definition of the secure operational ground segments, it is ongoing and on-time, several studies have been done internally.

The fifth activity linked to the user-related aspects of GOVSATCOM consists in supporting the Commission in defining implementing acts (i.e operational user requirements, hub location, sharing and prioritization and service portfolio). This activity was closed on time, 3 implementing acts were adopted using inputs related to the user needs and requirements collected previously.

The last activity aims at ensuring the coherence of the technical specifications of the GOVSATCOM infrastructures with the user operational requirements and the service portfolio implementing acts. This activity was closed on time.

Intervention 8 Qualification

6 out of 6 activities (i.e 100%) implemented as per Contribution Agreement

Intervention 9: Downstream activities

The downstream activities intervention covers 3 activities with no precise timeline assigned except the 2021-2027 interval and which are on time.

Among them, one activity has already been closed, the coordination of the network of users and the analysis of their needs and requirements through the ENTRUSTED survey.

The remaining 2 are ongoing and one is a continuous process (the biennial publication of market and user technology reports). Regarding this point, a study covering the analysis and assessment of the current and future secure SATCOM capacities and services, user technology and user demand has recently been completed.

Intervention 9 Qualification

3 out of 3 activities (i.e 100%) implemented as per Contribution Agreement

Intervention 10: SLAs

Two activities are covered in this intervention linked to the implementation of service level agreements. These activities have no precise timeline except that they must begin between 2021 and 2027, upon request of the Commission. No deviation from the Contribution Agreement was noted.

Intervention 10 Qualification

2 out of 2 activities (i.e 100%) implemented as per Contribution Agreement

Intervention 11: Support to system and services evolution

This intervention covers one activity regarding guidance on the future needs and evolution of the ground space segment. At the time of writing of this report, the assessment of this task would not be accurate (as it is linked to the **evolution** of the ground space segment), however it must be noted that this activity has no precise timeline assigned except that it has to start between 2021 and 2027 and no delay is expected, so this is in line with the Contribution Agreement.

Intervention 11 Qualification

Implemented as per Contribution Agreement

Intervention 12: Security support

The security support intervention encompasses 6 activities with no precise timeline assigned, except that they must start between 2021 and 2027. These activities are all on time and no issue has been detected so far. Two of them are already closed, three are continuous processes lasting during the whole timeline (for example the compliance with the security baseline and the provision of technical expertise and support to the Commission upon request) and one has not started yet (because waiting for the HUB infrastructure) but no delay is expected, so all these activities are in line with the Contribution Agreement.

Intervention 12 Qualification

6 out of 6 activities (i.e 100%) implemented as per Contribution Agreement

Intervention 13: Security aspects related to GOVSATCOM Hubs

This objective encompasses 5 activities linked to the security requirements, accreditation files, monitoring and more generally tasks related to the GOVSATCOM Hubs. These activities have no precise timeline assigned except the 2021-2027 interval, they are all on time and no delay is expected even for the proposition of evolutions of the security requirements baseline,

which is dependent of the Hubs infrastructure and has not started yet but is expected to be on time. It must be also noted that some of these activities are continuous processes, for instance providing technical expertise to the Commission (as a reminder, the full list of activities and KPIs is available in the Appendix and specifies which activities are continuous processes).

Intervention 13 Qualification

5 out of 5 activities (i.e 100%) implemented as per Contribution Agreement

Intervention 14: Security aspects of the EuroQCI

This last intervention encompasses 5 activities linked to the EuroQCI initiative, with no precise timeline assigned except the 2021-2027 interval. All activities are on time, no delay is expected. As regards to the status, either no request has been submitted yet from the Commission (and the associated activity is upon request of the Commission) or the Commission asked for support and the required support has been provided. It has also to be noted that one of the activities, the participation and support to the Commission in the EuroQCI Security group and upon request, in other relevant stakeholders' fora is a continuous process lasting for the whole Contribution Agreement timeline. All the activities under this intervention are in line with the Contribution Agreement.

Intervention 14 Qualification

5 out of 5 activities (i.e 100%) implemented as per Contribution Agreement

Summary

The initial set up of the procurement process by the Commission and especially with regards to the definition of the procurement conditions (participating member states etc.) led to a delay in the implementation of some steps of the GOVSATCOM component. However, EUSPA, together with the Commission managed to mitigate this risk and the activities entrusted to the agency are currently running smoothly. Three main elements have to be taken into account regarding the component: **the Hub** (which is on its way, the specifications are ready and the procurement phase will begin in a short time), **the availability of the satcom resources from the resources providers** (under the Commission's responsibility which has to negotiate with the operators) and **the determination of the Hub location site** to host the ground infrastructure (a call for expression of interest has been issued with a due date at the end of July, which will be followed by an evaluation and the selection of 2 sites probably in 2 different countries by the end of the year).

GOVSATCOM tasks entrusted to ESA

Intervention 1: Support to space and ground segment

Under this intervention 3 activities were covered by ESA. One activity consists in assessing the need for an additional GOVSATCOM space component, the second one is linked to the implementation of the R&D activities related to the need of any future GOVSATCOM space segment and its related ground segment and the third one refers to the implementation of the development and deployment of end-to-end demonstrators of the latter.

Under this intervention, one work plan has been approved and the tendering process (2-stage tendering process) is currently ongoing. In parallel, ESA has worked together with the Commission to assess the needs for an additional space component and the options to respond to this need. The analysis paved the way for the design of the Union Secure Connectivity Programme (IRIS²) (which is not another space component but a separate programme was designed to fill the gaps identified). Regarding the development of end-to-end demonstrators, one demonstration has been done to underline some key features of the GOVSATCOM Hub and 2 parallels contracts may arise.

There was no precise timeline assigned for these activities except that they had to happen between 2021 and 2027 so this is totally in line with the Contribution Agreement.

Intervention 1 Qualification**3 out of 3 activities (i.e 100%) implemented as per Contribution Agreement*****Intervention 2: Technical coordination activities***

This intervention linked to the preparation of Horizon Work Programme has been closed on time. There was no precise timeline assigned to this, except the 2021-2027 interval so this is totally in line with the Contribution Agreement.

Intervention 2 Qualification**Implemented as per Contribution Agreement*****Intervention 3: Implementation of demonstration activities***

This intervention also encompasses demonstration activities mentioned above. As per Contribution Agreement, testbeds in support to demonstration activities were expected to be deployed in a consistent way with the need to conduct a first set of demonstrations in 2022 and pursue them over the 2022-2024 timeframe. One testbed was deployed in support to meet the needs of the Commission and the activities under this intervention are still on going and are on time, so this is totally in line with the Contribution Agreement.

Intervention 3 Qualification**Implemented as per Contribution Agreement*****Intervention 4: Provision of technical input***

This intervention encompasses 5 activities linked to the provision of ESA's technical expertise to the Commission. Under this intervention group, 3 activities are ongoing, one has been closed and one is dependent on the request from the Commission.

Indeed, no request has been made by the Commission for ESA to coordinate EU national research institutes and national space agencies for the consolidation of an upstream GOVSATCOM R&D roadmap. However, there is no precise timeline assigned to this activity except the 2021-2027 interval which means that this is in line with the Contribution Agreement.

The activity which has been closed on time refers to the provision of input to evaluate the need for additional space infrastructure. The outcome of the analysis was expected to be made available to the Commission by latest Q2/2024. As mentioned above, ESA had already contributed to the analysis of additional needs which led to the development of Union Secure Connectivity Programme (IRIS²), so this is in line with the Contribution Agreement.

Among the ongoing activities, one refers to the identification and assessment of relevant options for EuroQCI space segment and related ground segment for which ESA works in close collaboration with the Commission. No particular timeline was attributed to this task except the 2021-2027 interval so this is in line with the Contribution Agreement.

The two other activities are linked to the provision of technical expertise for the relevant Commission Programme Committee configurations and to the participation of ESA in the integrated project teams set-up for the implementation of studies launched by the Commission towards the European space-based secure connectivity initiative. These activities had the 2021-2027 interval as a timeframe. ESA had been solicited on various subject, especially test beds and the assessment of the needs for an additional space infrastructure mentioned above. It must be underlined that 25 persons within ESA were working in joint team with the Commission and that ESA experts are providing support for the definition of the security requirements for the future GOVSATCOM Hub, in the frame of the Working Group Security of GOVSATCOM (Notably during the July, September and November 2022 Working Group meetings). Thus, this is in line with the Contribution Agreement.

Intervention 4 Qualification**5 out of 5 activities (i.e 100%) implemented as per Contribution Agreement**

Intervention 5: EUCI

This intervention encompasses 2 activities linked to the support in the distribution of the EUCI and the management of the classified network. The first activity's timeline is starting in 2021 but is upon request and the second activity's timeline is the 2021-2027 interval. No request has been formulated by the Commission regarding these 2 points for now, so this is in line with the Contribution Agreement.

Intervention 5 Qualification

2 out of 2 activities (i.e 100%) implemented as per Contribution Agreement

Summary

The tasks entrusted to ESA and related to the GOVSATCOM component are **running smoothly** despite the same initial delay that the one experienced by EUSPA due to the set-up of the procurement process by the Commission. The **milestones are expected to be met on time** and **the agency fully participates in the activities** related to the implementation and deployment of GOVSATCOM, which also includes (for the assessment of the needs of additional features) the **preparatory activities for the Union Secure Connectivity Programme (IRIS²)**.

3.4.3.2. Assessment of the performance of the Space Programme

Regarding GOVSATCOM component and in addition to the indicators defined previously, some KPIs have been set at a service level, to assess the performance of the Space Programme.

Those KPIS are the following.

Table 263: KPIs used to assess the performance of the GOVSATCOM component

Indicators	KPIs
Number of users	Number of GOVSATCOM users providing, where possible, information such as the type of user, geographical distribution and sector of activity (including user satisfaction and assessment of GOVSATCOM capacities as regards user needs)
Service	Availability of Services
Contracts signed schedule (%)	Cumulative nr of contracts signed/Cumulative nr of contracts planned for the same period
Contracts commitment ceiling (%)	Sum actual commitment ceiling/Sum planned contribution ceiling for the same period
R&D contracts cost accrued (%)	Sum actual cost accrued/Sum planned cost for the same period
Milestone chart achievement	Cumulative nr of milestones completely achieved/cumulative nr of milestone for the same period

However, it must be underlined that, according to the information available in the 2022 Annual Implementation Report, most of them are not applicable yet, as such:

- **For the contracts signed schedule**, the indicator is not applicable because no contracts were planned to be signed as per updated financial baseline defined in the GOVSATCOM semestrial implementation report S1 2022 ('SIR#1') ;
- **For the contracts commitment ceiling**, the indicator is not applicable because no contracts commitments were planned to be signed as per updated financial baseline defined in SIR#1 ;
- **For the R&D contractors cost accrued**, the indicator is not applicable because no contracts costs were planned to be accrued in 2022, as per updated financial baseline defined in SIR#1 ;

- **For the Milestone achievement chart**, the indicator is not applicable because no milestone were planned to be achieved as in 2022, as per updated financial baseline defined in SIR#1.

The remaining 2 indicators were not mentioned in the 2022 Annual Implementation Report. However, as previously underlined, the service is not operational yet so the indicators are not applicable neither.

Nevertheless, overall, the EU GOVSATCOM aims to provide initial services within 2024 (with the deployment of the final operational configuration expected in 2027) and will ensure long-term availability of reliable, secure and cost-effective governmental satellite communications.

3.4.3.3. Takeaways on the effectiveness of GOVSATCOM

Regarding the GOVSATCOM Component, we can state that overall, the implementation of the tasks by EUSPA **is totally aligned with the Contribution Agreement**. Indeed, even if a delay (according to the Work Programmes not the Contribution Agreement) linked to the set-up of the procurement approach was noted, this delay was external to EUSPA and was necessary to ensure that the conditions of participation were well defined by the Commission. Indeed, the sensitive nature of the GOVSATCOM component requires careful consideration while defining these conditions. Regarding the risks linked to this delay, **EUSPA has taken steps to mitigate the issues and they are not expected to have a consequence on the initial service provision**. Overall, the tasks assigned to EUSPA **were achieved successfully** and the Agency is contributing efficiently to the development of the component.

Regarding ESA, the Agency participates very actively in the development and implementation of the GOVSATCOM component. All the tasks entrusted to it are running smoothly, are on time despite the same initial delay as the one faced by EUSPA and **their implementation is totally in line with the Contribution Agreement**. In addition, ESA's participation in the assessment of the need for additional space component **paved the way for the design of Union Secure Connectivity Programme (IRIS²)** and the Agency provided a **valuable technical expertise with 25 people jointly working with the Commission** (for which ESA did an additional effort because this was not planned in the budget).

Overall, **both entities contributed actively to the implementation of the GOVSATCOM component**. Since the service is expected to be operational by the end of 2024, the assessment of the Programme itself could not be done by a strict KPIs reporting because they were not applicable by the time of writing of this report. However, GOVSATCOM will ensure long-term availability of reliable, secure, and cost-effective governmental satellite communications for EU and national public authorities managing security critical missions and infrastructures. **The service will address crucial challenges and will ensure an appropriate level of EU non-dependence on third parties' technology**, especially in sensitive areas in which actors such as governmental security entities will be able to rely on secure satellite communications.

Overall, based on the results of the assessments above, it can be established that the GOVSATCOM Component **has been effectively implemented** between 2021 and 2023 under the 2021-2027 MFF.

3.4.4. Benefits assessment of GOVSATCOM

In the PwC study called "Study in support of the Impact Assessment of an EU GOVSATCOM initiative" (2017) for the European Commission, different options of governance were evaluated together with their potential benefits. As of today, option 3 has been chosen as the future governance model of GOVSATCOM. Here, this option will be described since it represents the basis of the impact assessment of the space programme's component.

The only part considered of option 3 is the first phase, called “Pooling and sharing of existing commercial and governmental capacities”. Here, the capacity of MS is supplemented by the capacity of commercial satellites. This means that the Hub will need to combine the tasks from the two different capacity providers. This option offers high flexibility, in addition to the possibility for small EU MSs that do not own their own SatCom asset, by offering the opportunity to choose between high secure governmental terminals and less secure but more affordable commercial ones.

It is very important to mention that at the time of the previous study and to date, GOVSATCOM is not operational therefore the impact assessment was qualitative and high level as not enough information was available to enable quantification of benefits. In this study, the team also looked into a specific use case for the GOVSATCOM service to quantify the size of economic losses in this use case that GOVSATCOM could potentially address.

3.4.4.1.High level qualitative description of benefits extracted from previous PwC study

In the previous study the future impacts of GOVSATCOM were segmented in security impacts and additional impacts gathered through stakeholders’ consultations.

The first ones relate to the effectiveness of GOVSATCOM, depending on the chosen governance option, to ensure secure connectivity. The additional impacts relate to how GOVSATCOM would benefit European Union in different layers, such as its industry and more broadly its society. Below the main insights for the two categories of impacts, that aim at providing an high-level overview of how GOVSATCOM would benefit its users and the European Union in general.

Security impacts

As previously mentioned, the security impacts are assessed in qualitative manner. They are based on the suitability score between the chosen SatCom satellites with the different High Lever User Needs (HLUN) that are non-confidential. For example, the impact related to systems interoperability covers the needs of Interoperability and Standards (6.1), Terminal needs for crisis management (7.6), Terminal needs for Land transport systems (9.4.2) of the HLUN.

GOVSATCOM will exploit commercial and national/military satellites in its first deployment phase. As a consequence, some considerations can be done, especially by comparing this option with the absence of an EU intervention (GOVSATCOM not implemented):

- **Prioritization of users:** to be effective in user’s prioritization there is the need of a central hub, and GOVSATCOM Hub is ideated for this reason. In the current governance option, the control and access to GOVSATCOM services would be properly guaranteed.
- **Adequate geographic coverage:** commercial players manage to cover almost all the zones of the world, and even more by adding governmental or military satellites.
- **Availability of secure communication links:** by having national, military and governmental satellites in the programme, GOVSATCOM will ensure high-end secured national systems, thus reducing the use of non-secured communications.
- **Time to service deployment:** conservatively, the performance on timeliness to be available (when punctual demand is received by operators) does not vary significantly from a scenario in which there is no EU intervention (GOVSATCOM is not implemented). However, more control on the system (by implementing GOVSATCOM) means having a quicker response.

- **Sustainability of the frequency bands allocation:** by having national, military and governmental satellites in the programme, GOVSATCOM will ensure the security of a higher share of capacity.
- **Risk acceptance and information assurance:** this impact encompasses in the cluster the mitigation of theft of sensitive information, of ill-intentioned acts, of cyber-attacks and the warnings of the user in case of information usurpation. Basically, the fact of introducing governmental and military satellites gives a huge advantage in terms of end-to-end encryption solutions, especially about the security level and the satellite signal itself. In the same logic, the selection of security accredited providers only excludes all the “low security” systems currently used by some users that would not be in the pool of providers.
- **Long term eligibility of the provider:** by having national, military and governmental satellites in the programme, GOVSATCOM would ensure a better long-term eligibility of the providers, thus saving time and resources.
- **Non dependence from 3rd parties for infrastructure supply chain and service provision:** the stake for dependence on 3rd countries is dual, on the supply chain (space infrastructure, ground infrastructure, terminals) and on the service provision. Regarding the latter, it is differentiating (with respect to no EU intervention) if governmental and high-end security national satellites are involved in the programme, since they ensure more control on the service provision process. On the supply chain side, commercial satellites tend to rely on non-EU providers for the manufacturing of the satellites. For this reason, a greater independence would be reached with governmental and military satellites in the system.

Additional impacts through Stakeholder's consultations

In the impact assessment study of GOVSATCOM conducted in 2017 by PwC, different stakeholders belonging to different stages of the value chain have been involved. During these interviews, their opinion on some benefits have been assessed. The stakeholders are grouped into experts for public authorities, manufacturing industry, satellite operators, service providers, users' groups. From a general perspective, the outcome of the consultation indicates that the chosen governance scheme has better impacts than the baseline scenario with no implementation of GOVSATCOM, positively impacting the EU society. In particular:

- **Process optimisation for suppliers of secured SatCom and equipment:** Taking suppliers' point of view, a mix of commercial and governmental providers is then expected to facilitate business between suppliers and users on short term. This situation is expected to get even better in the longer term with the implementation of additional infrastructure, either by a PPP option or by an EU-owned infrastructure option.
- **Process optimization for users of secure SatCom:** the impact under the chosen satellite mix and the implementation of the GOVSATCOM Hub would be extremely strong. Having additional infrastructure in the EU GOVSATCOM initiative seems to have a significant impact on facilitating secure SatCom from end-users' point of view.
- **Costs of doing business and administrative burden for private sector:** looking at this impact, the results from the assessment shows that it would imply a positive and moderate impact on these costs. A mix of commercial and governmental SatCom providers seems then to significantly reduce cost of doing business and administrative burden for private companies. This impact is considered even higher when additional infrastructure would be developed on the longer-term.
- **Costs of doing business and administrative burden for public sector:** a very similar pattern is observed when looking at this impact on public sector. Indeed, according to the median scores provided by the group of experts, these costs would be affected positively,

especially for the EU and MS public sector in the short term, with a strong impact in the long term.

- **GOVSATCOM-like bandwidth capacity to be provided:** the idea that a mix of commercial and governmental providers would be able to provide enough GOVSATCOM-like capacity in the short-term provokes a medium positive level of confidence among stakeholders and a strong level of confidence in the fact that additional infrastructure, either acquired through an EU PPP or owned by the EU, will increase GOVSATCOM-like bandwidth availability.
- **Ability to face threats in the future:** A mix of commercial and governmental providers is then expected to respond well to evolving security risks and threats on the short term and respond very well if additional infrastructure is procured on the long-term.
- **Guaranteed access to SatCom:** A mix of commercial and governmental providers is thus expected to provide a significant level of guaranteed access on the short term and a higher level of guaranteed access once additional infrastructure will be provided on the long-term.
- **Affordability of SatCom services:** A mix of commercial and governmental providers are expected to have short-term significant positive impact on the affordability of such type of services. On the long term, additional EU-owned infrastructure does not add a higher impact on this affordability whereas EU PPP is expected to have a high positive impact on GOVSATCOM-like services affordability.
- **Confidence in European space and ground infrastructure supply and renewal:** On the long term, stakeholders are significantly confident that EU MSs will keep developing national assets on national budget. A mix of commercial and governmental providers would be expected to offer the same level of confidence than the governmental solution's option on short term. On the longer term, additional infrastructure would increase stakeholders' level of confidence in the supply and renewal of appropriate GOVSATCOM space and ground infrastructure.
- **Setting up and operating the EU GOVSATCOM Hub:** complexity and cost of the GOVSATCOM Hub is expected to be very high. Additional infrastructure through EU PPP is expected to have a higher negative impact (medium). This can be explained by the fact that having an EU PPP with satellite operators already included in the pool of accredited satellite capacity providers can lead to higher complexity and potentially require more control. Another issue could be the fact that the extra capacity owned by satellite operators through additional infrastructure could potentially be resold into the pool of accredited satellite capacity providers.
- **Impacts on the cost in the SatCom supply chain:** the chosen frame shows to have moderate to high positive impacts on cost in the supply chain. The choice of the EU to support the development of additional infrastructure on the long-term is then expected to have a medium (EU PPP) and high (EU-owned infrastructure) positive impacts on the manufacturing prices of components and technologies related to secure SatCom services, enhancing the capacity of EU market to influence purchasing decisions.
- **Competitiveness of the EU space industry on the global markets:** The EU space industry being already strongly competitive, such impact could not be strongly positive in any EU intervention. Nevertheless, it can stimulate long-term competitiveness in the field of secure SatCom, especially vis-à-vis protected market in third countries such as the US. As raised by several stakeholders, impact on competitiveness is strongly linked to the capacity of the EU GOVSATCOM initiative to have a significant impact on prices in the supply chain for ground and space infrastructure, as well as user technologies.

- **Effects on SMEs:** As raised by SMEs representatives, in many cases SMEs are not always considered, as they are usually in the shadow of by bigger players. Specific rules enabling further SMEs involvement in the procurement of the EU GOVSATCOM initiative would be beneficial for SMEs and for the EU, as it would favour innovation.
- **Stimulation of innovation and research:** Development of additional infrastructure, either through an EU PPP initiative or EU-owned infrastructure, are expected to fill-in gaps where no business case seems viable. This context pushes the EU to include innovation in this additional infrastructure. Many stakeholders have raised the fact that innovation should play a key role and should be supported by ESA and the European Commission. EU non-dependence on third countries in the field of security will be acquired through innovation in the field of secured SatCom. As EU autonomy is a pillar of the EU GOVSATCOM initiative, the initiative must involve strong industrial R&D activities to foster innovation in the EU.
- **Impact on frequency allocation and orbital positions:** Finally, 67% of the experts participating in the consultation indicated that the GOVSATCOM initiative will have indeed an impact on frequency allocation and orbital positions. EU ownership of SatCom infrastructure (partial in a PPP; complete in an EU-owned infrastructure) is expected to have an impact on frequency allocation and orbital positions. GOVSATCOM implementation is expected to significantly increase EU influence at the ITU and contribute to enhance EU strategic leadership. Note that stakeholders consider that all options will have at least an impact on frequency allocation and orbital positions.

3.4.4.2. Economic impacts – A potential use case developed for GOVSATCOM

As mentioned above, due to the impact assessment previously performed being qualitative and high level, the team chose one use case for the GOVSATCOM programme to go into more details and project the expected economic losses that GOVSATCOM could potentially help reduce. However, it is critical to highlight that this potential use case does not provide a sizing of the benefits that GOVSATCOM will bring (i.e. the attribution factor of benefits to GOVSATCOM is not determined) and this is due to the lack of information to date, because of GOVSATCOM's pre-operational phase.

The selected potential use case is mitigation against cyber-attacks. GOVSATCOM will provide availability of communication, effective and efficient communication, and very importantly secure communication. This last parameter one of the main reasons for which GOVSATCOM component was designed, and the mitigation of cyber-attacks is key to information assurance and risk reduction in critical communication.

GOVSATCOM Potential Use Case for Mitigation against Cyber Attacks

The global financial loss to cyber-attacks in 2021 was equivalent to 6 trillion USD¹⁷¹, and as key activities are more and more digitalized there is not a sector which is not threatened by cyber-attack risks. Reflecting the importance of this matter, the European Commission introduced the European Programme for Critical Infrastructure Protection (EPCIP) in 2006. EPCIP provides a comprehensive, Europe-wide framework for safeguarding critical infrastructures against all potential threats. In fact, critical infrastructures are becoming top targets for cybercrime, and this can have detrimental effects on the countries, organizations, and people that rely on them. Infrastructures have started to rely more and more on connectivity, which often improves the efficiency of the service delivery but also exposes the

¹⁷¹ Cybercrime Magazine

infrastructure itself at a higher level of vulnerability from the digital side¹⁷². The sectors that are the most targeted are Education and Research, Government and Military, Healthcare, which is also characterized by the sharpest growth of received cyber-attacks Year over Year in 2022 Q3. The other two sectors with the most relevant growth of cyber-attacks are Retail and Transportation¹⁷³. Since many of the transportation infrastructures are owned or managed by National or EU actors, the segment is covered in the domains of the future GOVSATCOM component.

In fact, GOVSATCOM's scope is to ensure secure communication in three different intervention types: border surveillance, crisis management and key infrastructures. Among the encompassed infrastructures there are Space infrastructure, Europol communication, Institutional Communication and finally, as mentioned, Transportation infrastructure. In practice, in air traffic management SatCom is used for communication in remote regions, since a permanent link is maintained between the aircraft and the ground for aircrafts flying under the Instrument Flight Rules, which uses mostly terrestrial networks in EU. Nonetheless, SatCom represents potentially an important back-up connection in case of disruption of services. Global surveillance of airline flights and continuous aircraft tracking with SatCom is considered for the future, thus an increasing dependency of air safety on SatCom is expected. Regarding the rail segment, 4G gives interferences to adjacent bands so SatCom is very useful for train control and operations management by exploiting higher frequency bands (above 30GHz). In addition, it would increase the train capacity in the Eu train control system and improve the internet connection onboard. Finally, public authorities, road operators and service providers would be supported by GOVSATCOM in the road segment too. They would benefit from a back-up connectivity in case of terrestrial network disruption and could potentially access critical communication with a safer and more secured approach.

The protection of key infrastructures is a very critical aspect, and GOVSATCOM would be beneficial in these terms. **Given the relevance of protecting transportation infrastructures from threats such as cyber-attacks, and the potential help that GOVSATCOM would bring for this purpose, the team decided to focus on this area of intervention.**

To study the cyber-attack phenomenon in the transportation industry, the team used as main source the 2023 report of ENISA, the European Union Agency for Cybersecurity. Before elaborating on the potential uses case, it is useful to clarify what we considered as cyber-attacks. In fact, among the incidents reported in the ENISA study abovementioned, the prime threats are ransomware (38%), data breaches (30%) and general malware (17%). In particular, they are defined as:

- *Ransomware*: defined as a type of attack where actors take control of a target's assets and demand a ransom in exchange for the return of the asset's availability
- *Threats against data*: when sources of data are being targeted with the aim of unauthorized access and disclosure and manipulating data to interfere with the behavior of systems.
- *Malware*: overarching term used to describe any software or firmware intended to perform an authorized process that will have an adverse impact on confidentiality, integrity or availability of a system.

¹⁷² Muciaccia T., Tedesco P. "Future scenarios for the infrastructure digitalization: The road ahead" (2023)

¹⁷³ Check Point Research: Third quarter of 2022 reveals increase in cyberattacks and unexpected developments in global trends

Other types of attack include denial of services, phishing, supply chain attacks, intrusions, fraud and vulnerability exploitation.

The ENISA 2023 report analyses and classifies almost 100 cases of cyber-attacks to the EU Transportation industry, in the years 2021 and 2022. With the objective of understanding the potential economic loss of these cyber-attacks to the infrastructures, the team defined narrowed the scope on two axes:

- *Time frame*: between 2025 and 2035. This choice is done to ensure coherence, accordingly to the starting operational activity of GOVSATCOM and to the time frame used for the benefits in this study for the other components.
- *Subsegments*: Aviation, Rail and Road. The choice follows the as-of-today known scope of GOVSATCOM, thus the Maritime sector (included in the report of ENISA) has been excluded by the calculations.

The aim is to bring a relevant quantitative potential use case that underlines one of **the reasons why GOVSATCOM would have an impact** on the society. Here below the summary of the steps taken to calculate the potential economic loss for this potential use case, followed by the explanation of each step.

Table 264: Methodological approach for the potential use case - GOVSATCOM

Methodological approach to potential GOVSATCOM impact on cyber-attacks to key infrastructures

In order to calculate the potential impact of GOVSATCOM on cyber-attack mitigation, information has been extracted from the ENISA report for transportation in the EU. Taking the reported cyber-attacks in the EU to transportation infrastructures, we:

- Extracted the number of cyber-attacks in 2021-2022 in Europe, targeting Aviation, Rail and Road segment.
- Extracted the number of cyber-attacks that targeted public authorities and bodies.
- Forecasted their number up to 2035 with three different growth factors, to account for three scenarios, thus for uncertainty.
- Multiplied the number of cyber-attacks for the average costs faced when receiving a cyber-attack to an infrastructure.

Potential Economic Loss (EUR)	=	Cyber-attacks to key infrastructure in Europe	X	Cyber-attacks to Public Authorities and Bodies	X	Average cost of a cyber-attack to infrastructures

The cyber-attacks on key infrastructure in Europe have been calculated through multiple steps. First of all, the number of reported cyber-attacks in Europe targeting Aviation, Rail and Road segment in 2021 and 2022 have been extracted from the ENISA 2023 report. To further restrict the scope, only the attacks to public authorities and bodies have been considered, since GOVSATCOM is intended to serve National and EU actors mainly.

Secondly, their growth until 2035 was predicted with a growth factor of 32% in the medium scenario. This growth factor is the result of the average between the growth from 2021 to 2022 of cyber-attacks in the transportation sector of the ENISA report excluding the maritime segment (not in GOVSATCOM scope) and the growth coming from a research of Check Point.¹⁷⁴ To account for uncertainty, three different scenarios of growth have been

¹⁷⁴ Check Point Research: Third quarter of 2022 reveals increase in cyberattacks and unexpected developments in global trends

implemented: 32% for the medium scenario as above-mentioned, 22% for the low scenario and 42% for the high scenario.

Finally, we extracted the average costs to bear for an attack to a key infrastructure, which is estimated at around \$5 million¹⁷⁵ following the IBM report on cyber security.

As a result, the potential economic loss of cyber-attacks to transportation infrastructure in Europe until 2035 are calculated. They range, cumulatively, between 3.7 and 18.3 billion EUR, proving that there is room and need for GOVSATCOM to support the infrastructure segment and allow safer, cheaper, and more effective communication.

Table 265: GOVSATCOM potential impact on cyber-attacks to transportation infrastructure

IMPACT: GOVSATCOM potential impact on cyber-attacks to transportation infrastructure	Low scenario	Medium scenario	High scenario
Cumulative: 2025-2035	3 780 559 016€	8 412 179 900€	18 325 648 110€

The calculations and potential impact refer to a total addressable scenario of damage, not at the direct benefits of GOVSATCOM. It is rational to assume that the EU space component will be able to mitigate part of this damage, allowing economic benefits for the interested entities. Nonetheless, as GOVSATCOM is not operational and its benefits will materialize in the future, predictions and forecast embed for definition a level of uncertainty.

3.4.4.3.Takeaways on the GOVSATCOM impacts

The security impacts are influenced mainly by the type of satellites used, with clear gaps between state-owned capabilities and commercial capabilities in terms of information assurance, and between non-EU and EU satellites in terms of confidentiality and non-dependence. When comparing the scenario of no EU intervention with the setup of GOVSATCOM, some impacts lead to a rather moderate differentiation, such as the effective prioritization of users, the time to service deployment and the sustainability of the frequency bands allocation. Other impacts offer a more distinct differentiation of the situation, in particular the impacts related to risk acceptance and information assurance. By implementing GOVSATCOM, the benefits on this side become great since state owned and military or governmental systems are better suited for security and non-dependence from 3rd countries.

By taking stakeholders’ point of view, the implementation of the GOVSATCOM initiative is seen as having several positive impacts. These include streamlining business interactions for suppliers and users of secure SatCom, reducing costs and administrative burdens for both the private and public sectors, ensuring access to SatCom services, and enhancing affordability. The initiative is expected to boost confidence in infrastructure supply and renewal, stimulate innovation, and influence global competitiveness. However, setting up the GOVSATCOM Hub is seen as complex and costly.

To conclude, given the future role of GOVSATCOM in risk acceptance and information assurance for communication, a potential use case has been developed. The economic losses related to cyber-attacks in the transportation infrastructure in Europe have been forecasted up to 2035, with three scenarios of growth. In the medium scenario, transportation infrastructure will face 8.4 B EUR of economic losses. Being one of the future domains of GOVSATCOM,

¹⁷⁵ IBM Report: Half of Breached Organizations Unwilling to Increase Security Spend Despite Soaring Breach Costs, Jul 24 2023

the EU transportation infrastructure will potentially benefit from the availability of secure communications.

3.4.5. Efficiency and Cost Benefit Assessment of GOVSATCOM

The following efficiency analysis builds on the benefit assessment above, and adds the costs related to the GOVSATCOM component. In addition, a comparison of these two factors is developed in order to understand to what extent are the costs involved justified and proportionate to the benefits achieved. The efficiency section aims at answering to what extent has the intervention been cost effective.

Benefits of GOVSATCOM

As described in the benefit assessment, GOVSATCOM will be operational starting 2025 and will support different European users by bringing secure communication. The latter will be ensured by prioritizing the users through the GOVSATCOM Hub, providing secure communication links through its network of satellites, allowing a quicker and better controlled response to emergencies, and finally by creating non dependence from 3rd parties for infrastructure supply chain and service provision.

More benefits are related to the bigger picture of the EU industry, including SatCom and other sectors. Indeed, GOVSATCOM would optimize the process for suppliers of secured SatCom and equipment, while optimizing the process for users of the secure communications; at the same time, the costs of doing business for both private and public sector would decrease. The space component would also increase the access to SatCom for EU players and increase their ability to face threats, making the EU industry more competitive on the global market, while stimulating the research and innovation in different sectors.

The expected benefits of GOVSATCOM services utilization could not be quantified and forecasted at this point. However, one potential use case was assessed to look at the size of economic losses in this use case that GOVSATCOM could potentially partially address, and it gave the following outcome:

Table 266: Potential GOVSATCOM use case

Potential Use Case: Use of GOVSATCOM to mitigate cyber-attacks on transportation infrastructure	Total projected economic losses from cyber-attacks on transportation sector (without GOVSATCOM)		
	Low Scenario	Medium scenario	High scenario
Cumulative: 2025 - 2035	3 780 559 016€	8 412 179 900€	18 325 648 110€
Cumulative 2025 – 2027	399 081 015	554 337 532	754 363 309
Cumulative 2027 - 2035	3 381 478 000 €	7 857 842 368 €	17 571 284 800 €

Not enough information was available to estimate the contribution of GOVSATCOM to saving some of these costs. Nonetheless, this potential use case highlights the necessity of the GOVSATCOM service.

Costs of GOVSATCOM

The total GOVSATCOM budget, provided by the EC amounted to 4,5 M EUR for 2014 – 2020 and 175 M EUR for the current MFF (2021-2027) as shown in the figure below, which amounts to a total of 179,5 M EUR.

Table 267: Spending segmentation per time frame and spending type of GOVSATCOM

Spending type	Time Frame	Amount in M€
Old MFF		

Total Commitment	2014-2020	4,5
New MFF		
Total Commitment	2021-2027	175
Total Spending (2014-2027)		179,5

Cost-benefit assessment outcome

Since the potential benefits of the GOVSATCOM component are not quantitatively computed yet, it is not possible to quantitatively assess the benefit to cost ratio, especially provided that the service is expected to become operational in 2025, therefore there would only be 2 years of operations in the timeframe under assessment.

However, what can be said, is that the committed and planned costs until 2027 equal to 179,5 M€, at entrusted entity level to provide a service for secure communication that is needed in the EU, bringing multiple benefits such as:

- *Independence*: due to potential events of conflicts (such as the invasion of Ukraine), being independent from 3rd parties in situations of crisis management, border surveillance or key infrastructure is a critical aspect for the EU. It allows to mitigate the risks of interception, while speeding up the communications.
- *Supply chain and Industry*: the EU industry and supply chain would be positively impacted, with a facilitation of the business in the SatCom segment and reduced costs of doing business. Moreover, the choice of the EU to support the development of additional infrastructure on the long-term is then expected to have medium-high positive impacts on the manufacturing prices of components and technologies related to secure SatCom services, enhancing the capacity of EU market to influence purchasing decisions.
- *Economy*: positive effects will impact also SMEs, which would be more involved in the SatCom market thanks to GOVSATCOM. Research and innovation would be stimulated, with start-ups providing new ideas and the EU becoming more and more non-dependent and competitive.
- *Service effectiveness*: the process of communications for critical actors in the domains of border surveillance, crisis management and key infrastructures would become more effective. In fact, the performances would be enhanced in terms of security, user's prioritization and time to service deployment as a consequence, sustainability of the frequency bands allocation thanks to a greater capacity. To conclude, the geographic coverage would also be extended in remote zones of the world such as the Arctic region.
- *Risk acceptance and information assurance*: as the main aim of GOVSATCOM is to provide secure communication, the risks faced during this process would decrease. Critical information will be protected against threats such as cyber-attacks, and GOVSATCOM could be used as a back-up solution for terrestrial network in some cases, allowing to reduce risks.

The benefits provided by GOVSATCOM are invaluable for the European society, ranging from security to independence, up to the creation of economic cost savings and business opportunities.

While the use case assessment did not provide a quantification of benefits but provided a quantitative indication on the size of benefits GOVSATCOM could bring in one domain, it could also be used to provide a quantitative indication on the Costs versus Benefit.

Over the period 2025 – 2027, the potential economic losses due to Cyber-attacks on transportation is 554.3 M EUR (see previous section). The total cost of GOVSATCOM was

180 M EUR. This means that if GOVSTACOM contributed to reducing 32 % of the economic losses from this one single use case, then the cost would be equivalent to the benefits for end users. This percentages goes to 23% in the low scenario, and 45% for the low scenario. However, this use case is only one out of many possible.

3.4.6. *Relevance Assessment of GOVSATCOM*

As mentioned previously for the other components, the relevance assessment evaluates the extent to which the EU interventions are relevant to the end users. This is done by identifying the user needs in different domains and checking to what extent these user needs are met. The data in this section was gathered through desk research and consultations with EUSPA and EC.

Regarding GOVSATCOM, a large **survey** led by EUSPA was done within the **ENTRUSTED project** aimed at identifying user needs and use cases. However, do to the particularly sensitive nature of the GOVSATCOM component, **the results of this survey are classified**. For this reason, this relevance assessment section will focus on a high-level assessment mainly describing the process used in gathering the necessary inputs.

The survey was designed in order to collect inputs from the relevant participants and was addressed to public authorities, agencies, institutions and other entities, entrusted with the supervision, management, and/or execution of security-critical missions, operations and infrastructures in the EU.¹⁷⁶

The work followed a critical assessment of the **High Level Civil Military User Needs for Governmental Satellite Communications** which was done in 2017 and served as a baseline for the ENTRUSTED work. A **user representatives' network** was built based on this which actively participated in the survey - the largest survey conducted in this area with approximately 140 answers. Each representative was responsible for consulting their respective **national user communities**. They **collected and aggregated individual requirements**, which were then **aggregated again into overall user requirements**. ENTRUSTED thus permitted to build the baseline and EUSPA is now ensuring to **maintaining up to date knowledge of these requirements**, the outcome being integrated to the User Consultation Platform.

Even though the precise results are classified, overall, **GOVSATCOM will meet a substantial percentage of the user requirements**. For some of the remaining ones and to fill the gaps, Union Secure Connectivity Programme (IRIS²), a separate programme, will complement the catalogue of services offered by the GEO-based space assets of GOVSATCOM.

3.4.7. *EU Added Value*

As previously mentioned, this section analyses the added value of an action at the Union level compared to what would have been the results of actions by Member States acting alone. The data in this section was gathered through desk research and consultations with EUSPA, ESA and EC.

The necessity of an action at EU level is clear regarding the GOVSATCOM component. Indeed, **security risks extend beyond national borders**, highlighting a disconnect where secure satcom tools are predominantly organized at national level. Therefore, addressing this mismatch necessitates a unified approach at a Union level to effectively tackle these challenges. An initiative at EU level would guarantee all security stakeholders to have assured

¹⁷⁶ ENTRUSTED Website, survey page, <https://entrusted.eu/resources/survey>

access to satellite communication meeting **EU-standardized minimum-security levels** and would result in heightened security, enhanced operational efficiency, reduced administrative complexities, and notable economic advantages. This access will empower them to operate more effectively in missions and operations that typically involve substantial personal and material risks.

Practically, most of the Member States, especially those without nationally owned satcom infrastructures, lack capabilities to effectively address this challenge on a national scale due to budgetary constraints or technological limitations. This unified approach allows these states to leverage benefits of a resources pooling and sharing mechanism, particularly during crisis or emergency situations, where they may struggle to establish secure satcom independently. Even for Member States with national satcom capacities, this system will **enlarge the coverage** in terms of geography, capacity and services and will thus have an EU added value.

One of the main reasons for an action at EU level is **financial** in nature. Indeed, a budget is associated with this initiative used for 2 reasons. First, to build an **infrastructure**, currently not existing in the EU, capable of handling the orders in an automated and structured way – the Hub-. Second, to procure the capacity, by purchasing and redistributing it to Member States at no cost. Moreover, an initiative at EU level permits to aggregate the demand and to **negotiate favorable financial conditions for the users**. When acting at national level, the prices for the required services could be much higher and the vast majority of the Member States could not have afforded it. On the other side, this system would also benefit operators because the aggregation of demand would result in **larger volume and more longer-term contracts**, ultimately reducing the administrative burden associated with managing multiple small ad-hoc contracts for numerous clients.

Member States' individual needs in this domain can vary significantly and encompass a wide range of requirements in terms of scope, capacity, timing and location. The pooling and sharing mechanism would tackle this challenge by ensuring that the **services are efficiently allocated to the Member States in regard to their needs**. The initiative also aims at establishing **a unified and transparent interface** which will be compatible with each satellite operator's system, ensuring a cohesive experience to the user.

Finally, it must be highlighted that the Hub will not only be used for this component but also to **address forthcoming challenges and initiatives** – for example for the Union Secure Connectivity Programme.

Overall, this initiative will **avoid duplication of efforts across** the Union and Member States and will **ensure better exploitation of existing assets**.

3.4.8. Policy coherence

As mentioned previously, the policy coherence section underlines how well or not different interventions, EU/international policies or national/local policy elements work together. It may highlight areas where there are synergies which improve overall performance or on the contrary, point tensions e.g. objectives which are potentially contradictory, overlapping or approaches which are causing inefficiencies. The data in this section was gathered through desk research and consultations with EUSPA, ESA and EC.

Coherence between the implementation of GOVSATCOM and the rest of the Union Space Programme

First, the GOVSATCOM component is coherent **with other Space Programme components** and mainly with **Galileo**. Indeed, one of its use cases, alongside with crisis management and surveillance can be the support to the management of key infrastructure, including EU space infrastructures such as Galileo. It should also be noted that the **procedures between these**

two components are also coherent because GOVSATCOM is going through the same procedures as Galileo (security accreditation etc.).

Once the service will be operational, potential synergies could also be found with **Copernicus**. Indeed, to effectively carry out their missions and address a range of threats from natural disasters to cyberattacks, the EU and national actors engaged in security-related activities require reliable communication capabilities. These capabilities are crucial in situations where **ground-based communication systems may be unavailable**, for example if such systems are non-existent (in remote regions or high seas) or if they are disrupted or unreliable. In this perspective, GOVSATCOM will support public and governmental actors in events such as natural and man-made disasters, humanitarian crises or missions related to the Common Security and Defence Policy (CSDP) missions and will provide them with a portfolio of secure communication services. This aligns seamlessly with the **Copernicus Emergency Management Service**, as GOVSATCOM can augment the existing service by delivering secure communication solutions during disaster management activities.

In a similar way, GOVSATCOM can be used to **support surveillance operations** by providing surveillance actors with features such as transmission of high-resolution radar and optical images or secured access to specific information systems. These actors can include civilian security and military forces in charge of overseeing EU borders and conducting maritime surveillance. In this way, GOVSATCOM can serve various application within **the Copernicus Security Services domain**, including the provision of secure communications for border and maritime surveillance.

Coherence between the implementation of GOVSATCOM and various EU and international policies

GOVSATCOM is also particularly well aligned with the objectives of the new **Union Secure Connectivity Programme** which emphasizes the importance of satellite communication as a strategic asset for governments and civil society alike. The Programme aims at deploying an EU satellite constellation - IRIS²-, focused on LEO and MEO and aiming at ensuring guaranteed access to EU to secure communication by avoiding dependencies on third countries. This will complement **GOVSATCOM's GEO-based offer, pooling from existing satellites**.

GOVSATCOM component is also coherent with wider EU policies and mainly with **EU Space Strategy for Security and Defence** focused on safeguarding EU space assets, defending its interests, deterring hostile actions in space and strengthening its strategic posture and autonomy. Among the objectives, the Commission aims at initiating preparatory initiatives to ensure the EU's independent access to space, with a specific focus on addressing security and defence requirements.

Similarly, GOVSATCOM is in line with the **EU Digital Europe Programme**. This Programme aims at strengthening **critical digital capabilities** within the EU by concentrating on pivotal domain such as AI, supercomputing, advanced digital skills, cybersecurity and ensuring a wide use of digital technologies across the economy and the society. One of its actions mentioned in the Work Programme¹⁷⁷ is to ensure the deployment of a **secure quantum communication infrastructure** for the EU (EuroQCI). EuroQCI-related aspects are also incorporated into the tasks assigned to the entrusted entities for the GOVSATCOM component as specified in the Contribution Agreement. They include for example the participation and support to the Commission in the EuroQCI Security Group or the support to

¹⁷⁷ Annex to Commission Implementing Decision on the financing of the Digital Europe Programme and the adoption of the multiannual work programme for 2021 - 2022

the Commission in analysing security related documents produced by the contractors in the context of the EuroQCI.

These initiatives are aligned with one another because they address the emerging challenges where the evolution of computing capabilities, coupled with increasingly sophisticated threats from different sources **poses a potential risk to the security of telecom and data communication networks**. Consequently, EU's communication networks and the sensitive information they convey could face a **high level of vulnerability**. To address these concerns, the implementation of the EuroQCI could be a solution and would have the potential to contribute to the security requirements of the GOVSATCOM initiative.

This component is overall interconnected with various other **Union policy domains**, including maritime security strategy, telecommunications policies, humanitarian aid, border management etc. whose efficacy is expected to be boosted by the component. Moreover, several **EU services** are also interested by the service which will be delivered by GOVSATCOM as they will get a significant **added value using secure communications to perform their duties** – for example DG ECHO or agencies such as Frontex or Europol.

Lastly, GOVSATCOM **will ensure better protection of personal data** since communications via EU GOVSATCOM will provide an enhanced level of information assurance against eavesdropping, spoofing etc. by third parties, which is also in line with the **Charter of Fundamental Rights**.

3.4.9. Additional insights to the GOVSATCOM component

Two further aspects were assessed for this component: the **pricing policy** and the **evolution of the available capacities for pooling and sharing**. The data in this section was gathered through desk research and consultations with EUSPA, ESA and EC.

Pricing policy

As mentioned previously, GOVSATCOM aims at providing **cost-effective secure satellite communication**. The Commission will thus negotiate with the resources providers - operators- to include resources in a pool, through contracts or agreements and procure the capacity to the users at no cost.

The pricing policy has been defined in implementing acts and will consist in a system of tokens to **facilitate the sharing and prioritization**. This system will contribute to provide fair and optimized use of the available GOVSATCOM resources. These resources will be tailored to the needs of each participant and based on the supply and demand of pooled and shared satellite capacities and services procured.

The pool will be divided into two parts:

- A fixed part supporting guaranteed provision of services; and
- A dynamic allocation linked to unplanned needs.

To **facilitate the efficient use of resources** and **avoid market distortion**, a system of tokens has been established with compensation values based on the level of priority of the requests (with a possibility for buying additional tokens or to donate tokens to another participant). The total number of tokens will be defined by the Commission according to the available budget as well as the conditions of the contracts and agreements and will be divided in the Member States' total share, EU institution's share and a crisis margin – used to support the provision of services for unplanned, urgent and high priority needs.

In practical terms:

- Each Member State will receive a percentage in tokens of the Member States total share proportional to the number of votes in the Council.
- Each EU institution will receive a percentage in tokens according to the *EU institution sharing plan*, which will be defined by the Commission.

In practice, each participant will have to determine the relevance of its users and the criticality of its request and the hub should perform matchmaking of the service request with the resources of the pool – if not possible, a conflict resolution mechanism will be available.

In addition to the pre-paid tokens, users will have a **pay-on-demand** part which will be used for the compensation of services request using pay-on-demand mechanisms. Indeed, users will be given the possibility to use euros to buy additional tokens through the Commission according to the conversion ratio of tokens to euro defined for the occurring PPT¹⁷⁸. These additional tokens will be added to the pay-on-demand part of this user's account. With this principle, GOVSATCOM will have the capacity to **provide secure connectivity to users at no cost**, which is especially **crucial** in specific domains. Yet the system will remain **flexible enough** to be adapted to the needs of each use through the **additional pay-on-demand part**.

Evolution of available capacities for pooling and sharing

The Space Regulation states in its article 62 that under the GOVSATCOM component, satellite communication capacities and services shall be combined into **a common Union pool of satellite communication capacities and services**, with appropriate security requirements. The sharing and prioritization aim to provide **fair** and **optimized** use of the available GOVSATCOM resources tailored to the needs of each participant and based on the supply and demand of pooled and shared satellite capacities and services procured.

The pool will be divided into two parts:

- A **fixed part** supporting guaranteed provision of services; and
- A **dynamic allocation** linked to unplanned needs.

A **system of tokens** will also be implemented as a compensation mechanism and in order to avoid market distortions. The total number of tokens will be divided in the Member States' total share, EU institution's share and a crisis margin – used to support the provision of services for unplanned, urgent and high priority needs.

In practice, each participant will have to determine **the relevance** of its users and the **criticality** of its request and the hub should perform matchmaking of the service request with the resources of the pool – if not possible, a conflict resolution mechanism will be available.

The pooling and sharing mechanism encompasses 3 elements:

- The Hub itself;
- The availability of the resources from the resources providers which is linked to the existing capacities;
- The Hub location site: a call for expression of interest has been released among the Member States with end of July as a due date. Following the results, an evaluation will be performed and 2 sites will be selected until the end of the year.

¹⁷⁸ Pool Programmatic Term : the fixed term period for which contracts or agreements have been concluded between the Commission and resources providers for the inclusion of their resources to the Common Union pool.

The service is not expected to be constrained by the capacity of the HUB, more by the **limited number of providers in EU** but this number can **increase** in the future. Indeed, regarding the capacity, the system will be **modular** and can be **scaled up to meet the needs**: it will be possible to add **additional elements and/or interfaces without constraints**.

3.5. Horizontal Actions supporting EU Space Programme

3.5.1. IOD/IOV entrusted activities

Introduction to IOD/IOV initiative

The IOD/IOV initiative started prior to the current MFF, under the 2018 – 2020 Work Programme of the previous MFF, as a component of the H2020 programme. Today it continues as a component of the Horizon Europe Programme under the work programmes of 2021 – 2022 and 2023 - 2024. The IOD/IOV initiative allows new technologies to be tested in orbit by providing aggregation, if needed, launch services and operations. It allows academia, research organisations, SMEs and larger industrial companies to effectively test new technologies in orbit, reducing the time it would otherwise take to bring them to market. In providing flight heritage, it provides a major boost to start-ups in the EU and accelerates their time to market. It also contributes to the EU space skills agenda by exposing students to activities required for designing, building, testing, integrating, and operating a satellite. IOD/IOV entrusted tasks (interventions) to ESA include:

- Contribution to the preparation of the Call(s) for expression of interest and providing support to the Commission in the pre-selection of IOD/IOV Experiments
- Implementation of IOD/IOV Project(s) activities and management of the related procurements and interfaces with industry
- Implementation of IOD/IOV Project(s) launch services and management of the related procurements and interfaces with industry
- Upon request of the Commission, contribution to the preparation of the Horizon Europe Work Programmes to be prepared and adopted by the Commission when relevant to the IOD/IOV activities.

Effectiveness of the implementation of IOD / IOV

As described above, the IOD/IOV service aims to enhance and integrate European industry's competitiveness and non-dependence in advanced technologies. By providing a regular, cost-effective services for end-users to launch and test their technologies In-Orbit (utilizing EU manufactured platforms and launch services), these solutions can then be validated and de-risked and further brought into market. **The objective, as listed in the Work Programmes is to have at least one opportunity every year during the HE implementation period.** The IOD/IOV activities are expected to support European launcher exploitation by relying as far as possible on EU manufactured launchers launched from EU territory. **The expected outcome associated with the opportunity is to reduce time to market or operational use of the innovations being tested.**

Activities under IOD/IOV include the following:

- System studies, at ground and space level, including the compatibility with the available launchers;
- Input to the launch mission analysis performed by the launch service provider; Selection, assembly, integration and testing of the spacecraft(s) and related ground segment;

- Management of interfaces with and between the different IOD/IOV experiments, between the spacecraft and the launcher and between the spacecraft and the ground segment;
- Preparation of the spacecraft(s) for the flight.
- In-orbit testing and operations including data provision.

The budget allocated to IOD/IOV for the 2021 – 2027 MFF amounted to 62.65 M EUR: 24 M EUR from the 2021 budget, 10.55 M EUR from the 2022 budget, 15.1 M EUR from 2023 budget and 13 M EUR from the 2024 budget. It must be noted that, as of 2023, the launch services for experiments in the form of complete systems can also be partially co-financed by ESA and the experiment providers.

The assessment of the implementation of IOD/IOV by the entrusted entity (ESA) is measured via a set of KPIs defined in the contribution agreement and they are listed in the table below:

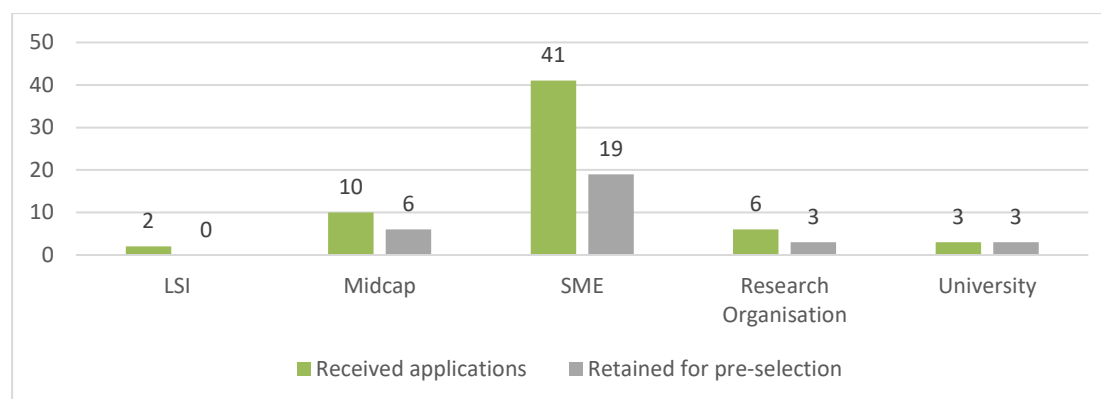
Table 268:KPIs to assess the performance of the implementation of IOD/IOV

Process	Title	Description	Key Indicator
Procurement schedule	ITT / RFQ issued	Trend chart showing the % of the cumulative number of ITTs / RFQs issued vs. the cumulative number of ITTs /RFQs planned for the same period	$KI1 = \frac{A}{B} \times 100$ A= cumulative nr of ITTs and RFQs signed B= cumulative nr of ITTs and RFQs planned for same period
	Contracts signed schedule	Trend chart showing the % of the cumulative number of contracts signed vs. the cumulative number of contracts planned for the same period	$KI2 = \frac{C}{D} \times 100$ C= cumulative nr of contracts signed D= cumulative nr of contracts planned for same period
Procurement Commitment ceiling	Commitment ceiling	Trend chart showing the % of the cumulative actual commitment ceiling vs. the cumulative planned commitment ceiling for the same period	$KI3 = \frac{E}{F} \times 100$ E= $\sum$ Actual commitment ceiling F= $\sum$ Planned commitment ceiling for same period
Procurement Cost accrued	Contracts cost accrued	Trend chart showing the % of the cumulative actual cost accrued vs. the cumulative planned cost for the same period	$KI4 = \frac{G}{H} \times 100$ G= $\sum$ Actual Costs Accrued H= $\sum$ Planned cost for same period
Projects schedule	Milestone achievement chart	Trend chart showing the number of milestones achieved vs the number of milestones planned	$KI5 = \frac{I}{J} \times 100$ I= cumulative nr of milestones completely achieved J= cumulative nr of milestones planned for same period
Overview of budget usage	Contract price	Table showing the actual price of each contract	
	MS participation rate	Histogram showing the actual cumulative share of each country in the value of the contracts	

Introduction to IOD / IOV activities under the New MFF

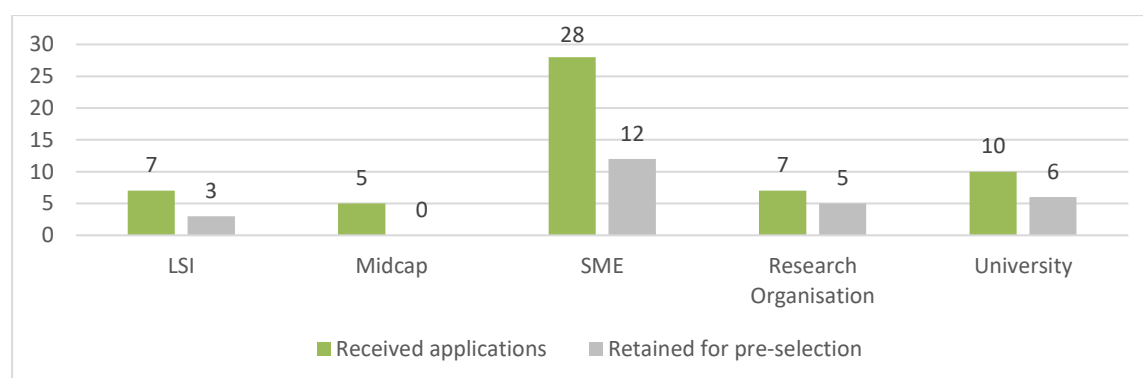
In the years 2021 - 2023, 2 calls for expression of interest were launched for IOD / IOV experiments that received a total of 62 applications, the majority of which (41 applications) coming from SMEs, and the rest from MidCaps, LSIs and Universities. 31 of these applications (50%) were retained for pre-selection as demonstrated in the graph below:

Figure 88: Total number of applications received and retained for pre-selection for the IOD IOV calls of 2022-2023 under HE



It can be seen that at the level of the received and retained applications, in these 2 years the IOD/IOV initiative under Horizon Europe has already performed better than under H2020 according to a few indices. The H2020 applications for IOD/IOV are presented in the figure below for comparison.

Figure 89: Total number of applications received and retained for pre-selection for the IOD IOV calls under H2020

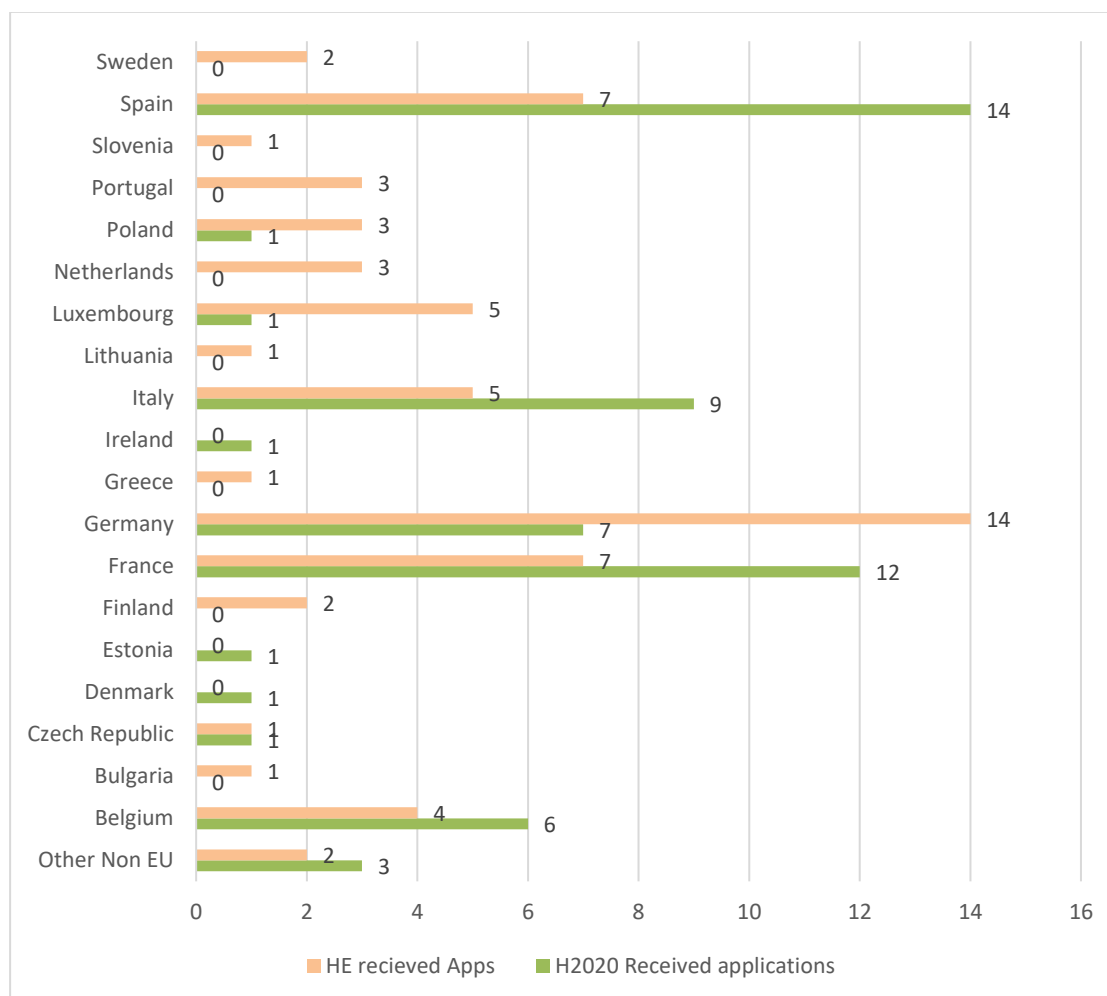


Overall, more applications were received under HE in 2 years than from H2020 in 3 years. Under H2020 a total of 57 applications were received from the 2018 call as compared to the 62 received under HE, from the 2022 and 2023 calls. Additionally, 45.6% of the received applications in H2020 were retained, and this rate increased to 50 % under HE. The larger percentage of the applications retained (going from 26 applications retained under H2020 to 31 retained under HE) is a direct indication of the improved quality and credibility of the applications being received because these applications are selected first based mainly on technical and programmatic fitness and secondly based on compatibility with the platforms/IOD/IOV mission.

Additionally, it can clearly be noted that there has been a growing participation from SMEs in IOD/IOV experiments. Under H2020, a total of 28 applications were received from SMEs (representing 45% of the total applications received). This value increased to 41 applications from SMEs under HE, which is 66% of the applications received.

Additionally, in terms of geographical coverage, applications under H2020 spanned around 11 countries in Europe whereas those under HE spanned around 17 countries from Europe as shown in the graph below.

Figure 90: Geographical distribution of the received applications under H2020 and HE



Implementation of ESA's entrusted Tasks

The tasks of the intervention are implemented per the Contribution agreement

Entrusted task 1 - Contribution to the preparation of the Call(s) for expression of interest and providing support to the Commission in the pre-selection of IOD/IOV Experiments: According to the consultations held with the EC and ESA, ESA has effectively supported the EC in the preparation of the call(s) for expression of interest launched in 2022 and in 2023. ESA supported the EC in the drafting of the text and held workshops with the industry and applicants (around 120 companies per workshop) to address their inquiries and uncertainties about the calls and application. ESA as well has effectively supported EC in the preselection of the IOD/IOV experiments for 2022 and 2023. Since ESA is entrusted the task to prepare and implement the IOD/IOV Projects activities with selected experiments, it is important for them to have access to all the necessary information before-hand in order to facilitate the preparatory activities of the IOD/IOV projects and therefore they are active in this preparatory task.

Entrusted Task 2 - Implementation of IOD/IOV Project(s) activities and management of the related procurements and interfaces with industry: According to the consultations held with the EC and to information gathered from ESA, ESA has effectively supported the implementation of the IOD/IOV projects and is managing the procurements with the industry. In fact, in 2023, ESA authorized two procurement contracts for CubeSat carriers and the associated services for the aggregation of pre-selected IOD/IOV experiments, both of which have been signed. These 2 contracts are in-line with ESA's objectives and plans for this period. However, ESA is also preparing an ITT that brings a new approach for implementing

these projects, based on a rideshare concept (procuring a slot for experiments on an already planned commercial satellite missions, with its planned launch). However, this ITT, meant to be launched in 2023 has not been launched yet, but due to it being a new approach it is expected to take more time to launch the first ITT (more information on this item and entrusted task is provided below under the KPIs evaluation).

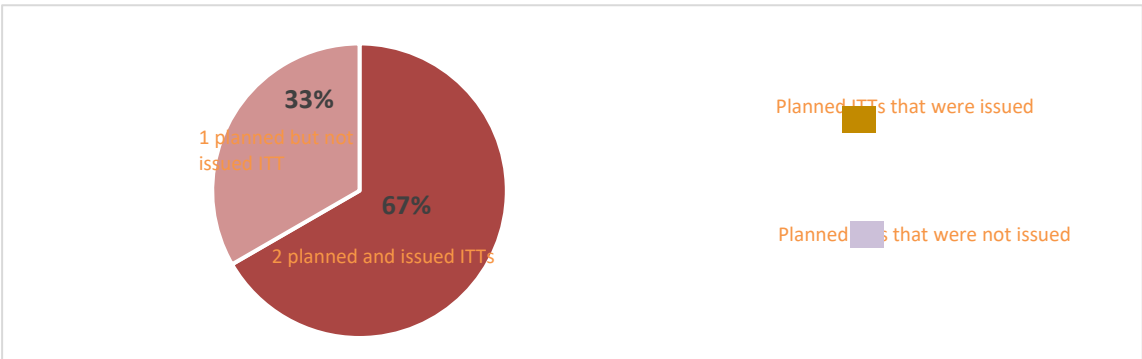
Entrusted Task 3 - Implementation of IOD/IOV Project(s) launch services and management of the related procurements and interfaces with industry: According to the consultations held with the EC and to information gathered from ESA, in October 2023 ESA launched an ITT for the procurement of launch services under the newly developed “Flight Ticket Initiative”, in-line with what was planned. For that ITT an amendment of the contribution agreement was required due to the new requirement of the launch services being under the European Flight Ticket Initiative. This ITT is expected to lead to the signature of at least one frame contract with a European launch service provider between end 2023 and early 2024.

Procurement Schedule

ITT issued:

The trend chart showing the % of the cumulative number of ITTs issued versus the cumulative number of ITTs planned for the same period (2021 – 2023) is presented below:

Figure 91: Ratio of cumulative ITTs issued under Horizon Europe



Under the new MFF, i.e. under the Horizon Europe Work Programmes, 67% of the cumulative planned ITTs have been issued by ESA (2 out of 3) whereas 33% of planned ITTs (1 out of 3) is planned but has not been issued yet.

The figure below presents the % of the number of ITT issued versus signed, per year over the relevant timeframe:

Figure 92: Ratio of ITTs issued and signed per year



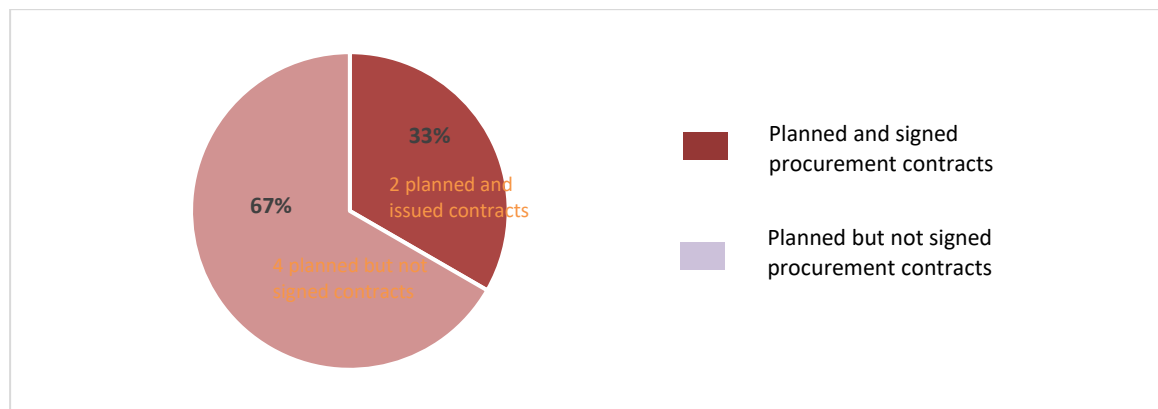
In more details, in the year 2022, ESA had planned to launch an ITT for the procurement of CubeSat carriers and the associated services for the aggregation of pre-selected IOD/IOV

experiments, which it effectively did issue and resulted in signature of contracts with two system integrators. In the year 2023, ESA was expected to issue 2 ITTs. The first one refers to the “Flight Ticket initiative” which aims to procure launch services from European launch service providers, which ESA issued in Q4 2023. The second tender refers to an innovative approach which aims to procure a rideshare opportunity that includes aggregation, launch service and operations for pre-selected IOD/IOV experiments needing aggregation that cannot be accommodated on a cubesat mission. This approach reduces costs and efforts required from ESA and facilitates the management of the IOD/IOV projects. This ITT has not been issued yet, and while the year 2023 is not over, according to the European Commission a delay could be anticipated due to several factors. As a first impediment is the fact that this is a new approach being implemented, which requires careful consideration and planning to define specificities ad hoc since there are no set of rules today to govern what this service would look like in details. In addition, given the requirements to use EU based solution for both platform and launch service and considering the challenges linked to availability of EU launch services, this ITT is being postponed to allow the development of commercial missions to be planned with European launchers. Finally, for the most optimized use of resources, ESA encourages implementing actions based on the needs of the experiments to be launched under IOD IOV. Per discussion with ESA, in certain cases it is more efficient to be driven by the needs and requirements of the experiments and to adapt their activities accordingly. In these lines, ESA highlights that there are no particular experiments today that are ready or suitable for rideshare. Therefore, putting in place this ITT does not serve the experiments’ needs, at the moment.

Contracts signed schedule:

The trend chart showing the % of the cumulative number of contracts signed versus the cumulative number of contracts planned for the same period.

Figure 93: Ratio of planned to signed contracts for 2021 - 2023



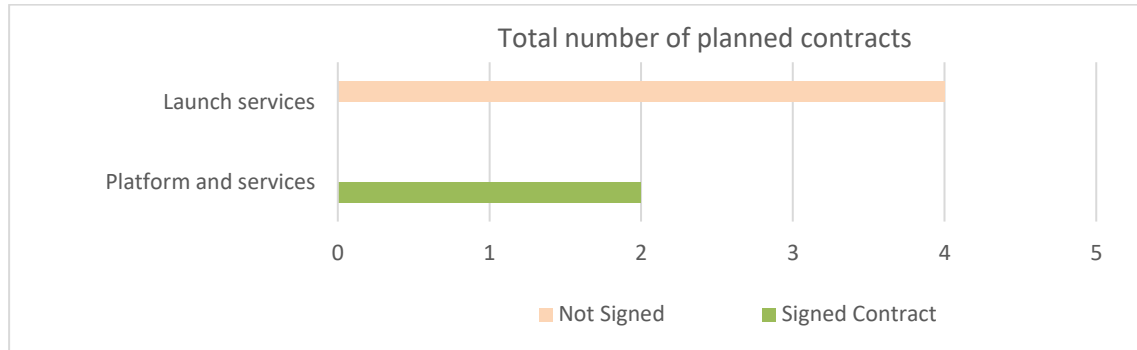
Under the new MFF, i.e. under the Horizon Europe Work Programmes, 33 % of the procurement contracts that are planned to be signed by end of 2023 have been signed (2 out of 6) whereas 67% of the contracts planned to be signed by the end of 2023 (4 out of 6) have not been signed yet.

According to the discussions with the EC and ESA, and to the entrusted tasks of ESA, three types of procurement contracts are identified that ESA is expected to sign with the industry to provide services to the IOD/IOV experiments and they are the following:

- Procurement contracts for satellite carriers (platforms), aggregation services and (1 year of) operations
- Procurement contracts for the launch services (of the procured platforms, of the complete systems preselected that are ready for launch)

- Procurement contracts for rideshare (the rideshare service is expected to cover the entire services i.e. aggregation of the experiment on a satellite platform, launch and operations. For the years 2021 and 2022 no contracts were planned, however for the year 2023, a total of 6 contracts were planned as shown in the figure below¹⁷⁹.

Figure 94: Types of the cumulative number of planned and signed contracts for 2021 - 2023



2 of the planned contracts are of the first contract type listed above, and effectively the first one of these planned contracts was signed in April 2023 and the second in September 2023.

The remaining 4 contracts planned for the year 2023 are of the second type listed above, and they are contracts to provide launch services for one aggregated IOD/IOV project and 3 complete systems. So far, none of these contracts has been signed, a delay in the signature of these contracts is anticipated. Several factors play into the reason behind this delay. This anticipated delay can be primarily attributed to the fact that the ITT for Launch services was issued in Q4 2023 under the new “Flight Ticket Initiative” open competition approach with a closing date in January 2024. Adding layers of difficulty to the signature of these contracts in 2023 is the launch service scarcity witnessed in Europe considering that the launch services providers must be European. Additionally, according to consultations with ESA, it appears that none of the preselected experiments are currently ready for launch and they will not be ready before 2024/ 2025. Therefore, there is no imminent urgency to have such contracts in place at this very moment. I.e., even though the launch contract signature was planned in 2023, the actual launch activity in these 4 contracts is expected for the years 2024 and 2025, and therefore the potential delay in signing the contract might not necessarily translate to a delay in launching the IOD/IOV experiments. According to ESA, when the objective of 4 contracts for launch services was set for 2023, ESA had believed that the experiments would be ready to launch in the period 2023/2024, which is no longer the case.

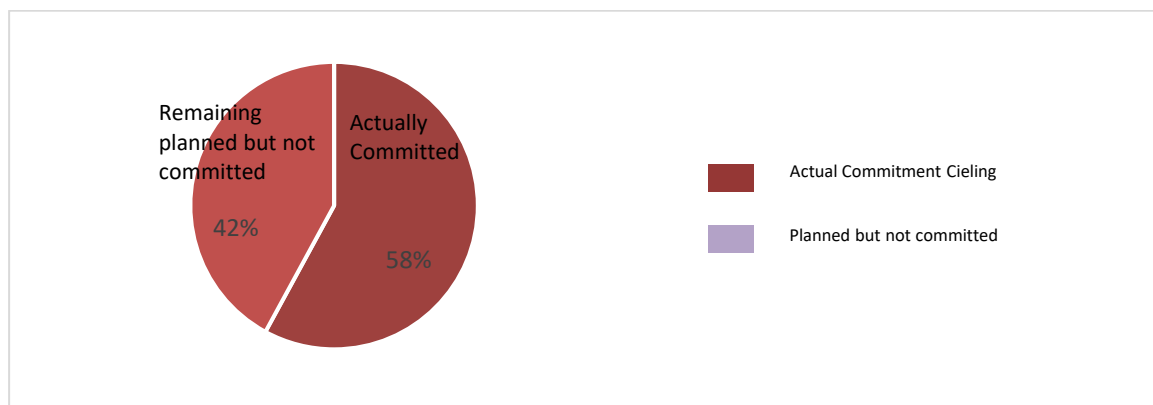
Procurement Commitment ceiling

Commitment Ceiling:

The trend chart showing the % of the cumulative actual commitment ceiling vs. the cumulative planned commitment ceiling for the same period is presented below :

¹⁷⁹ Counted from the table on planned contracts from the revised work plan

Figure 95: Ratio of actual versus planned commitment ceiling for 2021 – 2023 (data extracted from the ESA SIR4)



Under the new MFF, i.e. under the Horizon Europe Work Programmes, 58% of the planned commitment ceiling (equivalent to 4,545 M EUR) has actually been committed and it refers to the two CubeSat carrier contracts in addition to an additional ESA remuneration (145 K EUR). Ultimately, 42% of what was planned commitment ceiling in the updated work plan has not actually been committed this year and these commitments refer to the 4 launch services contracts. Of course, this is because no contract has been signed for the launch services as described above. ESA highlighted however, that the planned commitment ceiling for the launch services (initially set at 3.3 M EUR) is a figure that is subject to be reviewed given the limited visibility of the possible launch services solutions and their associated prices.

Procurement Cost accrued

The trend chart showing the % of the cumulative actual cost accrued vs. the cumulative planned cost for the same period is presented below:

The total actual costs accrued expected by the end of 2023 is 3,53 M EUR coming from payments under the two Cubesat contract signed and an annual ESA remuneration that was committed upon signing the agreement.

According to consultations with ESA, the full value of the planned accrued costs translated into actual costs and therefor this KPI is completed at 100%.

Projects schedule

According to consultations with ESA there was 1 payment milestone this year for the SDR for one of the Cubesat projects and it was achieved therefore this KPI was completed at 100%.

Overview of budget usage

Contract Price:

The table showing the actual price of each contract is presented below:

Figure 96: list of contract prices (2021 – 2023)

#	Year	Contract name	Value	MS participating	Status
Horizon Europe	2023	IHE1-3 Cubesat Project	1.8 M EUR	Spain	Signed
Horizon Europe	2023	IHE1-1 Cubesat Project	2.6 M EUR	Netherlands	Signed

MS participation rate:

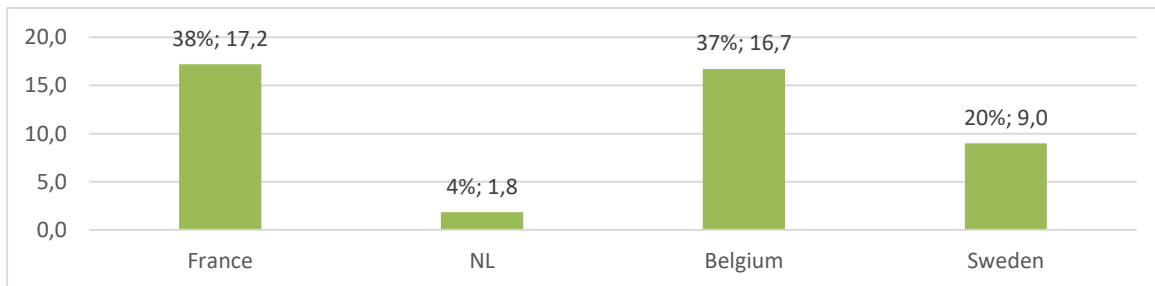
A histogram showing the actual cumulative share of each country in the value of the contracts is presented below:

Figure 97: MS participation rate in signed contracts under Horizon Europe



At the moment only 2 contracts can be accounted for, one in Spain and the other in the Netherlands. While it is too soon to determine a representative participation rate of the MSs given that only 2 out of 6 planned contracts have been awarded, already a small comparison can be made with H2020 contracts showing that the country Spain, which was not represented in H2020 contracts is represented under HE. Additionally, at the moment a good distribution between MS is shown given that there is a 59% / 41% distribution of contract value between the 2 appearing MSs whereas in H2020 the contracts were unevenly distributed as the MS participation rate diagram of H2020 is shows below:

Figure 98: MS participation rate in signed contracts under H2020



Takeaways:

Overall, according to consultations with the EC and ESA, ESA has effectively implemented its delegated tasks under the IOD IOV initiative. Its KPIs have been reached with the exceptions of the ones related to launch services. However, this delay in developing the contracts for launch services is on the first hand not expected to impact the implementation of the IOD IOV missions so far because the experiments themselves are not ready for launch. However, this is subject to an EU wide crisis in the launch service supply, which should be anticipated, because when the preselected experiments are ready for launch, if the industry itself is not ready to provide launch services, the objective of reaching regular launches and tests will not be achieved.

On the other hand, another point was highlighted regarding the relevance of the KPIs in evaluating the implementation of IOD IOV itself. Given that the number of ITTS and Calls or contracts etc is limited to a couple per year, it was reflected by ESA that these KPIs might not be reflecting properly the implementation of the programme as they would for Galileo/EGNOS and Copernicus that have a different scale of activity. Additionally, in IOD IOV the activity of ESA is usually bound to or driven by the experiments themselves which are out of control of the European institutions therefore certain updates to the objectives might be needed.

However, at this point in time there is no sufficient data available to evaluate the benefits that the IOD IOV programme has led to for the end users and whether it has facilitated their commercialization of their products. However, IOD IOV initiative is expected to support the other EU Space Programme components (such as Galileo, EGNOS, Copernicus, IRIS² etc.) by providing a platform that can easily and quickly test certain equipment and payloads in space.

3.5.2. CASSINI initiative and entrusted tasks under scope of assessment

The assessment of this chapter for extracting the entrusted interventions (within the study scope) that are under the CASSINI program and evaluating their implementation was based on desk research and literature review of the documentation related to the CASSINI program, followed by exhaustive consultations with the relevant entrusted entities. Documents reviewed in particular for extracting the interventions were the following:

- Horizon Europe Work Programme 2021 – 2022 (7. Digital, Industry and Space)
- Annex to the Commission Implementing Decision on entrusting budget implementation tasks to the European Union Agency for the Space Programme and the European Space Agency
- Annex to the Commission Implementing on the financing of the EU Space Programme and its components and the adoption of the work programmes for 2021-2027 - Horizontal part of the 2021-2027 Work Programmes of the EU Space Programme and its components
- Horizontal part of the 2022 Work Programmes of the Union Space Programme
- Horizontal part of the 2023-2024 Work Programmes of the Union Space Programme

As mentioned, in addition to the desk research, the team conducted several consultations with the entrusted entities (EUSPA) in order to confirm, validate or update the interventions and the programs mapped and extract the information and data necessary to evaluate the performance of the implementation of these interventions.

3.5.2.1. Introduction to CASSINI and entrusted tasks under scope of assessment

The CASSINI initiative of the EC aims primarily to support the growth and development of the private space sector and industry via the stimulation of entrepreneurship, SMEs and start-ups development. CASSINI targets the different domains of the EU Space programmes (EO, Navigation etc.) and equally addresses the upstream segment of the space value chain in addition to the downstream segment. CASSINI shall stimulate and support the space ecosystem in the EU via different types of actions that include promotion activities, innovation competitions, business growth (accelerators), access to finance and investment and matchmaking.

The CASSINI Space Entrepreneurship Initiative 2021-2027 gets funding from multiple sources i.e. Horizon Europe (for business development, competitions, inducement prizes and In-Orbit Demonstration & Validation), the Space Programme (blending for equity investments under InvestEU and matchmaking), and a matching contribution from InvestEU for blending operation.

Under the investment action, the CASSINI Facility will deploy a €1 billion investment capacity over 2021 – 2027 to boost space companies and support entrepreneurship in space-related businesses in the EU. The initiative is tailored to meet the needs of companies in different growth stages from seed to mid-caps. Both companies developing space technology and those marketing digital applications can benefit.

The CASSINI Space Entrepreneurship Initiative 2021-2027 is made of many initiatives, tools and activities that can be segmented into three groups of interventions, the first is entrusted tasks to EUSPA, the second is entrusted tasks to the European Investment Fund and the third is the direct management activities by the EC. However only the delegated or entrusted tasks are under the scope of this study assessment:

Tasks entrusted to European Investment Fund

CASSINI Seed and Growth Funding Facility (InvestEU blending operation): This initiative aims to create funds and help existing ones that want to invest in the space sector, mainly to avoid that the space companies of Europe seek foreign investment and consider moving abroad. The Cassini Seed and Growth Funding Facility will provide equity investment to venture capital funds who will invest in early- and growth-stage companies developing or operating with space technology or digital services based on space data. It will provide financial guarantees, i.e. additional capital, to (on average) 4-6 selected financial intermediaries per year (venture capital funds, private equity, co-investment vehicles, and technology transfer funds). The total investment capacity of the financial intermediaries (capital from the Union Space Programme, InvestEU, EIF and private capital) will enable (on average) 60 new venture capital investments per year (first investments and follow-on investments). The target for the facility is to mobilise EUR 1 billion of investments for the period 2021- 2027. The InvestEU Guarantee Agreement was concluded in Q4 2021, containing the terms of the Joint Equity Product including the CASSINI Seed and Growth Funding Facility. The advantage of the Facility will be the creation of a fund-of-funds with capital earmarked for investments in space-related companies. This specific focus on space investments is enabled by the blending operations of the Union Space Programme. The Commission will ensure that the setup of the CASSINI Seed and Growth Funding Facility will involve a sizeable capital contribution by European Investment Fund, and leverage two to three times additional private capital contribution. The Facility will be clearly promoted to venture capital and private equity funds to enlarge Europe's base of investors active in the space industry. This should lead to a sustainable long-term increase in risk capital supply. The co-financing action is delegated to the EIF, while the Commission and EUSPA organize capacity building workshops for investors and bring together a network of VC partners, but no budget is entrusted to EUSPA for this task.

It began activities in May 2022 and has successfully signed investment agreements, provided funding to Venture Capital funds and actively supported and enabled investment and fund raising in space start-ups and SMEs¹⁸⁰ however the details and full extent of the assessment of this activity will be done at a later stage for the Mid Term evaluation of InvestEU.

Tasks entrusted to EUSPA: Support to European "New Space" entrepreneurship

Under this group, EUSPA is entrusted the task for the implementation of specific actions stemming from the CASSINI Space Entrepreneurship initiative, including by means of blending operations under Article 21 of Regulation (EU) 2021/696 and subject to specific authorization of the Commission, aimed at increasing the number of innovative solutions using EU space technologies and the success rate of new ventures proposing them. The initiatives falling under this group are the following CASSINI components:

¹⁸⁰ Discussion with the EC

- **CASSINI Prizes:** these include the CASSINI prize for digital space applications which is funded by Horizon Europe, and **CASSINI Challenges (MyEUSpace Competition)** which is funded via the Space Programme and it aims to support startups in the development of their ideas and concepts into final products. In fact, for MyEUSpace competition, the prize pot is in total 1 M EUR per year of which 750 K EUR is from GALILEO and 250 K EUR is from Copernicus, however the prize support activity budget is another 1 M EUR for 2 years, which comes from horizon funding.
- **CASSINI Hackathons & Mentoring:** which is funded via the Horizon Europe programme and they aim to promote as widely as possible the EU Space Programmes and the notion that space can have synergies with a lot of other domains, and to democratize the space sector and enhance its integration with other sectors.
- **CASSINI Space Academy:** Initially this started as a EUSPA activity, labelled the EUSPA Space Academy, which was funded from the delegated budget for capacity building activity (Space Programme budget). However it was later decided to put this activity under the umbrella of CASSINI and it was rebranded as the CASSINI Space Academy, which is an action that provides online training for start-ups (budget of around 300 – 400 K per year).

Direct Management activities

While only delegated tasks are covered under the scope of this study, it is important to highlight that the CASSINI initiative consists of several other tools that are critical and complementary to the programme, that are currently under the direct management of the EC. The two CASSINI tools that have been under the EC direct management but that are expected to be delegated to EUSPA later on under this MFF are the following:

- **CASSINI Business Accelerator:** For many entrepreneurs developing either space technology or space data solutions, achieving commercial growth is a challenging phase in the company's development. To secure external investment for such growth plans, the company needs to show its investment-readiness, and this is where CASSINI Business Accelerator can assist space entrepreneurs. The Commission has set up CASSINI Business Accelerator to provide business development advice and growth acceleration to Europe-based start-up companies. The 2023 launch of this action reinforces the commercialisation objectives of the EU Space Programme and Horizon Europe, and ensures synergies with the InvestEU programme. It ensures complementarity with other business incubation programmes, e.g. ESA-BIC. The objective of the action is to increase the number of space-based companies that achieve high revenue growth and attract significant external investments. This will in turn enable the companies to raise debt financing and participate in both private joint ventures and public procurement. CASSINI Business Accelerator is run in direct management by the European Commission and will have a mid-term review by the end of 2024
- **CASSINI Matchmaking:** The action, funded by the Union Space Programme, consists of the organisation of a series of matchmaking events for start-ups and SMEs to create broader professional networks. The events involve two types of matchmaking: i) investor matchmaking, to make companies investment-ready and provide leads to active investors; and ii) industrial partnering, to offer matchmaking with large companies who may provide product testbeds, potential customers, distribution channels and industrial partnerships. It is an important complement to the Seed and Growth Fund. In the year 2021, the Matchmaking action was under the direct management of the Commission and in the year 2024 its management will be delegated to EUSPA. EUSPA collaborated with the Commission during 2022-2023.

All the CASSINI actions and initiatives are complementary and aim to support the space SME and start-ups ecosystem in Europe at different stages. The Cassini initiatives under scope of

this study (i.e. delegated to EUSPA and funded by the Space Programmes) from the ones listed above are MyEUSpace competition and the CASSINI Space Academy. However, it was decided with the EC that Cassini Matchmaking would also be covered because EUSPA has collaborated with the Commission on this initiative that is expected to be delegated to them soon

3.5.2.2. Effectiveness of the Implementation of CASSINI initiatives

1 KPIs to assess the implementation of the entrusted tasks and entrusted entities

The interventions under the scope of this study are assessed according to a set of criteria and KPIs that measure if and to what extent these interventions have achieved their objectives and targets.

Intervention 1: Cassini Matchmaking

The matchmaking program helps start-ups and SMEs in building networks and connections with investors and other larger companies within the space ecosystem. The CASSINI matchmaking activities take place at existing tech events (such as Vivatech, Websummit, 4 Years From Now, NSE etc.) bringing together the companies with the VCs and corporates of the space ecosystem, and gives them a platform to communicate and network. This is done through stage pitching and 1on1 meetings.

The CASSINI Matchmaking action has been managed directly by the EC, however in 2023 EUSPA launched a new call for tender for the matchmaking program which would be effective in 2024. EUSPA has worked with the European Commission on the implementation of this program.

The first call for matchmaking started in the end of 2021, and the events and activities under it started in the beginning of 2022 with 80 companies selected for that first round. In 2023, a second round of open call was started with another 80 companies selected.

The matchmaking action includes, physical events with pitching and 1on1 networking, as well as *online 1on1 networking*. Companies and investors receive briefings and entrepreneurs get advice on how to prepare investor presentations. Individual introductions and curated networking is also part of the action.

The CASSINI matchmaking contract is 1.2 M EUR for two years of activities.

The KPIs selected for the assessment of CASSINI Matchmaking are gathered from the description of the expected outcomes of the program, in addition to other Indicators that could be tracked by EUSPA. These KPIs are expected to demonstrate the three following critical impacts of Matchmaking:

- Outreach and Increase awareness of space programmes especially in the VC investor ecosystem
- Facilitate access to finance and VC funding for Space Start-ups and SMEs
- Facilitate and enable networking for space start-ups and SMEs

Table 269: list of KPIs to assess the results and impacts of the matchmaking initiative

#	KPIs	Target	2022 value	2023 Value	Comment / takeaways
1	Number of matchmaking events organized for start-ups and SMEs	5 per year	5	4 (in Q1 & Q2) 3 more planned for Q3 & Q4	12 expected for 2022 – 2023 (above target)
2	Number of attendees from Start-ups and SMEs (and number of pitches)	NA	94	97 (for Q1 & Q2)	Increase in attendance number is witnessed and further expected when the remaining planned events

#	KPIS	Target	2022 value	2023 Value	Comment / takeaways
					are done
3	Number of attendees from investors	NA (increasing trend sought)	25	44 (for Q1 & Q2)	Almost doubled number of investors, expected to be larger by end of 2023.
4	Countries represented – number of participating nationalities in all events	NA (increasing trend sought)	24	24 (in Q1 & Q2)	Around 90% of EU MS
5	Number of 1-1 meetings between start-ups and investors at Cassini events	NA (increasing trend sought)	45	114 (in Q1 & Q2)	More than doubled per year. 2023 value expected to be larger by the end of 2023.
6	Number of 1-1 meetings between start-ups and corporates at Cassini events	NA (increasing trend sought)	58	95 (in Q1 & Q2)	Almost doubled per year. 2023 value expected to be larger by the end of 2023.
7	Number of Companies successfully accessing VC	Done in takeaways chapter for all Cassini initiatives (cannot be separated)			NA
8	Size of VC gathered	Done in takeaways chapter for all Cassini initiatives (cannot be separated)			NA

The table above shows a positive trend in the matchmaking initiative achieving its objectives or improving its performance and effectiveness over time. It demonstrates that it has successfully and increasingly brought together the space companies' ecosystem with the VC and private financing ecosystem and enabled space start-ups and SMEs to network and promote their business ideas. Additionally, this table shows that Matchmaking has successfully increased awareness of VC in space businesses as more and more VCs are brought into the events.

Intervention 2: MyEUSpace Competition

One of the prizes and competitions organized by EUSPA is myEUSpace Competition that is funded by Galileo and Copernicus. This competition aims to enable start-ups and companies to further develop their innovative ideas, prototypes or products that utilize the EU Space Programme data, into viable commercial businesses. The prize pot is of a total of 1 M EUR (EUR 750 K coming from Galileo and EUR 250 K from Copernicus).

Two editions of this competition have been organized. The most important update in the competition is that the first edition that was awarded in 2022 consisted of two tracks, one for ideas and the other for prototypes. Applicants could apply for an innovative “idea” that they were then required to transfer into a prototype, or they could apply for an innovative prototype that they were required to transfer into final products. A total of 43 different teams were awarded prizes in this first round. The second round was awarded end of June 2023, and it was a slightly different regime than the one followed for the first edition. This competition consisted of 3 tracks, the first two were also Ideas and prototypes however the third was a prize for innovative products that could be scaled up and commercialized after. This change came about in order to increase the focus on later stage developments and near market developments, because this would enable EUSPA to offer continuation to the companies through other CASSINI tools such as accelerators, and VC funding. Therefore, EUSPA for the second round prioritized having more mature products even if it meant less prizes awarded. In the 2nd round a total of 30 teams were awarded prizes, 15 applicants were chosen for the most innovative ideas proposed, with 10 000 EUR awarded to each, 10 applicants were chosen for the best prototypes with 30 000 EUR awarded to each and 5 applicants were selected for the best product and will receive an award of 100 000 EUR each.

The results and the desired impacts of the myEUSpace competition are depicted in the table below, evaluated via KPIs:

Table 270: results and impacts of the myEUspace competition

#	Impacts	KPI s	Value for 2022	Value for 2023	Comments and outcome
1	Outreach and Increase awareness of space programmes and attracting companies to develop space based solutions	1.1 Increase in the number of applicants	233 applicants	245 applicants	Positive trend in attracting more actors and focusing more on higher maturity solutions
		1.1.1 Applicants for ideas	146	92	
		1.1.2 Applicants for prototypes	87	95	
		1.1.3 Applicants for products	NA	58	
		1.2 Diversification and maximization of (EU) Countries represented	24 EU countries + Norway + Switzerland	25 EU MS + Norway + Switzerland + Iceland	
2	Supporting and enabling the European industry (at all the stages of development and maturity) to build solutions utilizing EU SP	2.1 Number of teams receiving support and size of financial support given	43 teams (1 M EUR)	30 teams (1 M EUR)	
		2.1.1 Awarded ideas	23 (10 K each + additional 25 K to one final winner)	15 (10 K each)	Total funding level to industry sustained, more financial support is given per company (except for ideas) which enables more progress and results per company. This observed trend also meets EUSPA's objective of increasing focus on higher maturity products and near-market products
		2.1.2 Awarded prototypes	20 (15 K each + additional 50 K to one final winner)	10 (30 K each)	
		2.1.3 Awarded products	NA (0)	5 (100 K each)	All companies from 2022 awards have survived and are being tracked. However for 2023 its not possible to make these assumptions yet since they have just been awarded.
		2.2 User satisfaction	A survey was conducted post award with lots of useful qualitative appreciation and suggestions for improvements. Suggestions for example related to the application process were implemented in the following edition.		Positive engagement of stakeholders in feedback activity and active implementation of EUSPA to these activities
		2.3 Number of trainings and attendees on how to use and access Copernicus data	All the participants	All of the participants	In general around 20 requests per month are supported however it is done via the EUSPA core team, not utilizing this initiative budget
3	Enable the development of European based products and services that utilize data from the EU Space Programmes	3.1 Number of Prototypes supported into viable business opportunities	20 Prototypes supported into viable business opportunities	28 Prototypes supported into viable business opportunities	More advancements were achieved in 2023 in turning prototypes to final products, and final products to viable business opportunities.
		3.2 Number of final products and viable business propositions supported	5	15	This also materialized because the 2023 edition focused on more mature concepts and provided more funding to the users, therefore better results were achieved even though, in absolute number, less awards were given.
		3.3 Number of products or companies that was supported in scale – up	NA	NA	NA – it is too early to assess today this KPI, but it will be done in later years

While it is still too soon to see the direct results of this activity for each participating company, EUSPA is monitoring the activities of these entities to be able to evaluate the impacts of the competition in due time. However, it can already be deduced from the table that via this competition EUSPA is promoting and increasing awareness about the opportunities for utilization and uptake of space data for multiple business solutions and has positively and increasingly helped start-ups and SMEs to further develop and build on their innovative ideas and proposed solutions bringing more space-based businesses and solutions closer to market each year.

From the end-user's perspective (based on a survey done in 2022 for the first-round participants), the end users expressed satisfaction with the competition organization, implementation and value for time invested (rating of above 4.4/5 for all 3). Useful feedback was shared to enable improvement. For example 64% of participants found that the allocated time was too short whereas the rest found that it was just enough. However, 82% found that the cash prize was indeed or maybe enough and the remaining participants did not

Intervention 3: CASSINI Space Academy

Originally a capacity building program, the Space Academy is today officially a CASSINI program whose first edition was implemented in 2022. Preparations of the Academy started in 02/2022 after the contract signature, lectures were released in 06/2022 and the follow up activities launched in 08/2022. The second edition is currently under preparation to be launched in October 2023.

For the Space Academy, EUSPA has created a set of online tools to support start-up trainings which can be categorized under two main streams: either technical training or business training. Under the technical trainings, EUSPA helps the companies understand the basics of the Space Programmes and technologies or capacities behind them so that these companies learn how to better integrate space data from the Space Programmes in their services and products. For example, some companies already use EO data and want to integrate Galileo signal but do not know how and therefore the basics of this information is provided to these companies via the Academy. The business training on the other hand explains to start-ups how to approach investors, how to prepare their pitches and business models, how to pivot when necessary and all other aspects of running a business (hiring, retention etc.). Several hundreds of participants have attended the Space Academy so far and obtained certificates. The Space Academy provides 4 types of training options, starting from (1) Lectures, which constitute prerecorded tutorials on 18 different topics that users can choose from. The other options are follow-up activities including (2) mentoring where participants can choose up to 4 highly customizable sessions of individual mentoring with experts, (3) workshops on specific thematic with networking opportunities and (4) office hours.

The following table summarizes the main KPIs reporting on the results and outcomes of the implementation of the Space Academy by EUSPA for the 1st edition of the EUSPA Space Academy

Table 271: Results and impacts of the CASSINI Space Academy

#	KPI	Value for first edition (2022)
1	Number of Participants	678
2	Number of Start-ups registered	450+
3	Number of learning modules provided	18
4	Average views per module	120
5	Number of mentoring sessions provided	100+ sessions, 330 Hours
6	Number of expert lecturers, trainers and mentors	50+
7	Office hour and workshop sessions provided	32+

8	Social media outreach	419K
9	Satisfaction rate	86% would recommend the program

2 end-user surveys were performed to gather the end-user perspective, however the low response rate makes it complicated to draw representative conclusions (less than 4.6%).

From those that did respond to the survey, 40% gave a rating of 8/10 on how helpful the programme was in their entrepreneurial journey and 30% gave a rating of 6/10. The remaining 30% gave ratings less than 5/10. The majority agreed that the lectures and the mentoring activity were the ones bringing the most benefits to them. While overall it seems that there remains room for improvement (as is always the case), a good level of satisfaction has been reached with 86% of the respondents that would recommend the programme and with positive feedback shared through final statements. However, for a more representative sample, more end users should be encouraged to respond to the survey.

The KPIs for the Academy cannot be evaluated against specific target values, nor can a growth trend be evaluated yet since only one edition has been implemented. However what can be seen already in the table above is a large number of activities being developed under the Academy (modules, sessions etc.) and a significant participation in the trainings available. Additionally an 86% user satisfaction is a positive indicator of the effectiveness of the initiative. More insights can be extracted on the performance of the Space Academy following the second edition. Follow up editions are expected to continue to be organized as long as positive and desired impacts are witnessed through these tools, therefore the planning of the second addition can be seen as an indication of reaching expected outcomes.

2 Takeaways on the effectiveness of the CASSINI

As demonstrated via the KPIs above, EUSPA's support to the entrusted downstream activities of the Space Programme and its support to the industry via CASSINI and its capacity building activities have already achieved and are expected to continue to achieve significant impacts on the EU Space industry and ecosystem particularly on

- Improving awareness and know-how of the European industry on the use and utilization of EU Space Programme data and services across different market verticals and sectors
- The promotion and support of start-ups or companies across the downstream segment of the space value chain. I.e. in developing solutions and services utilizing Copernicus and Galileo data in different domains and sectors
- Enhancing the Venture Capital ecosystem in the EU and particularly stimulating private investment in the space sector and facilitating access to finance for the EU Space companies and start-ups.

EUSPA has been working on implementing the activities and tools entrusted to it and on continuously improving and updating them per lessons learnt and user needs in order to achieve the objectives and the benefits that the Union has set for them.

While only one or two editions have been organized for the tools under scope of the assessment, follow-up editions are being planned, indicating that these initial editions have resulted in positive/desired outcomes leading to planned continuity in these.

Furthermore, EUSPA has taken the initiative whenever necessary to implement support activities as a facilitator or catalyst for these activities. Five years ago, the EU did not have any VC funds dedicated to investing in space companies or space solutions. Through the CASSINI actions and capacity building workshops, a broader network of investors, entrepreneurs, corporations and public institutions has been created. This is expected to lead to higher private investment. The Commission, EUSPA, ESA and EIF organised 6 capacity building workshops in 2022, thereby creating a network of approximately 30 active investors interested and involved in the space sector.

EUSPA also appoints a point of contact for each company or start-up to guide and support them when the company needs help, and to keep track and monitor their progress and activities (their funding activities, development of solutions, scaleups, commercialization etc.). These start-ups can get EUSPA support at any point in time when they need it, and EUSPA has tools (such as newsletters) to share with these start-ups all information available about the different ways they can receive help, the different tools available for them, the dates for applications etc.

EUSPA receives in general around 20 requests for support per month from companies interested in developing space-based solutions and it supports them via ad-hoc trainings, mentoring and capacity building activities .

Overall and as a result of the different tools offered by Cassini, between 2022 and 2023 around 36 space start-ups and SMEs that participated to Cassini activities via one tool or another have successfully accessed and received external funding already. The total funding size received in these two years by these 36 companies amounts to 302 M EUR¹⁸¹.

3.6. Growth Indicators

In addition to the KPIs identified and evaluated at EU Space Programme Component level to assess the performance of the implementation of the component, the performance of its services and the benefits it generates, an additional list of KPIs was evaluated that is not specific to one particular component but to the EU Space Programme as a whole. These KPIs evaluate the overall growth and health of the EU space industry thanks to the collective of the EU Space Programme components.

Table 272: Growth KPIs as extracted from the RFP

#	Group	Indicator:
1	Hubs and SMEs	a) Number and Location of space hubs in the Union
		b) Share of SMEs established in the Union as a proportion of the total value of contracts relating to the Programme
2	Upstream Activities	Development of the Union space upstream sector measured, when available, by a) Number of jobs created by Member State b) Turnover by Member State and c) The global market share of European space industry Using Eurostat when available
3	Downstream activities	Development of the downstream sector measured, when available, by the a) Number of new companies using Union space data, information and services, b) Jobs created and c) Turnover, by Member State, using Eurostat when available Using Eurostat when available.

Group 1: Hubs and SMEs

A – Number and location of Space Hubs in the Union

In 2019, PwC performed a study for the European Commission: Mapping, analysis and characterization of “Space Hubs” in the EU. The assessment of this KPI is based on the

¹⁸¹ EUSPA analysis of Dealroom.co data based on 2022 and 2023 funding rounds

findings and results of that study and updated it slightly with a few more Hubs identified on the European Cluster Collaboration Platform.

In that study, PwC identified a list of active hubs with space activities in MS 27 + 1 which covered the European Union (EU) Member States and the United Kingdom, but not collaborating countries and non-EU Member States despite their being listed in the European Cluster Collaboration Platform (e.g. Turkey, Switzerland and Norway).

The list of identified hubs is presented in the table below

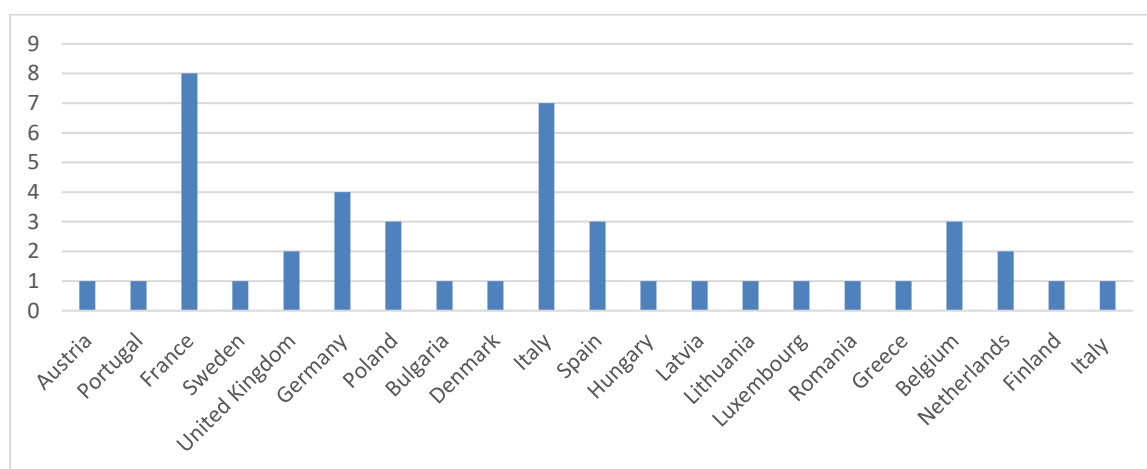
Table 273: List of identified hubs (Source: PwC, 2019. Mapping, analysis and characterization of “Space Hubs” in the EU)

1	Hub Name	Region	Nation
#01	ACstyria Mobilitätscluster GmbH	Steiermark	Austria
#02	AED Portugal	Portugal	Portugal
#03	Aériades	Grand Est	France
#04	Aerospace Cluster Rhône-Alpes Auvergne	Rhône-Alpes	France
#05	Aerospace Cluster Sweden (ACS)	Östergötland	Sweden
#06	Aerospace Valley	Midi-Pyrénées	France
#07	Aerospace Wales Forum	Wales	United Kingdom
#08	ALPHA-RLH Route des Lasers et des Hyperfréquences	Aquitaine	France
#09	ASTech Paris Region	Île-de-France	France
#10	AVIASPACE BREMEN e.V.	Bremen	Germany
#11	Aviation Valley	Podkarpackie	Poland
#12	bavAIRia e.V.	Bavaria	Germany
#13	CASTRA	Yugozapaden	Bulgaria
#14	CenSec	Midtjylland	Denmark
#15	Distretto Aerospaziale della Campania	Campania	Italy
#16	Distretto Tecnologico Aerospaziale	Puglia	Italy
#17	Harwell Space Cluster	Oxfordshire	United Kingdom
#18	HEGAN Basque Aerospace Cluster	Pais Vasco	Spain
#19	HÉLICE Andalusian Aerospace Cluster	Andalucía	Spain
#20	HunSpace	Northern Hungary	Hungary
#21	Latvian Space Technologies Cluster	Latvia	Latvia
#22	Lazio Connect	Lazio	Italy
#23	Lithuanian Space Association (LSA)	Lithuania	Lithuania
#24	Lombardia Aerospace	Lombardia	Italy
#25	LRT - Kompetenzzentrum Luft- und Raumfahrttechnik Sachsen/Thüringen e.V.	Saxony and Thuringia	Germany
#26	Luft- und Raumfahrt Baden-Württemberg	Baden-Württemberg	Germany
#27	Luxembourg Space Cluster (LuxInnovation)	Luxembourg	Luxembourg
#28	Madrid Aerospace Cluster	Madrid	Spain
#29	NAE - Normandie AeroEspace	Haute-Normandie	France
#30	Polish Space Industry Association	Warszawa	Poland
#31	Romanian Cluster for Earth Observation	Ilfov	Romania
#32	SAFE Cluster	Provence-Alpes-Côte d'Azur	France
#33	si-Cluster	Attica	Greece
#34	Skywin	Brabant Wallon	Belgium

#35	Space Business Incubation Centre	South Holland	Netherlands
#36	TeRN	Basilicata	Italy
#37	Torino Piemonte Aerospace	Piemonte	Italy
#38	Umbria Aerospace Companies	Umbria	Italy
#40	IBN SPACE 4.0 (flemish space industry)	Flemish region	Belgium
#41	Bretagne Aerospace	Brittany	France
#42	Baltic Sea and Space Cluster	Pomorski	Poland
#43	AFDA - Association of Finnish Defence and Aerospace Industries	Helsinki -Uusimaa	Finland
#44	SpaceNed	South Holland	Netherlands
#45	DISTRETOT AEROSPATIALE PIEMONTE	PIEDMONT	Italy

The distribution of these 45 identified hubs per country is then presented in the table below

Table 274: Distribution of Space Hubs in the Union per country



It can be noticed that Space Hubs tend to be more present in the EU countries with historical space activities and larger industries namely France, Italy and Germany that host a high number of Hubs in comparison to other Member States. Taking the assumptions that space activities are also being conducted in these hubs, the increasing investments in the space sector has led several Member States to expand their space capacities which is translated by an increasing creation of dedicated hubs. To that effect, Member States who have only had national space agencies for a couple of years or that have newly decided to improve their activity and involvement in the space sector have also actively engaged in the creation of hubs (e.g. Luxembourg)

B - Share of SMEs established in the Union as a proportion of the total value of contracts relating to the Programme

In September 2022 ESA announced that over the last 5 years, i.e. 2018 – 2022, it worked with over 1380 SMEs on ESA programmes, representing more than 27% of companies contracted. ESA also declared that SMEs were involved in around 33% of all contracts placed and received 10M of the corresponding commitments.¹⁸² This figure went up from the 1069 SMEs that worked in total with ESA in the 2015 – 2019 period per the SME4ESA report. According

¹⁸²https://www.esa.int/About_Us/Business_with_ESA/Small_and_Medium_Sized_Enterprises/ESA_business_boosts_small_space_companies

to that report The SME figure increased from 2014 to 2019 at a rate of 17.3 % and these SMEs had a collective turnover of 2 B EUR per year in 2018.¹⁸³

Taking the ESA and EU space projects into account though, ESA declares that in 2020 around 1800 SMEs were accounted for working on these 2 programmes and together they had a 3.9 B EUR annual turnover and employed around 33 000 Employees.¹⁸⁴ Around 400 – 500 SMEs are reported to be active in the European Upstream segment of the Space Sector employing around 6000 people.¹⁸⁵

It should be noted however that SMEs working with ESA can be from all the ESA Member states and not the European Union Member States despite the very large intersection.

The total value of contract relating to the programme over 2014 – 2022 is around 14.2 B EUR (data provided by the EC). **Therefore, its estimated that since 2014 each 1 B euro of Programme contracts would support 126 SMEs.** Alternatively presented it can be seen that 7884 EUR would support 1 SME

Group 2: Upstream Activities

A - Number of jobs created in the upstream segment by Member State (when available)¹⁸⁶

Information to assess this indicator were extracted mostly from the following report: Structure of the European Space Manufacturing Sector by ASD EUROSPACE (2021).

The European Space Industrial Supply chain employs around 52822 persons with more than 1000 companies active in this segment. This segment takes into account employment in the design, development and manufacturing of space systems i.e. spacecraft, launch systems, ground infrastructure and facilities for testing assembly and operations. (This does not account for downstream sector).

This employment, and the European space industrial supply chain activities can be credited to 6 types of companies:

The big 4 Aerospace and Defense companies: this constitutes 4 main conglomerates that employ around 60% of this total for their space activities. These conglomerates are Airbus, Thales, Leonardo and Safran (however it should be noted that their space business represents no more than 10% of their global business). Together with their subsidiaries they are responsible for the employment of 28500 persons in Europe.

Other Large aerospace groups: large groups, but smaller than the big four such as Kongsberg, RUAG etc. contribute to around 5 – 6% of that total employment with around 2500 – 3000 employees;

Smaller space business units incorporated in large non-aerospace groups (such as AirLiquide, CGI etc.). such units only employ around 100 people in their space businesses and together they account for around 6% of the total employment (workforce around 3000);

Midcaps such as OHB, Avio, GMV etc. employ around 8000 persons in space activities;

¹⁸³ https://www.sme4space.org/Leaflet_Study_on_European_Space_SMEs.pdf

¹⁸⁴ https://www.esa.int/About_Us/Business_with_ESA/Small_and_Medium_Sized_Enterprises/ESA_business_costs_small_space_companies

¹⁸⁵ <https://euospace.org/wp-content/uploads/2021/01/structure-of-the-space-manufacturing-sector-v2021.pdf>

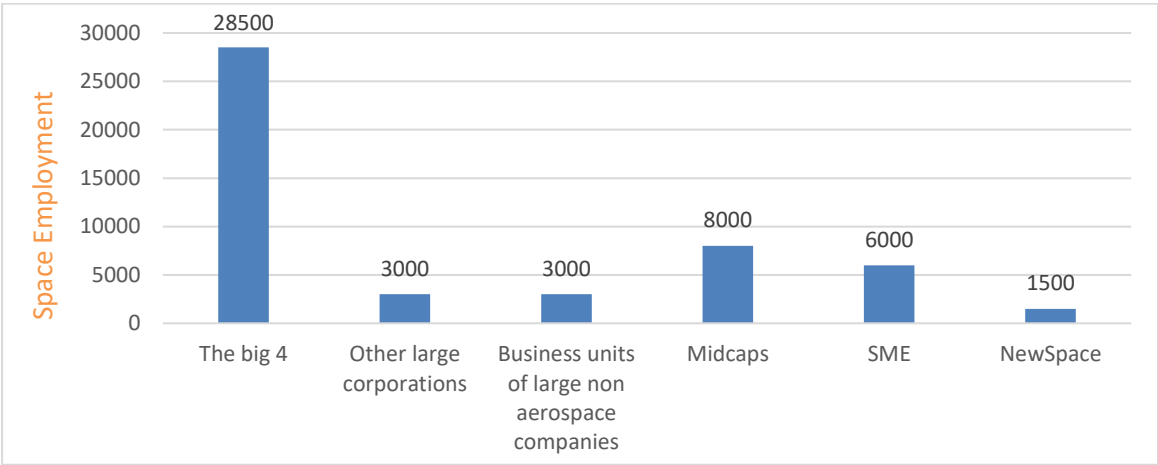
¹⁸⁶ ASD EUROSPACE, 2021. Structure of the European Space Manufacturing Sector

Supply chain SMEs: constitutes between 400 and 500 SMEs active in the European Space Supply chain activities even if partially. An average of around 10 people are considered space workforce in these types of SMEs that are not usually Space specific or centered, but have some space activities. Overall, they are estimated to be responsible for a workforce of 4000 to 6000 of the total.

NewSpace Companies: 10s of these companies have been emerging in Europe thanks to the new space trends (micro launches and smallsat constellations etc). represents around 1500 employees from the total.

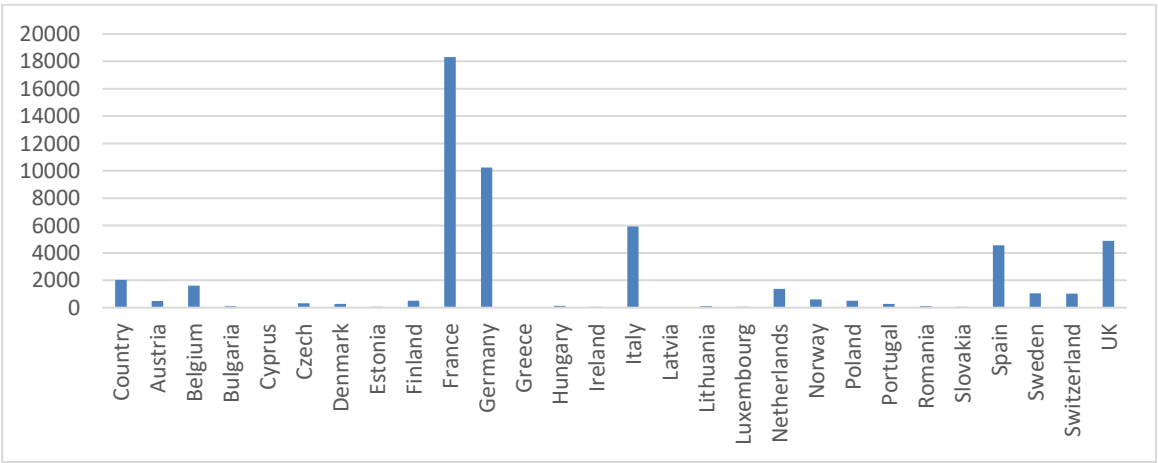
The distribution of employment in the Upstream segment of European Space activities per company type is presented in the graph below:

Table 275: Distribution of European space employment in the Upstream segment (source: PwC analysis and ASD EUROSPACE, 2021. Structure of the European Space Manufacturing Sector)



The distribution of the employment in the Upstream Space segment in the year 2021 across 27 countries in Europe (24 EU MS in addition to 3 non-EU MS, but MS of ESA in the European continent) is extracted from the Facts and Figures report, 6th Edition, July 2022 and is presented in the following graph

Table 276: Distribution of Employment in the Upstream Space Segment in Europe in 2021 (Source: Facts and Figures 2022, Eurospace)¹⁸⁷



¹⁸⁷ <https://eurospace.org/wp-content/uploads/2023/07/facts-figures-report-2022-web-release.pdf>

The 6 major ESA member states France, Germany, Italy UK, Spain and Belgium account for 90% of this space employment.

B - Turnover by Member State (when available)

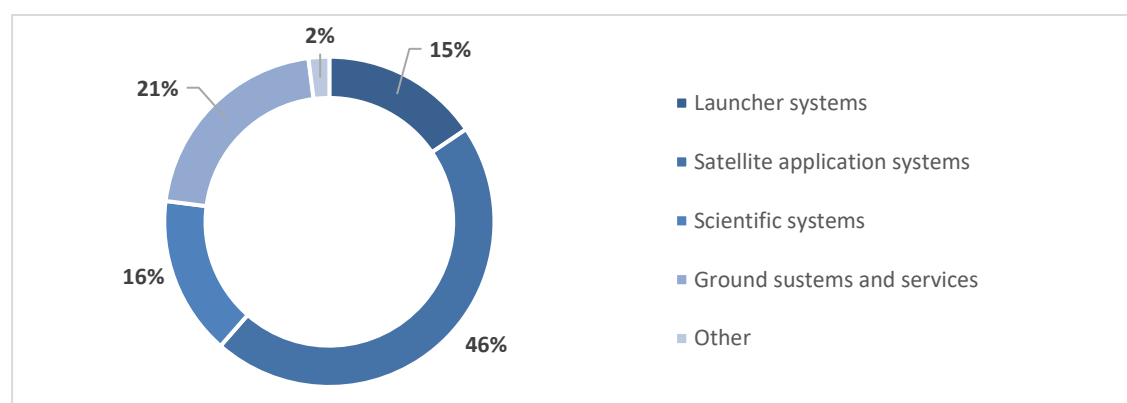
According to the European Commission (from the Space Market report developed by the Policy Department for Economic, Scientific and Quality of Life Policies Directorate-General for Internal Policies in 2021), the Upstream segment of the European Space sector generates around 8.8 B EUR.¹⁸⁸

According to the Eurospace Facts and figures report of 2022, the European upstream segment of the Space industry reported 8.6 B EUR in sales (employing 52822 workers directly with additional 2422 workers of other supporting personnel on site.

5.5 B EUR of these sales are attributed to European public customers which include, among others, the EC, ESA and EUSPA. 1.3 B EUR are attributed to private European customers, 1.5 B EUR is rest of world (public and private customers) and the remaining value is not known. European customers (ESA and EU countries) account for 81% of total sales.

The largest portion of these sales is attributed to the satellite manufacturing activities as demonstrated in the graph below, as the European industry in 2021 reported the successful delivery of 89 spacecrafts (and 7 launchers).

Table 277: Distribution of European 2021 upstream space sector sales by final product segment (Soucre: PwC analysis and Facts and Figures 2022, Eurospace)



Not enough information was found to be able to distribute the turnover of the upstream segment of the European Space Sector by Member state, however it was clearly stated in the Eurospace report that their survey demonstrated that the industry is distributed across all Europe, with the main industrial sites located in France, Germany, Italy, and, to a lesser extent, United Kingdom, Spain and Belgium.

C- The global market share of European space industry (when available)

According to the European Commission (from the Space Market report developed by the Policy Department for Economic, Scientific and Quality of Life Policies Directorate-General for Internal Policies in 2021), the European Space industry is considered the 2nd largest in the world, employing a total of 231000 persons and around 53 – 62 B EUR.¹⁸⁹

A third of the world's satellites is estimated to be manufactured on the European continent where Europe continues to be a strong industrial player, with around EUR 9.5 billion of

¹⁸⁸ [https://www.europarl.europa.eu/RegData/etudes/STUD/2021/695483/IPOL_STU\(2021\)695483_EN.pdf](https://www.europarl.europa.eu/RegData/etudes/STUD/2021/695483/IPOL_STU(2021)695483_EN.pdf)

¹⁸⁹ [https://www.europarl.europa.eu/RegData/etudes/STUD/2021/695483/IPOL_STU\(2021\)695483_EN.pdf](https://www.europarl.europa.eu/RegData/etudes/STUD/2021/695483/IPOL_STU(2021)695483_EN.pdf)

satellite exports registered over the last ten years or so and a flourishing global commercial satellite market. It has been estimated that 10% of the EU's GDP relies on the use of space services. Additionally, the European launcher industry, which has accounted for 15% of global launch capacity over the last decade, has generated over EUR 10.6 billion, however this is expected to be changing currently due to the launch crisis in Europe instigated by the Russian – Ukrainian war.¹⁹⁰

The global market for upstream space activities is estimated at 51 B USD by Euroconsult in 2022, which amounts to 46.7 B EUR.¹⁹¹ **This means that the European market share of Upstream space activities (8.6 B EUR) is 18.4%.**

The global Space Economy as calculated by Euroconsult amounts to 464 B USD i.e. around 424 B EUR. Which means that the **EU Space market would constitute around 14.6% of the global space market (considering a 62 B EUR market in Europe).** The team utilizes the 62 B EUR figure found in the Space Market report developed by the Policy Department for Economic, Scientific and Quality of Life Policies Directorate-General for Internal Policies in 2021, instead of the 94 B EUR figure developed by Euroconsult, because it is expected that the Euroconsult figure covers many more countries than just the EU 27 as it is labelled as for Europe.

Group 3: Downstream Activities

Number of new companies using Union space data, information and services (when available)

According to stakeholder consultations, EUSPA tracks 400 - 500 new start-ups and SMES utilizing Galileo and Copernicus data for their business (EUSPA consultation) however no information was found to enable the team to provide the actual number of these companies.

Particularly for the case of the Copernicus Component: EUMETSAT's report on Copernicus data user uptake (2021) reported that there are **6480 active users of Copernicus data and services worldwide** (including institutions and individuals). 3804 of these users come from the continent of Europe (3241 of which from the EU), the next region in number of users is Asia (1314) followed by Africa (465), North America (445), South America (301) and Oceania (78).¹⁹²

Number of Jobs created by Member State (when available)

Total employment in the European Space Sector is estimated at 231 000 (See above), and the employment in the Upstream segment is estimated at 52822, **this leaves around 178178 persons employed in the downstream segment.**

Not enough data could be found to assess the distribution of employment by Member state for the Space Downstream segment in Europe, however it was possible to do so for the EO domain only.

For EO downstream activities: According to an EARSC survey, the total number of employees in the downstream sector of EO in Europe (covering 32 countries in Europe that are all ESA or EU member states) was 11600 in 2020. France has the largest number of employees: 1794, followed by Germany (1434) and then the UK (1049). Spain comes very

¹⁹⁰ [https://www.europarl.europa.eu/RegData/etudes/STUD/2021/695483/IPOL_STU\(2021\)695483_EN.pdf](https://www.europarl.europa.eu/RegData/etudes/STUD/2021/695483/IPOL_STU(2021)695483_EN.pdf)

¹⁹¹ <https://www.euroconsult-ec.com/press-release/value-of-space-economy-reaches-424-billion-in-2022-despite-new-unforeseen-investment-concerns-2/>

¹⁹² <https://www.eumetsat.int/media/50138>

close after UK (1000+), followed by Italy (1000-). Sweden and Netherlands follow with around 500 and the rest of the countries have under 500.

Turnover, by Member State, using Eurostat when available

Based on the data previously extracted, the European Space market was estimated at 53 – 62 B EUR, and the Upstream segment of the industry was estimated at 8.6 B EUR. **It can be deduced that the downstream market segment of the European Industry is around 44 – 53 B EUR.**

This figure is then validated with the EUSPA market report values. EUSPA market report provides estimates for the EU27 downstream market size for EO and GNSS activities that are valued 49.7 B EUR from a supply perspective, which is in the range provided above. However not enough information was found to enable the split of the turnover per Member State

Market Share¹⁹³

EUSPA in its annual market report calculates the market size for EO and GNSS globally. PwC utilizes these values to calculate Europe's market share for the downstream space activities. The figures from EUSPA's report are based on the commercial EO market only, and the quantification of market can capture only commercial transaction and not grants-funded activities.

The market is segmented into two types of products: EO data and EO VAS. There are two ways that the European market share was calculated, either by calculating the revenue generated from European demand (for EO data and EO VAS), which is presented in the table below, or by calculating the revenue generated by European supply for providing for EO data and EO VAS (EU companies).

Table 278: Downstream EO market share based on EO demand

2021			2031	
	Market value	Market share	Market value	Market share
EO demand market size				
EU 27				
EO Data	82 M EUR	15.4%	117 M EUR	14.6%
EO VAS	342 M EUR	15.3%	664 M EUR	14.2%
Total EO downstream	424 M EUR	15.3%	781 M EUR	14.3%
Global				
EO Data	536 M EUR	100%	797 M EUR	100%
EO VAS	2236 M EUR	100%	4662 M EUR	100%
Total EO downstream	2772 M EUR	100%	5459 M EUR	100%
EO services supplied by EU				
EU 27 market size: in 2019 Europe accounted for 42% of the global Data Acquisition and Distribution market and 34% of the global Data Processing market.				
= 42% (536) + 34% (2236) = 225.12 +760.24= 985. 36 M EUR				

From EO demand perspective, the European Union market for downstream EO activities is 15.3% of the global market in 2021 expected to be 14.3% in 2031;

¹⁹³ https://www.euspa.europa.eu/sites/default/files/uploads/euspa_market_report_2022.pdf

However, from a supply perspective, in 2019 Europe accounted for 42% of the global Data Acquisition and Distribution market and 34% of the global Data Processing market

Table 279: Downstream GNSS market share

2021			2031	
	Market value	Market share	Market value	Market share
GNSS Demand market size				
EU 27				
Devices Revenues	12.1 B EUR	25%	21.6 B EUR	24.8%
Services Revenues	27.4 B EUR	18.2%	53.7 B EUR	13.3%
Total GNSS downstream	39.5 B EUR	19.8%	75.3 B EUR	15.2 %
Global				
EO Data	48.4 B EUR	100%	87 B EUR	100%
EO VAS	150.5 B EUR	100%	405.2 B EUR	100%
Total EO downstream	198.9 B EUR	100%	492.2 B EUR	100%
GNSS services supplied by EU				
EU 27 market size: while Europe is a close second (25%). Of global market share .				
= 25% x 198,9 M BUR = 49.7 B EUR				

4. EVALUATION OF THE PERFORMANCE OF THE EUSPA TASKS

The EU Space Programme Regulation was adopted in April 2021 and encompasses all EU space activities in a single legal act. In particular, the Art. 102 foresees the evaluation of the implementation of the EU Space Programme's components and actions and the performance of EUSPA by 30 June 2024. EUSPA has indeed been entrusted with tasks related to four components of the EU Space Programme: Galileo, EGNOS, GOVSATCOM and SSA, as well as downstream-related tasks. These entrusted tasks have been defined and agreed in the Commission-EUSPA Contribution Agreement and EUSPA-ESA Contribution Agreement signed in June 2021. EUSPA also has its own core tasks funded by its own budget that are also under scope of this assessment.

The study scope required a dedicated assessment of the performance of the implementation of the EUSPA tasks (the core and the entrusted ones) in addition to a high level assessment of the EUSPA Policy on Conflict of interest.

However, it must be noted that a large part of the EUSPA entrusted tasks are already covered in the relevant Space Programme component (this is described in later on).

4.1. EUSPA Core Tasks

4.1.1. Introduction to the core tasks

The evaluation of the entrusted tasks of EUSPA is developed through the whole report. In particular, the tasks relative to different components of the EU Space Programme are under the sections relative to each component. In this section, all the core tasks not evaluated before are addressed: Security accreditation; operational security for EGNSS; Operation of the Galileo Security Monitoring Centre; Public Regulated Service; Communication, promotion and market development; Agency Management.

Core task 1: Security accreditation

The Security Accreditation Board ('SAB'), an independent body within EUSPA, is in charge of security accreditation activities and acts as the security accreditation authority for all the components of the Space Programme – Copernicus, Galileo, EGNOS, SSA, GOVSATCOM.

The security accreditation activities include:

- **SAB secretariat** which encompasses but is not limited to the facilitation of the SAB and its subordinate bodies' meetings;
- **Support to SAB management** which includes management and drafting of the work programme and budget;
- **Management of special subordinate bodies** by providing for example professional expertise for special subordinate bodies such as the Security Accreditation Panel.
- **System, service and operation level activities** including for example service and operation accreditation aspects;
- **Independent security assessments and audits**, coordinated by the staff allocated to the SAB to verify the security posture of the system and in particular the status of cyber measure implementation;
- **Ground station level activities** including security audits and assessment of sites against security requirements coordinated by the staff allocated to the SAB;
- **Authorisations of bodies to develop or manufacture sensitive technology**, for example by developing and manufacturing PRS security modules in the case of Galileo.

These activities enable the SAB to make informed decisions, most notably on :

- The approval of satellite launches;
- The authorisation to operate the systems set up under the components of the Programme or the elements of these components in their different configurations and for the various services they provide, up to and including the signal in space ;
- The authorisation to operate the ground stations ; and
- As regards the networks and the equipment connected to the PRS service or to any other secure service stemming from the components of the Programme, the authorisation of bodies to develop and manufacture sensitive PRS technologies, PRS receivers or PRS security modules or any other technology or equipment which has to be checked under the general security requirements referred to in Article 34(1), taking into account the advice provided by national entities competent in security matters and overall security risks.

Core task 2: Operational security for EGNSS

The responsibilities outlined in core task 2 of EUSPA and the entrusted tasks complement each other, with the core tasks to be undertaken in a particular year approved by the Administrative Board through the Single Programming Document. To reflect the interactions of these core tasks with the management of activities in the EGNSS instead entrusted to EUSPA, these entrusted activities themselves are covered in the entrusted tasks sections above.

This task deals with ensuring the security of both components of the EGNSS component of the Union Space Programme. There are two parts to each component (for Galileo and for EGNOS). First, there is the threat and risk analysis, and second there is the operational security.

For the threat and risk analysis, subtasks include:

- Maintaining the service and system security plan registering for the different system and service milestones
 - Risk and threat analysis
 - Identified security risk
 - Identified treatment plans and status of implementation
 - Statement of compliance to the Galileo high level security requirements
- Maintain the component Security Accreditation Milestones and Schedule
- Assessment of security risks associated with the Galileo system, its operations and services delivery
- Report the status of the security risks and the required mitigations to the relevant Management Boards and bodies proposing risk management actions
- Prepare, deliver and report on the accreditation files to the Security Accreditation Board (SAB) and its subordinate bodies to obtain the required authorisations and maintain the security accreditation certificates

For the operational security, subtasks include:

- Monitor the status of implementation of the applicable high-level security requirements, ensuring the compliance status of:
 - Infrastructure in operations and under development (including ESA contribution and other infrastructures to be connected to the operational system, e.g. GNSS Service Centre)
 - Hosting/Site security conditions for the system in operations and future sites
 - Compliance to security operational requirements from the different operational entities (e.g. GSOP, GSMC, SGDSN...)
- Monitor and track the implementation of the identified treatment plans for the system in operations
- Ensure security oversight of Galileo operators
- Ensure implementation and follow up of the EGNOS SMP at programme and Service Provision contracts level
- Ensure security oversight of the GEO and EGNOS Service Providers contract activities in the field of security
- Ensure management of security incidents raised by the Services Providers for the part concerning the Agency (impacts on the programme)

Core task 3: Operation of the Galileo Security Monitoring Centre

This task deals with ensuring the continuity of GSMC operations in line with the SLA of the PRS IOC. This includes ensuring the full operation of the two GSMC sites (FR and ES).

The first subtask is to **ensure that Galileo services and operations are secure**. There are three main parts to this objective:

- The first part deals with monitoring the health and security of the system, and with detecting and containing any incidents. This generally refers to monitoring the network (global network of antennas and control sites to ensure the programme is operational), in coordination with the Galileo Control Centres (GCC) in Italy and Germany.

- The second part deals with ensuring that all authorised users and only authorised users can access the PRS. This activity also includes ensuring that the new GSMC systems are properly validated and ready, and that the service offered is aligned with the SDD.
- The third part is to support the Council and the high representatives of the Union in case there is a threat against the Union Space Programme and then to decide on the appropriate response against the threat.

The second subtask is **ensuring engineering activities in support of deployments and operations**. This is comprised of four main parts

- The first refers to the engineering tasks related to GSMC operations. The Engineering processes is monitored and centralized by EUSPA through Engineering department.
- The second refers to the contribution of GSMC for evolution of system on requirement and service itself. To ensure that all evolutions of the system, deployment and validation is consistent with expectations – in collaboration with all departments at the GSMC site, both for system and service. They need to train and certify all operators.
- The third refers to how the GSMC operates the system, the processes needed, etc. Configuration is done by another department to ensure that they system has the right configuration to run as planned. It is a highly critical task as it requires multiple audits and reviews to make sure its 100% consistent.
- The fourth relates to site and system security accreditation and is done by both GSMC and member states and deals with aligning with accreditation in terms of the site and system. Final accreditation is done by SAB.

The third subtask is to **ensure availability of hosting services**. This subtask was no longer present in 2023, since after the reorganisation it was shifted to the ITF department. The task is still completed and refers to ensuring that they two sites are configured for the system deployed. It is done with the host member states ministry of defense at the host site. It involves facility management contracts to make sure the building is being improved. There are renovation activities that are important since each country has a different paradigm. Final configuration, after the building has been built, finalized and used.

The fourth subtask is to **ensure continuity of service of GSMC operations, continuous improvement, quality and efficiency** and is comprised of several activities summarised below:

- Management of the organisation and communication which is related to internal evolution of the GSMC within the space programme and the agency.
- Integrated Management System and Product Assurance which is linked to certification and recertification. And to support activities related to change management, change control, nonconformance review, etc. There is a dedicated multi-department team for these activities.
- Risk and business continuity and disaster management which relates to updating the risk plan when needed, such as when there is a system update or a change in the premises.
- Health and safety management which is supported by other departments. It is a task common to all sites of the agency. EUSPA and local policies are implemented under the delegation to Site Manager.
- Resolution and continuous improvement management which is a regular lessons learnt process with their product assurance quality assurance colleagues. After any important

event or activity, there is a lessons learnt session for next time. This task is also conducted for the delegated tasks as well.

The fifth subtask deals with local security but like with the third, this objective has been transferred, to Security Authority responsible for the GSMC Local security office. It is a general undertaking of security by the agency. The security authority is responsible for implementation of security rules now. The registry control management, which is registry of all documents going in and coming out is all up to date. They have processes to ensure physical security of the premises to ensure everyone is properly secure before entering the GSMC. COMSEC and crypto are done by security authority. INFOSEC is also done by security authority. GSMC is not following these on a daily basis but it reported regularly on tasks completion and compliance to operational objectives

Core task 4: Public regulated service

The responsibilities outlined in core task 4 of EUSPA and the entrusted tasks complement each other, with the core tasks to be undertaken in a particular year approved by the Administrative Board through the Single Programming Document. To reflect the interactions of these core tasks with the management of activities in the EGNSS instead entrusted to EUSPA, these entrusted activities themselves are covered in the entrusted tasks sections above.

The PRS activities deal with the implementation of tasks to ensure compliance with the PRS framework. This includes:

- Preparing and maintaining the PRS management plans (Access to PRS General Management Plan, PRS Management Plan (PMP) and the related PRS information management plan (PIMP) and PRS key management plan (KMP)) defining the organisational structure of the Agency's PRS Authority and the rules for implementing the management of PRS items, PRS technology and PRS information
- Reviewing the Article 14(c) arrangement (if required)
- Preparing Article 14 quarterly implementation reports and delivering them to the European Commission
- Carrying out regular inspections of the departments within the Agency dealing with PRS items and PRS classified information
- Supporting regular risk assessments
- Analysing those activities requiring the processing of PRS items and PRS information to ensure compliance with Article 14(c) arrangement
- Maintaining PRS items and PRS information database and drafting a report summarising movements, requests and security breaches associated with the PRS items/PRS information under the responsibility of the Agency

Core task 5: Communication, promotion and market development

This core task aims at stimulating demand for Union Space Programme components working on market uptake across user communities and engaging the entire value chain fostering the competitiveness of EU industries and SMEs.

It mainly encompasses the communication, promotion and market development activities of services offered by Galileo and EGNOS and data, information and services offered by Copernicus. For the latter, EUSPA cooperates closely with other Entrusted Entities (to ensure that there is no overlap with their activities). EUSPA ensures a close coordination of the communications efforts with the European Commission and execute a wide range of strategic communication campaigns related to the development of innovative EGNSS and Copernicus

solutions in order to ensure the needs of end-users and to become the main reference all over the world.

However, this task also covers activities related to all Programme components, such as:

- **In every vertical market segment:** Engagement of key actors in the value chain and users in priority markets to ensure continuous increase in adoption and use of the Union Space Programme components;
- **Transversal to the market segment:** Monitoring user satisfaction of the EU Space Programmes;
- **Communications in support of market development:** Event coordination, press activities etc.

Core task 6: Agency Management

This core task is an horizontal activity covering the Agency’s core and entrusted activities by providing support to operations in various areas : legal, procurement, grants, contracts, finance and budget, human resources management, IT and logistics, control and internal audit.

It includes objectives such as :

- The implementation of efficient management of all legal arrangements for the EUSPA, in line with the service delivery needs ;
- A successful compliance with personal data protection rules applicable to the EUSPA etc.

4.1.2. Evaluation of the effectiveness of EUSPA core tasks

The evaluation of the effectiveness of EUSPA core tasks has been done via desk research and several consultations. The objectives linked to each core task have been extracted from the EUSPA Programming Documents 2020-2022, 2021-2023, 2022-2024 ad 2023-2025 as well as the Annual Activity Report of 2021 and 2022.

For each objective, activities as well as a set of indicators and specific targets to be reached had been defined per year in the Programming Documents. Regarding the exact repartition of the extracted information:

- Activities, targets and indicators for 2021 have been extracted from the EUSPA Programming Document 2021-2023;
- Activities, targets and indicators for 2022 have been extracted from the EUSPA Programming Document 2022-2024;
- Activities, targets and indicators for 2023 have been extracted from the EUSPA Programming Document 2023-2025.
- Results and achievements for 2021 have been extracted from the 2021 AAR;
- Results and achievements for 2022 have been extracted from the 2022 AAR.

Each core task has been attributed a group of objectives, with a list of indicators defined to measure each objective. Due to the exhaustivity and longevity of the list of objectives and indicators, one example of a core task with its associated objectives, indicators and targets is demonstrated in the table below whereas the full list is available in the appendix.

Table 280 : Illustrative example of one EUSPA core task, its objectives, the indicators to measure them and their targets

Core task	Objective	Indicator	Target

Core task	Objective	Indicator	Target
Security accreditation	Support to SAB management	SAB relevant part of the multiannual WP provided to SAB for approval by established deadline	Yes
		SAB relevant part of the annual work programme provided to SAB for approval by established deadline	Yes
		SAB relevant part in the annual report provided to SAB for approval by established deadline	Yes
	Operate effective administration of the SAB so as to support timely decision making	Successful implementation of required administrative processes	100%
Etc.	Etc.	Etc.	Etc.

Once the objectives, indicators and targets have been listed per year, the effectiveness assessment consisted in determining if the targets had been reached, the objectives met and to what extent, and if not, the reasons.

4.1.2.1. Assessment of the implementation of the EUSPA core tasks

The evaluation of performance of the implementation of EUSPA's core tasks is divided per task. For the fluidity of the report, this chapter will assess the results at a higher level (objectives) but the full list of associated indicators and targets per objective is available in Appendix for more details. Please note that results for 2023 are not yet available at the time of writing of this report so this section will cover years 2021 and 2022. Moreover, for this section, the colour code is slightly different from the effectiveness assessment, green colour means that all targets have been met, light green means that most of the targets have been met and yellow means that the targets have not been met.

Core task 1: Security accreditation

The security accreditation task encompasses 7 objectives with associated indicators and targets per year.

Objective 1 – Operate effective administration of the SAB so as to support timely decision making

This objective covers 6 activities and is measured by one indicator, the successful implementation of required administrative processes, which is the same for the years 2021, 2022 and 2023. For years 2021 and 2022, the target of the indicator (100% of successful implementation) has been met.

Objective 1 Qualification	All targets have been reached in 2021
	All targets have been reached in 2022

Objective 2 – Support to SAB management

The support to SAB management encompasses 3 activities related to the Single Programming Document ('SPD'). Even though the indicators differ from year to year, the objective is mainly linked to the fact of providing the SPD on time to SAB for approval. This objective has been achieved in both year 2021 and 2022.

Objective 2 Qualification	All targets have been reached in 2021
	All targets have been reached in 2022

Objective 3 – Provide all authorisation statements needed by the Programme and approved by SAB

This objective is composed of several activities (5 to 7 activities, depending on the years) mainly linked to the provision of authorisations statements. Those activities are measured by one indicator in 2021 and 2 indicators in 2022 and 2023. As mentioned, the results for 2023 are not yet available but the targets have been met in both 2021 and 2022.

Objective 3 Qualification	All targets have been reached in 2021
	All targets have been reached in 2022

Objective 4 – Ensure management of the special subordinate bodies and their expert groups including the chairmanship

This objective is linked to the smooth running of meetings and is defined by a set of indicators linked to it. All the targets have been met for the years 2021 and 2022.

Objective 4 Qualification	All targets have been reached in 2021
	All targets have been reached in 2022

Objective 5 – Ensure independent assessment of system level security

2 indicators are linked to this objective related to the security of the system and the objectives set for them were achieved both in 2021 and 2022.

Objective 5 Qualification	All targets have been reached in 2021
	All targets have been reached in 2022

Objective 6 – Assurance for keys

This objective encompasses several activities (4 or 5, depending on the years) measured by 5 or 6 indicators (5 in 2022 and 2023 and 6 in 2021, with an additional indicator linked to the fact that all accreditation milestones and other decisions in SAB agenda, in need of a technical assessment were addressed by the group of experts).

All the targets set for the years 2021 and 2022 have been met except one of the 2022 target, the timely execution of tasks related to flight key assurance per each launch campaign, with a target of 2 launch campaigns and a result of 1 launch campaign – due to geopolitical context.

Objective 6 Qualification	All targets have been reached in 2021
	All targets have been reached in 2022 except one without any consequence ¹⁹⁴

¹⁹⁴ NB : Please note that the consequence regarding the launch itself has been taken into account in the Galileo section of the Report.

Objective 7 – Prepare for the new SAB regulatory responsibilities on Copernicus, GOVSATCOM and SSA

This objective was only defined for years 2021 and 2022 and the indicator was the same one: the plan for initial accreditation activities for Copernicus, GOVSATCOM and SSA in compliance to the SAB processes.

In 2021, the accreditation activities involving the SAB for Copernicus, GOVSATCOM and SSA didn't start however a meeting took place with the European Commission to have an exchange on security accreditation on GOVSATCOM. The objective was achieved in 2022, the SAB secretariat participated as observer to the working groups of GOVSATCOM, an exchange took place on security risk and threat analysis for Copernicus, first elements were outlined for the draft of the Security Accreditation Strategies and a regular slot was defined in the SAB Agenda meeting for status report by the Commission.

Objective 7 Qualification	N/A in 2021
	All targets have been reached in 2022

Core task 2: Operational security for EGNSS

Objective 1 – Galileo Threat and Risk Analysis

The evaluation of this objective is based on four indicators.

1. Risk analysis and identification for Galileo milestones delivery to SAB for decision
2. Galileo Services and System Security Plan
3. Galileo Statement of Compliance to the high-level Security requirements
4. Galileo Security Accreditation Milestones and Schedule

Each of these indicators refer to reports that EUSPA needs to provide for accreditation activities and meetings with the SAB. For 2023, these tasks and the production of these document is progressing well and without problems.

Only the final document(Galileo Security Accreditation Milestones and Schedule) has some external dependencies, as it is reliant on inputs from external stakeholders. The SAB does not need to validate this document but may provide comments and inputs, although historically they have not required any changes.

There were no targets set for 2021.

In 2022:

1. Indicator 1 was fully met
2. Indicator 2 was fully met
3. Indicator 3 was not assessed under core task 2. However, the statement of compliance with SSRS was one of the planned outputs of objective 2 under core task 3 and was met as planned.
4. Indicator 4 was met at 75%. This indicator (the SAMS for each of the quarterly SAB meetings) was not met for Q4 (December 2022 SAB) due to changes in the SB2.0 deployment activities and lack of schedule finalization which did not allow a proper update of SAMS.

Objective 1 Qualification	No targets set in 2021
	All targets have been reached in 2022

Objective 2 – Galileo Operations Security

2023

The evaluation of this objective is based on two indicators:

1. Number of service exploitation reviews (target 2)
2. Number of QSPR on GSOp – review of implementation reports (target 4)

There were no targets set for 2021.

In 2022, all targets met as expected

Objective 2 Qualification	No targets set in 2021
	All targets have been reached in 2022

Objective 3 – EGNOS Threat and Risk Analysis

The evaluation of this objective is based on five indicators

1. Number of accreditations Data packages prepared over the number of expected accreditation milestones
2. EGNOS V3 Services and System Security Plan (including sites)
3. EGNOS V3 Statement of Compliance to the High-level Security requirements (target TBD)
4. EGNOS V3 Security Accreditation Milestones and Schedule (SAMS)
5. EGNOS V3 Sites SAR

This objective is a mirror objective to the objective 1, but for EGNOS instead of Galileo. The reason there are more objectives is because there is EGNOS v3, which is not yet live. One of the indicators is still in the TBD stage as the EGNOS High-level security requirements were not approved yet by the Programme at the time of writing the Single Programming Document 2023-2025.

The “site acceptance review” (SAR) is one additional activity that refers to the security assurance of EGNOS sites. The indicator for this is checked based on the security accreditation milestone and schedule document, where the site security activities are planned.

For the SAR, there is external dependency on external contractors and other entities, which put some risk here as they require inputs from various entities. The SAR is the last step in process of developing sites, so delays further upstream can carry forward. Historically it has been smooth: the Annual Activity Report for 2022 reports good result considering all the external dependencies and the actual number of sites (some sites were delayed by a couple of months from the end of one year to the start of the next one.

There were no targets set in 2021

In 2022

1. Indicator 1 was fully met
2. Indicator 2 was fully met
3. Indicator 3 was not assessed under objective 2, but the statement of compliance with SSRS was one of the planned outputs of objective 2 under core task 3 and was met as planned.
4. Indicator 4 was fully met

5. Indicator 5 was met 89%. This is related to the EGNOS V3 sites, where 14 of the 16 milestones have been concluded in 2022, and the outstanding 2 have been shifted to Q1 2023 due to status of the relevant sites.

Objective 3 Qualification	No targets set in 2021
	All targets have been reached in 2022

Objective 4 – EGNOS Operational Security

This is similar to objective 2. It is measured through three indicators

1. Number of Service Exploitation Reviews – security sessions (EC/Agency QPM)
2. Number of EGNOS Service Provider Reviews – security sessions
3. Number of EGNOS GEO Service Providers Reviews – security sessions

All targets were met at 100%.

Objective 4 Qualification	All targets have been reached in 2021
	All targets have been reached in 2022

Core task 3: Operation of the Galileo Security Monitoring Centre

Core task 3 is comprised of five objectives. This objective is generally classified, therefore the interview dealt with understanding the objectives and whether EUSPA is achieving them.

Objective 1 – Ensure that Galileo services and operations are secure

There are three indicators for this objective:

1. Incident handling/defined SLA
2. PRS access service within agreed response time
3. PRS operations contingency plans rehearsal
4. GSMC availability

The targets and attainment are both classified. But the unclassified parts are discussed below:

For (1), there are stringent KPIs for time within which an incident is handled. Once an incident is detected by the GCC or GSMC, they must report it, validate that its not a false positive, and act. KPIs are all reported in the (classified) monthly report. As both target and attainment are classified, nothing was disclosed to PwC.

For (2), the indicator is reported regularly in the Service Exploitation Review (SER). When EUSPA deploys a system, it is first qualified by industry, then there is an operations validation campaign to ensure functionality, then they deploy the service and have a service validation campaign to sure ensure actionable compliance with SDD There have been no issues in the assessed time period.

For (3), attainment is at 100%, there are regular tests at switching the primary site between France and Spain.

For (4), the target is classified but the GSMC available has been continuously available 24/7 since 2016, so 100% attainment is implied.

Objective 1 Qualification	All targets have been reached in 2021 (<i>non-disclosed targets not assessed</i>)
	All targets have been reached in 2022

Objective 2 – Ensure Engineering activities in support of deployments and operations

There are 2 indicators for this objective where the objective is 100%

1. % of success rate of operator training (certification)
2. Percentage of data packs timely released for accreditation requests (new or renewals) against annual plan baseline schedule

The first was achieved at 100% for 2021 and 2022. There are yearly trainings (lasting 4 – 6 weeks) done for each operator before they can be authorised to join the shift team. 100% of operators on shift are certified. The certification board is composed of several departments of the Agency and witnesses and approves the result of the trainings.

The second indicator is lined to security accreditation. They have never lacked accreditation and have always been timely enough to always have the site and system accredited successfully. Therefore there is 100% attainment in both 2021 and 2022.

Objective 2 Qualification	All targets have been reached in 2021
	All targets have been reached in 2022

Objective 3 – Ensure the availability of hosting services

This was a former objective that has been shifted to the ITF department. Nevertheless, the indicators can be checked as below:

1. Final Configuration (GSMC FR)
2. Final Configuration (GSMC-ES)

In 2021 and 2022, targets were set regarding the configuration of the sites. While the target for 2021 for the Spanish site was delayed to 2022 due to non-compliance of building with requirements and need for additional works from Spanish authorities, the 2022 targets for both sites were still met.

Objective 3 Qualification	All targets have been reached in 2021 except one without any consequence
	All targets have been reached in 2022

Objective 4 - Ensure continuity of service of GSMC operations, continuous improvement, quality and efficiency

There are three indicators for this task:

1. Management: Monthly/quarterly report released per year
2. Quality: percentage of audit performed/planned
3. Business Continuity plan update 1/year

In both 2021 and 2022, all targets achieved.

Objective 4 Qualification	All targets have been reached in 2021
	All targets have been reached in 2022

Objective 5 – Local Security: Prepare, ensure and maintain the local security needed to protect EU classified information and assets present on site.

This objective has been transferred, to Security Authority responsible for the GSMC Local security office. It is a general undertaking of security by the agency. The security authority is responsible for implementation of security rules now. The registry control management, which is registry of all documents going in and coming out is all up to date. They have processes to ensure physical security of the premises to ensure everyone is properly secure before entering the GSMC. COMSEC and crypto are done by security authority. INFOSEC is also done by security authority. GSMC is not following these on a daily basis but it reported regularly on tasks completion and compliance to operational objectives., No discrepancy detrimental to operations have been raised.

There are five indicators for this objective.

1. [Registry Control MGT]: receipt, dispatch, storage, destruction of classified documents and tracking of their lifecycle
2. [Local Security MGT]: New or leaving staff/contractors/visitors, need to issue and renew the security clearance
3. [COMSEC MGT]: new access requested, need to transfer COMSEC items, new COMSEC item, crypto operations (PKI, non-PRS keys, SINA VPN management, SPECTRA)
4. [Crypto Account MGT]: receipt, dispatch, storage, destruction of crypto materiel, need to execute the key management plan
5. [LISO MGT]: Communication and information systems SecOps, the Cyber, the GSMC SecOps and OSRD requirements, the reports from authorized users, the systems logs, users access requests.

In 2022, all targets were met.

Objective 5 Qualification	No data in 2021
	All targets have been reached in 2022

Core task 4: PRS Activities

Objective 1 – Implementation of PRS Article 14c Arrangement

The PRS Activities task is comprised of one annual objective. This activity focuses only on the core activities related to handling of PRS information and items. It is noted that the development, provision, etc. of PRS are all parts of the entrusted tasks. The core activities here refer to decision 1104/2011, where article 14c specifies that EUSPA must perform tasks as laid out in a specific arrangement with the EC. This objective therefore states that EUSPA must ensure the implementation of the activities in this arrangement.

There are two indicators:

1. Timely review of PRS management plans (and related processes)
2. Level of compliance

The first deals with the timely review of the arrangement, asking EUSPA to define plans, policies, and procedures on a yearly basis. This is ongoing, and this year an updated version of the PRS Management plans is already drafted.

The second indicator is about the level of compliance. In both 2021 and 2022 the compliance is slightly below the target set for 2023 (94% vs 95%) but achieving 95% is possible. Nevertheless, EUSPA states that going further is practically impossible as the way the arrangement is written makes it very difficult to achieve all the objectives for various reasons, including legal reasons.

EUSPA has asked the EC to review this arrangement in their regular reports to the Commission. Globally the core activity is well undertaken by EUSPA and meets the needs of the Programme.

Objective 1 Qualification	All targets have been reached in 2021 except one without any consequence
	All targets have been reached in 2022 except one without any consequence

Core task 5: Communication, promotion and market development

This core task encompasses 4 main group of activities:

- Market and technology monitoring;
- User scheme management in the sense of building user experience and satisfaction;
- Market development by user segment with the objective of identifying needs and opportunities for services and applications; and
- Development and implementation of targeted communication initiatives, as well as campaigns for the general public in order to ensure the management of effective and efficient communications strategy and initiatives.

Please note that the objectives were reorganized for 2023, but since the results are not yet available, the assessment will cover the years 2021 and 2022. For these years, it encompasses 14 objectives with associated indicators and targets per year.

Objective 1 – EU Space Programme components market development in aviation and drones

The objective linked to the aviation and drones sector encompasses 8 activities in 2021 and 7 activities in 2022 (one additional indicator regarding the update and agreement with stakeholders of EGNOS and Galileo adoption roadmap for aviation).

A set of targets has been defined to measure this objective constituted in 8 indicators for 2021 and 7 indicators for 2022. All the targets have been met in both 2021 and 2022.

Objective 1 Qualification	All targets have been reached in 2021
	All targets have been reached in 2022

Objective 2 – EU Space Programme components market development in road and automotive

This objective is constituted of 9 activities linked to the road and automotive sector, as well as their associated 9 indicators and targets for years 2021 and 2022.

All the targets have been met in 2021 except for the number of companies commercializing Galileo products, with a target of 200 companies and a result of 155 because new players entered the market which were not expected when initially fixing the targets. In 2022, all targets have been met.

Objective 2 Qualification	All targets have been reached in 2021 except one without any consequence
	All targets have been reached in 2022

Objective 3 – EU Space Programme components market development in Maritime and Inland Waterways

This objective encompasses 9 activities which are the same for years 2021 and 2022. Their 9 associated indicators have targets which have been met for both 2021 and 2022.

Objective 3 Qualification	All targets have been reached in 2021
	All targets have been reached in 2022

Objective 4 – EU Space Programme components market development in Rail

The objective related to the market development in rail sector is divided into 7 activities measured by 7 indicators which are the same for years 2021 and 2022. All the targets set have been met for these years.

Objective 4 Qualification	All targets have been reached in 2021
	All targets have been reached in 2022

Objective 5 – EU Space Programme components market development in Agriculture and Forestry

This objective encompasses 7 activities, measured by 7 indicators. Their associated targets have been entirely met for year 2021. For 2022, the percentage of Egnos receivers in overall number of models for Agriculture and Forestry was 93%, slightly less than the target (97%) because one of the solutions of the chip shortage was the extension of lifetime of the receivers already deployed, which leads to this difference between the targeted percentage and the actual one.

Objective 5 Qualification	All targets have been reached in 2021
	All targets have been reached in 2022 except one without consequence

Objective 6 – EU Space Programme components market development in Urban Development and Cultural Heritage applications

8 activities correspond to that objective, measured by 8 indicators. The targets for 2021 have been met but it should be underlined that the exact number of receiver models implementing High Accuracy Service is difficult to obtain so the information is not available yet; however, this segment is 90% focused on Earth Observation and in order to facilitate the standards, it was underlined as a recommendation that all solutions should use GNSS. In 2022, all targets have also been met except for the percentage of EGNOS receivers in overall number of models for Urban Development and Cultural Heritage (94%) which is slightly under the target (98%) for the same reason as for the Agriculture and Forestry segment.

Objective 6 Qualification	All targets have been reached in 2021
	All targets have been reached in 2022 except one without consequence

Objective 7 – EU Space Programme components market development in Consumer Solutions, Health and Tourism

This objective is composed of 6 activities measured by 6 indicators. All the targets have been reached for both the year 2021 and the year 2022.

Objective 7 Qualification	All targets have been reached in 2021
	All targets have been reached in 2022

Objective 8 – EU Space Programme components market development in Insurance and Finance, Infrastructures, Energy and Raw Materials

This objective encompasses 8 activities. It is measured by a set of 7 indicators accompanied by its targets. In 2021, all the targets have been met. In 2022, all the targets have also been

met except the percentage of Galileo receivers in overall number of Critical Infrastructures models (49%) which is slightly less than the targeted percentage (55%) for the same reason as previously mentioned.

Objective 8 Qualification	All targets have been reached in 2021
	All targets have been reached in 2022 except one without consequence

Objective 9 – EU Space Programme components market development in governmental use

This objective has 5 indicators and associated targets but encompasses only 3 activities. The targets have all been met both in 2021 and in 2022.

Objective 9 Qualification	All targets have been reached in 2021
	All targets have been reached in 2022

Objective 10 – EU Space Programme components market development in Emergency Management and Humanitarian Aid

This objective is defined by 6 activities and an identical number of indicators with their associated targets. All targets have been met both in 2021 and 2022.

Objective 10 Qualification	All targets have been reached in 2021
	All targets have been reached in 2022

Objective 11 – EGNSS market development in Space Users

This objective encompasses 4 activities in 2021 and 2022 with its associated 4 indicators and targets. In 2021, all targets were met, except the number of companies commercializing Galileo products (the target was 3 and the result was 2). In 2022, all targets have been met.

Objective 11 Qualification	All targets have been reached in 2021 except one without consequence
	All targets have been reached in 2022

Objective 12 – EU Space Programme components market development in Fisheries and Aquaculture

This objective contains 2 activities, 2 indicators and 2 associated targets for the year 2021 and 2022. Both targets have been met for both 2021 and 2022.

Objective 12 Qualification	All targets have been reached in 2021
	All targets have been reached in 2022

Objective 13 – Climate and Weather Services-Biodiversity, Ecosystems and Natural Capital

This objective has the same activities, indicators and targets as the precedent one but specific to this sector. Both targets have been met for 2021 and 2022.

Objective 13 Qualification	All targets have been reached in 2021
	All targets have been reached in 2022

Objective 14 – Services, Applications and R&D communications

The last objective for 2021 and 2022 is measured by 5 activities linked to communication relating to EGNOS and Galileo services, Copernicus data and GOVSATCOM and applications for research and development with its associated indicators and targets. All targets have been met both in 2021 and 2022.

Objective 14 Qualification	All targets have been reached in 2021

	All targets have been reached in 2022

Core task 6: Agency management

The Agency Management core task aims at supporting EUSPA's core and delegated mission by providing support in areas of legal, procurement, grants, contracts, finance and budget, human resources management, ICT, facility management and logistics.

It encompasses 17 objectives with associated activities, indicators and targets. As for the precedent core tasks, the assessment will cover years 2021 and 2022.

Objective 1 – Implement efficient management of all legal arrangements for the Agency, in-line with the service delivery needs

This objective covers 4 activities, measured by one indicator in 2022 and 2 indicators in 2021 and 2023 (one additional linked to the contract management). All targets have been met both in 2021 and 2022.

Objective 1 Qualification

All targets have been reached in 2021
All targets have been reached in 2022

Objective 2 – Identifying, developing and implementing activities leading to a workforce capable of delivering EUSPA's business needs

3 indicators have been assigned to this objective linked to people and talent management with their associated targets. All targets have been met both in 2021 and 2022.

Objective 2 Qualification

All targets have been reached in 2021
All targets have been reached in 2022

Objective 3 – Ensure administrative management at GSMC

This objective is only set for year 2021. The target - 0 - of the associated indicator – Avoid and/or reduce the number of exception reports was met.

Objective 3 Qualification

All targets have been reached in 2021

Objective 4 – Plan, manage and report on EUSPA budget and process all financial transactions

This objective has only one indicator – Commitment rate and rate of payment within prescribed time limits - the same for 2021, 2022 and 2023. The target set has been met for 2021 and 2022.

Objective 4 Qualification

All targets have been reached in 2021
All targets have been reached in 2022

Objective 5 – Provide a secure core digital working environment for EUSPA departments within the ICT-related domains of ICT security, operations, user- support and project management

This objective is set for years 2021, 2022 and 2023, however formulated differently. In 2021, all the targets set have been met. In 2022, there were slight differences between the targets and the actual results. Indeed, the indicator related to the core system availability and the one related to the detection of attempts to compromise core systems were met. However, the indicator related to L1 support responsiveness and the one related to the projects/delivery schedule were slightly below the targets set.

Objective 5 Qualification

All targets have been reached in 2021
All targets have been reached in 2021 except two without consequence

Objective 6 – Maintain operational capability of EUSPA premises in Prague to support EUSPA activities

This objective is only set for years 2021 and 2022. It has a unique indicator related to the monitoring of operational capability and its associated target has been met for both 2021 and 2022.

Objective 6 Qualification	All targets have been reached in 2021
	All targets have been reached in 2022

Objective 7 – Strategic planning and administrative board management

This objective refers to the identification and implementation of activities leading to successful Administrative Board activities. It was set only for years 2021 and 2022 and has two associated indicators with 2 targets which have been met for both years.

Objective 7 Qualification	All targets have been reached in 2021
	All targets have been reached in 2022

Objective 8 – Achieve EUSPA-wide capability for Records and Information management

This objective is set only for years 2021 and 2022. It refers to the smooth implementation of an enterprise content management system (policies, processes and procedures). This objective has 3 indicators and all have been met in 2022. In 2021, targets have been met for the Document Management System but not for the Record Management System.

Objective 8 Qualification	All targets have been reached in 2021 for DMS	No targets have been reached in 2021 for RMS
	All targets have been reached in 2022	

Objective 9 – Successful compliance with personal data protection rules applicable to the Agency

This objective, defined for years 2021, 2022 and 2023 has one indicator related to the percentage of compliance with data protection rules and associated target per year. All targets have been achieved in both 2021 and 2022.

Objective 9 Qualification	All targets have been reached in 2021
	All targets have been reached in 2022

Objective 10 – Successfully undertake risk management activities

This objective is defined for 2021, 2022 and 2023. It refers to the implementation of the corporate risks and opportunities management process and has one indicator related to the organization of quarterly corporate risk and opportunities board. In 2021, all targets have been met as well as in 2022 during which 4 Risk Management Board meetings were held.

Objective 10 Qualification	All targets have been reached in 2021
	All targets have been reached in 2022

Objective 11 – Measure and improve the quality of EUSPA processes

This objective is set for years 2021 and 2022 only. It has 3 similar indicators for both years related to ISO 9001 requirements, the progress of implementing quality audits and the implementation of open actions in the continuous improvement database.

In 2022, all targets have been met. In 2021, 2 of the 3 targets have been met and regarding the implementation of open actions the percentage (94.5% of not closed actions in the continuous improvement database) is slightly under the targeted percentage (100%).

Objective 11 Qualification	All targets have been reached in 2021 except one without any consequence
	All targets have been reached in 2022

Objective 12 – Ensure the Agency fulfils statutory obligations

This objective is set for years 2021, 2022 and 2023. It has 4 associated indicators covering the timely execution of statutory obligations.

All targets have been met in 2021. In 2022, one target has not been reached – the timely execution of the corresponding yearly audits – due to a delay in the release of auditors' reports and the need to launch a second audit on Galileo DA activity lowered the global performance.

Objective 12 Qualification	All targets have been reached in 2021
	All targets have been reached except one in 2022 without any consequence

Objective 13 – Develop Corporate Communications for EUSPA

This objective is set for years 2021 and 2022 only. In 2021, it covered 7 activities and had 5 targets associated to it, which had been met. In 2022, it covered 8 activities but only 2 targets associated and these targets have been met: the number of media clipping increased by 10%, the number of followers increased by 20%, a new social media has been created (Mastodon) and the annual communication plan has been published.

Objective 13 Qualification	All targets have been reached in 2021
	All targets have been reached in 2022

Objective 14 – Develop internal communications for EUSPA

The internal communications objective is set for years 2021 and 2022. It encompasses 4 activities each year with 3 indicators, however not the same ones. All the targets have been met both in 2021 and in 2022, for example regarding the involvement of staff in Agency internal communication activities, more than 100 EUSPA colleagues have added EUSPA as their employer to LinkedIn and actively engaged in EUSPA's LinkedIn activities.

Objective 14 Qualification	All targets have been reached in 2021
	All targets have been reached in 2022

Objective 15 – Develop stakeholder communications for EUSPA

This objective is set for years 2021 and 2022. It encompasses 6 activities but with 5 indicators in 2021 related to the increase on year-on-year basis in several domains (traffic to social media, number of attendees to event etc.) and 2 indicators in 2022. All targets have been met for both 2021 and 2022.

Objective 15 Qualification	All targets have been reached in 2021
	All targets have been reached in 2022

In 2023, there is an objective summing two of the precedent ones regarding the development of corporate and stakeholders' communications for EUSPA. It has 2 associated indicators : the increase in traffic to social media touchpoints and the YoY geographical repartition of the press pic-ups.

Objective 16 – Ensure full compliance with the Commission Security Rules for the Agency

This objective is set for years 2021, 2022 and 2023. It encompasses 5 activities, which are the same for the three years and has one associated indicator related to the percentage of

compliance with two specific Commission decisions. The target of 100% of compliance has been reached in 2021 and 2022 and the EUSPA Security Rules have been drafted and prepared for adoption in 2022.

Objective 16 Qualification	All targets have been reached in 2021
	All targets have been reached in 2022

Objective 17 – Assure the annual accreditation reviews of internal Agency systems/area

This objective is set for years 2021, 2022 and 2023. It covers 2 activities in 2021 with an indicator related to the number of internal accreditation reviews and 3 activities in 2022 and 2023 with one additional indicator related to the number of ISSB reviews. The targets have been met in 2021 and 2022, except for the number of ISSB reviews in 2022, with 2 reviews on a target aiming at more than 2 reviews.

Objective 17 Qualification	All targets have been reached in 2021
	All targets have been reached except one in 2022 without any consequence

Objective 18 – Support the electronic exchange of R-UE/EU-R information

This objective is set only for 2022. It encompasses 2 activities and 4 indicators but with unknown targets for 3 of them – only one for the number of community management requests (a target of 1800 for a result of 1342). Therefore, we can't say that targets have been met because there wasn't any for the majority of the indicators (75%) linked to this objective. However, there had been 320 keys generated, 213 distributions to external CDAs and 4589 key copies distributed.

Objective 18 Qualification	N/A

4.1.2.2. Additional insights on EUSPA

It is also worth highlighting that EUSPA has successfully evolved from GSA in order to be able undertake its new tasks and has demonstrated agility in achieving this. This has started with the definition of a new Agency mission and Agency values, and a new organization of the Agency decided by the Administrative Board in October 2021. This new organization defines and strengthens technical horizontal functions such as Engineering and Security Operations & Monitoring, making them available to all current and future programme components. This evolution is further witnessed by the growth in the establishment plan of EUSPA and its overall staffing, which has grown by 40 Temporary Agent (TA) staff in 2021, 40 TA staff in 2022 and is on track for growing by 36 TA staff in 2023 (20 TA staff from Space Programme Regulation, 11 TA staff from the transfer of SST Frontdesk, 5 TA staff from Secure Connectivity Regulation), in addition of a roughly doubling in the core budget of the Agency.

As well, the Commission has transferred contracting authority to EUSPA first for the EGNOS contracts where it was previously contracting authority, and more recently for Galileo contracts, increasing the level of responsibility exercised directly by the Agency as decided by the Commission. The ICT and facilities of the Agency, are also being transformed, seen through the new GSMC France and GSMC Spain facilities (both recently accepted), and work on new EUSPA HQ facilities, together with the development of new unclassified and classified (R-UE/R-EU & S-UE/S-EU) IT facilities and networks. These changes are completed with further fundamental work on Agency ethics, environmental management, diversity & inclusion and training & development, in addition to the adoption of the new Anti-Fraud Strategy as already included in the report. All in all, the Agency has transformed itself during a brief period, and although not captured directly by metrics used elsewhere in the report due to the nature of the changes, it is the result of substantial commitment of the Agency and fundamental to the achievement of the Programme.

4.2. EUSPA Entrusted Tasks

Overall, per the Annex to Decision C (ANNEX to the Commission Implementing Decision on entrusting budget implementation tasks to the European Union Agency for the Space Programme and the European Space Agency”, the EUSPA entrusted tasks were segmented in the following categories

- SSA tasks entrusted to EUSPA
- Galileo tasks entrusted to EUSPA
- EGNOS tasks entrusted to EUSPA
- Copernicus tasks entrusted to EUSPA
- GOVSATCOM tasks entrusted to EUSPA
- Downstream activities entrusted to EUSPA

The First 5 categories were each addressed under the report chapter relevant to the Space Component of interest.

However, the 6th category: **“Downstream activities entrusted to EUSPA” can be further broken down into 3 intervention groups:**

First group covers user uptake and other activities under Article 29(2) (a), (b), (c) and (d) of Regulation (EU) 2021/696. This can further be broken down into tasks related to Copernicus (covered under the Copernicus chapter), GOVSATCOM (covered under GOVSATCOM) and Galileo and EGNOS. The only tasks not addressed in the previous chapters from this intervention group is what regards the Galileo and EGNOS components.

Second group covers the development of downstream applications under the area of intervention “Space, including Earth Observation” under Pillar II, Cluster 4 “Digital, Industry and Space” of the Horizon Europe specific programme, as well as potentially other areas related to Space downstream in the Horizon Europe specific programme, when so provided in the Work Plan and approved by the Commission. This intervention group is funded by Horizon and is therefore not in Scope of the study.

The third intervention group covers Innovative and competitive space sector fostering activities under Article 6(1)(a), (b), (c) and (e) of Regulation (EU) 2021/696, covered by Article 29(2)(e) of Regulation (EU) 2021/696. The tasks falling under this group are listed below:

Table 281: entrusted tasks under the third intervention group of downstream activities entrusted to EUSPA, and their assessment status

Entrusted Tasks	Status / comments	Relevant Chapters
implementation of specific actions stemming from the CASSINI Space Entrepreneurship initiative, including by means of blending operations under Article 21 of Regulation (EU) 2021/696 and subject to specific authorisation of the Commission, aimed at increasing the number of innovative solutions using EU space technologies and the success rate of new ventures proposing them	Covered	Cassini assessment chapter
fostering centres of excellence building on the existing infrastructure (where appropriate) and excellences available at regional/national level on a certain downstream application, so that it can serve as example, demonstration, learning and testing facilities for other private and public entities in Europe, creating a spillover effect and attracting public and private financing.	Activity was cancelled, never made it to EUSPA (due to lack of funding)	NA

Entrusted Tasks	Status / comments	Relevant Chapters
fast development of products and solutions in the area of mass market (characterized by short time to market and high dynamic of innovation), addressing specifically start-ups and SMEs, including via business acceleration programmes, including by means of blending operations under Article 21 of Regulation (EU) 2021/696 and subject to specific authorisation of the Commission	Covered	Cassini Assessment (myEUspace Competition)
facilitating the access to finance, including venture capital (especially for start-ups), in close cooperation with the Commission including by means of blending operations under Article 21 of Regulation (EU) 2021/696 and subject to specific authorisation of the Commission	Covered	Cassini Assessment (Seed and Growth fund)
mentoring, matchmaking with investors and industrial partnering, for example by acting as technical and business advisor for both the innovators and investors	Covered	Cassini (matchmaking program)
supporting the Commission in the implementation of actions aimed at raising awareness of the importance of space	horizontal activity	Each component chapter has indicators related
supporting the Commission in its skills development initiatives by implementing educational and training activities	Covered	Cassini (Space Academy)
promoting research and development, industrial cooperation and capacity building, supporting the EU innovative space sector on global scale, as jointly agreed with the Commission	NA – No allocated budget from the Space Programme (budget has been allocated only from Horizon Europe)	NA
implementing research and development actions for demonstrating and making best use of space technologies, infrastructure and services, and for optimising the associated operations and service delivery		
managing and implementing Galileo PRS downstream R&D activities included in the PRS uptake roadmap.	Covered	Galileo and EGNOS assessment

The only component of “Downstream activities entrusted to EUSPA” segment that has thus not been addressed and should be is from the first intervention group, regarding Galileo and EGNOS Components: Support the development and evolution of fundamental technological elements, such as chipsets, receivers, antennas, software, test tools and supporting equipment with a special focus on longer term regulated segments (e.g. aviation, rail, maritime, road, governmental) and on Galileo and EGNOS differentiators, creating synergies with other space programme components. Implement other actions to support the user technology uptake, including blending operations.

4.2.1. Fundamental Elements

The Fundamental Elements programme is an EU R&D funding programme for enabling and supporting the development of EGNSS chipsets, receivers and antennas. The Fundamental Elements projects are part of the overall European GNSS strategy for market uptake, led by EUSPA. The objectives of the Fundamental Elements can be summarised as follows:

- Facilitate the adoption of the European GNSS Systems, building on their innovative services and differentiators;
- Improve the competitiveness of EU industry;
- Address user needs in priority market segments;
- Maximise benefits to European citizens.

The review of the Work Programmes of the Galileo and EGNOS components for 2021, 2022 and 2023 in addition to the review of the EUSPA Consolidated Single Programming document 2021 – 2023 led the team to identify EUSPA’s entrusted tasks for FE as:

Figure 99:Entrusted tasks and activities under FE

Intervention Group	Tasks	Activity
User Uptake for Galileo and EGNOS under Downstream activities entrusted to EUSPA	Manage scrutiny of EUSPA projects under FE, provide support in preparing specifications and approve next EUSPA Acquisition Plan including FE	1 Supervise the implementation of Fundamental Elements programme
		2 Manage the ongoing projects in terms of objectives, planning, budget and reporting.
		3 Define the plan for development and evolution of fundamental elements for EGNOS and Galileo
		4 Launch the 2022 – 2023 Fundamental Elements calls and manage the related projects portfolio

The total budget allocated to FE for 2021 – 2027 is 43 M EUR, to continue and develop the previous successful round of FE that started awarding in 2016 and to develop new projects. The 2nd FE round shall focus on:

- The continuity of being driven by user needs in all market segments
- Operational implementation of current differentiators (E.g. OS-NMA, HAS, triple frequency)
- Preparing for commercial implementation of new differentiators (E.g. Early Warning Satellite Service, CAS, ARAIM)
- Developing emerging, disruptive technologies (e.g. leveraging machine learning, artificial intelligence)
- Exploring synergies with other space systems on user technology (E.g. Copernicus, Secure Communications)

Activities 1 and 2:

Projects awarded under the FE programme are expected to be carried out anywhere between 1.5 and 4 years, with an average length of around 2 years. Therefore, under the current MFF, the implementation of many of the projects that were awarded in the previous MFF continues.

43 projects were still in-progress entering into the current MFF, and EUSPA, under its entrusted tasks for this MFF, continues to manage and oversee these activities. At mid July 2023, 29 projects of these 43 had been successfully concluded.¹⁹⁵

It is estimated that at least 11 of these 29 projects were concluded on time according to their schedule, and the others incurred little delays. According to the AIR 2022, 5 other projects of the 29 (ASGARD; BANSHEE, Blue BOX, GREAT and REMOT) had requested amendments with extension of projected duration, that were approved by EUSPA in 2021 and 2022. Today, the total number of projects that requested amendments is equal to 30 (from projects on-going or concluded). While this number is high it must be noted that these delays were in part due to external global crises witnessed particularly the COVID crisis and lockdown that prevented beneficiaries from being able to procure hardware or perform testing and it was

also due to the international shortage of micro-chip components. The delay incurred on the extended projects varied between a couple of months to less than a year.

On the other hand, regarding the 14 on-going projects remaining under supervision of EUSPA, more than half of them started in 2021, (one of which has successfully delivered its MTR according to the 2022 AIR), and a few had started in 2020 and 2018 (including AMETRINE and COBALT) which are expected to end soon, knowing that COBALT had requested amendments that were approved in 2022 by EUSPA. Another (ISSAR) requested a 6-month suspension.

All in all, and according to the EUSPA AIR 2022, EUSPA states that it did not face any critical issues. The request for amendments and extensions are of course causes for delays however, EUSPA tries to monitor their reasoning and their progress.

However, one critical point for the beneficiaries receiving the funding (particularly the SMEs and start-ups) is the time it takes to receive the funding. The current agreement with EUSPA is that as soon as a contract is signed, a 30% prefinancing is delivered to the beneficiaries, and this is delivered smoothly without delays. Next there is an interim payment around 1 year later of 30% and a final payment of 40%. These payments are supposed to be delivered within 90 days of receiving the necessary documentation and justifications from the beneficiaries however this is not usually the case. It typically takes around 6 - 8 months to pay these 2 remaining payments from the date of receiving necessary justification. This is due to all the exchanges and clarification requests that have to take place after the beneficiaries submit their justifications. Almost always, the justifications that beneficiaries share for the follow up payments are not enough, and this leads to additional requests for clarifications sent by EUSPA which pauses the count. Multiple exchanges happen after that, which takes a few months, until final approval can be given for payment. This naturally delays the payment time which can be quite problematic for start-ups and SMEs that do not have sufficient resources to keep their activities going without funding. Moving forward, EUSPA is trying to internally improve the process to ensure a more rapid payment process however this will require enhancing training of beneficiaries on the justification and submittal of their necessary documents to minimize clarification requests moving forward.

In the absence of specific KPIs that can be quantified to measure the extent to which EUSPA is meeting its objectives under these 2 entrusted tasks, it has been evaluated qualitatively. **EUSPA's reporting on the above in its AIRSs demonstrate that it is implementing activities 1 and 2 mentioned above. However, the outcomes of their intervention can be improved particularly via addressing the delays in the projects and the delays in payments.**

Activity 3:

Regarding the plan for development and evolution of fundamental elements for EGNOS and Galileo, this refers to a long-term plan that is developed at the beginning of the MFF period. In 2021 EUSPA effectively prepared this plan for calls for the new MFF timeframe (and more specifically defined this plan for 2022 and 2023) and defined a number of calls per year to be launched. The plan was approved by the European Commission in July 2021, leading to the preparation of the corresponding annual grant plans by EUSPA.

The fundamental elements initiative was developed to address a EUSPA entrusted task in the downstream sector under the Galileo and EGNOS component. Therefore, the objective of this plan has been mainly two-fold.

On one hand it was required to ensure that FE, its constituting calls and awarded projects are supporting the Galileo and EGNOS components of the Space Programme and feeding into their development and implementation. In fact, this has been demonstrated through multiple FE projects such as PATROL whose results were utilized for the validation of the GALILEO

OSNMA service and HAUT whose results were utilized for the validation of the HAS service. Other examples include the GIANO and GEARS projects that were utilized for the testing of the OSNMA service during validation. Furthermore, DFMC project that shall develop and EGNOS aviation receiver shall be utilized to test and improve the EGNOS service.

On the other hand, it is meant to ensure that FE, its constituting calls and awarded projects enable and promote the market uptake of GNSS signals particularly of GALILEO and EGNOS signals. As such, FE is expected to identify the gaps in the downstream markets across the different end-user verticals and focus its projects on near-market solutions that can be adopted by these vertical markets. Ultimately its objective is to see more and more end-users from across the verticals adopting technologies that utilize GNSS signals in general, and ideally GALILEO and EGNOS signals specifically.

Given that the number of proposals being received per call has decreased under this MFF to 1 or 2 per call (from 4 or 5 per call in the previous MFF) market uptake or interest seems to be declining however a full assessment of the market uptake was not done as it was not part of the study scope.

Therefore it can be said that EUSPA is implementing its entrusted activity number 3 as required, however the desired outcomes and impacts of this intervention are not being witnessed.

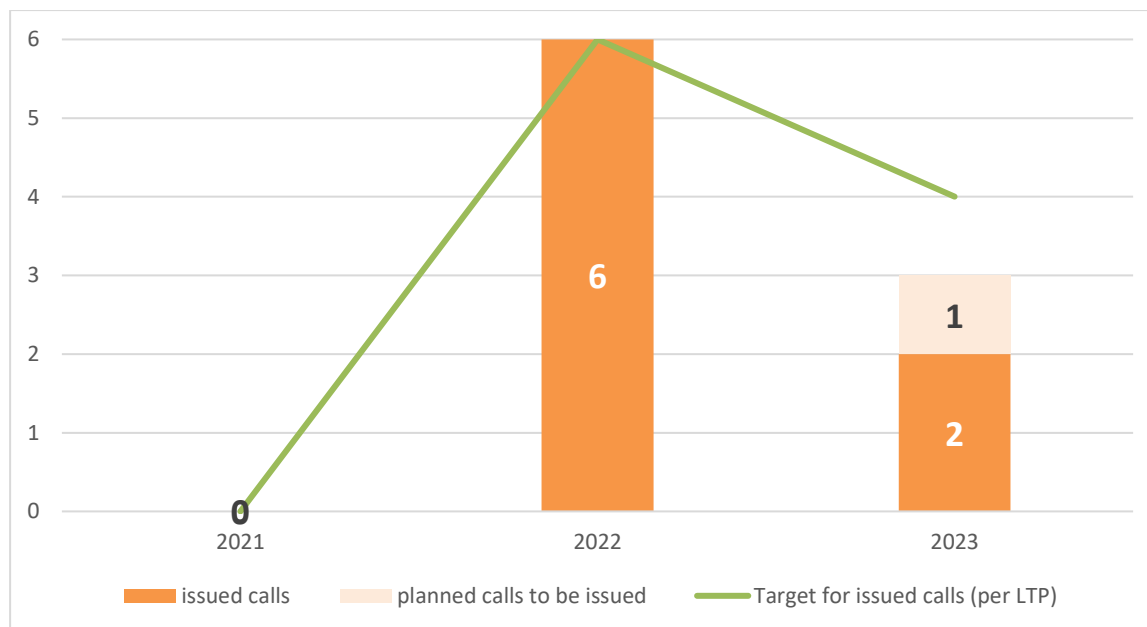
Activity 4:

The Fundamental Elements LTP has set objectives regarding the number of calls to be issued under the new MFF, and they go as follows: 0 new calls in 2021, 6 new calls in 2022 and 4 new calls in 2023 (and the rest after 2023).

Following consultation with EUSPA, it was stated that indeed for the year 2021 no calls were launched, and in the year 2022, EUSPA launched 6 new calls. EUSPA in the 2022 AIR states that during the Q4 2022 the calls OSNMA implementation for consumer solutions and HAS implementation in Agriculture & Geomatics, were under evaluation, and recent consultation confirms that 1 project has been awarded for the first call, while another project is currently under signature (at the time of writing the report) for the latter call. A new call, (Artificial Intelligence Machine Learning), was open for submission from the 2nd edition of the Fundamental Elements Programme (2021-2027) and the evaluation of the proposals to award projects is almost done (2 projects are currently under signature). The calls Emergency Warning Service Galileo devices and New remote beacon activation (RBA) for maritime have been finalized and were sent to the EC for scrutiny. The proposals have been received and are under evaluation. The EWS Galileo device call has been extended due to limited number of proposals received. Finally, the new FE call Connectivity is ready now and open for calls. A 6th call for SBAS authentication has been launched.

Furthermore, the calls will continue in 2023, with 3 new calls planned. The Fundamental Elements calls include “OSNMA implementation for consumer solutions” and “HAS implementation in Agriculture and Geomatics” that were ready for award period for Q1 2023 and the third call is expected to be ready soon. The figure below shows whether the objectives set by the LTP are being met:

Figure 100: set objective for the FE calls versus the actual issued and planned calls per year (Source: inputs from EUSPA and EC)



As the graph above shows, in 2021 and 2022 EUSPA met its objectives for launching calls, however in 2023 it is expected to meet 75% of its objectives by issuing 3 out of the targeted 4 calls.

Parallely, since 2021, EUSPA has effectively signed only one project, and is in the process of signing 3 others. A lot of time is spent in evaluating and assessing projects which could lead to a reduced rate of awarded studies and reduced interest.

Therefore, it could be deduced that over 3 years, EUSPA has met 90% of its target in relation to entrusted task number 4 (9 issued calls out of 10 targeted). However the outcome of this task is not as desired, given that only 1 project was actually signed at the time of the reporting.

Takeaways

EUSPA has implemented its delegated tasks and achieved most of its objectives. However, the desired outcome and results of the FE programme cannot be witnessed yet (such as increased participation rate from the industry, increased uptake of Galileo and EGNOS signals etc.). It is critical to highlight that this study does not incorporate a detailed quantitative assessment of the market uptake and benefits of FE programme (EUSPA is planning such an activity currently, but the data is still being gathered from the consortia that were awarded the contracts). The next update of the EUSPA market report and of the EUPSA technology report will be released in 2024 thus allowing to better assess the actual penetration of Galileo and EGNOS in the market, and in turn the efficiency of the FE programme in support of this objective.

A few issues identified under the management of the programs that persist are: the delays in payments to the companies awarded the projects which can impact the performance of these start-ups and SMEs; Systematic delays in the implementation of the projects (30 of 43 companies asked for these amendments) which is not completely under the control of EUSPA; A small delay in issuing the targeted number of calls in the year 2023; delays in evaluating and awarding projects, and a high administrative burden on the companies.

On the market uptake side, overall, it can be noted that EUSPA is trying to put efforts on the dissemination of the FE programme to reach a wider audience for the proposals in terms of diversity of company profiles and countries represented by the beneficiaries. EUSPA managed to award contracts to a few additional players that are not usual bidders such as RUAG space (Austria), Huld (Czech Republic), Orolia and Ubiscale (France), ChipCraft and Piktime (Poland), Qualinx B.V (Netherlands) and NTLAB (Lithuania). However unfortunately the number of proposals received per call has decreased from an average of 4 to 5 proposals per call in the previous MFF, to an average of 1 or 2 proposals per call in the current MFF. This issue is very important to address because it prevents FE from achieving one of its most important objectives which is enabling downstream market uptake of GNSS.

It is critical that EUSPA manages to evaluate what has caused the decline in the interest of the beneficiaries in order to better implement the FE initiative, and the reasons behind it could be many. According to EUSPA, this decline is attributed to the fact that the calls were launched for specific market segments or to foster specific differentiators. To highlight again, PwC has not evaluated the projects under the new MFF because data is still being gathered as mentioned above. However in 2021 PwC performed an impact assessment of the FE programme to assess the benefits, results and outputs that the FE projects lead to at European industry level. This impact assessment showed that the projects that are developed under the FE initiative have brought and are expected to continue bringing benefits to the European landscape and industry, however a few gaps were identified upon consultation with the consortia that could optimize the outputs of the FE initiative on market uptake. A few of these issues are expected to be similar causes for hindering market uptake under the new MFF mainly the following:

Various consultations indicated that very often the projects and the technologies or products that are being developed under them are not “user driven” enough. This implies that they do not answer to existing demand or to existing needs. They are rather “technology” or “innovation” driven, born from opportunities to develop new technologies.

The challenge in such projects is that even though they could be highly innovative and advanced, they might not have a proper business case, or the implication of technology adoption for the users have not been thoroughly addressed in the business case. End-users are most likely not going to adopt them given that the burden and the costs of that would outweigh the benefits. For example, if the state-of-the-art tech being developed is unnecessary for the users (i.e. higher accuracy levels, that do not impact the application for the user etc.), and the user would need to deal with complicated regulations, certifications, logistics, higher prices, changing the product in all their existing units, adapting their supply chain etc., then the user would refrain from adopting it. In this context, the commercialization and the go-to-market of the products under development would be extremely difficult, and unsuccessful.

Adding complexity to the situation is that within several projects, the consortia lacked the knowledge and expertise to achieve commercialization of their products and to launch them into market even though the consortia developed business plans as part of their project deliverables.

Therefore, the calls and the projects and the developments need to emerge from market gaps and user needs, be less driven by the willingness to develop a specific technology per se, and the adoption cost and implications considered in the business plan. They need to address a specific demand and user requirements to ensure a potential market uptake, and the consortia need to be better connected with the end users and their evolving needs and have a clearer market access. The calls also need to be more aligned with the developments and trends of the industry as it seeks to meet user requirements.

4.3. EUSPA's Conflict of Interest Policy

Introduction to EUSPA's Conflict of Interest Policy

According to its Anti-Fraud Strategy policy, EUSPA places the management of actual and potential conflicts of interest ('CoI') as a key element of its governance, as it contributes to maintain the trust of stakeholders and European Union citizens in its integrity. Moreover, an effective management of conflicts of interests enhance the credibility of the European GNSS and ensure legality and regularity of the Agency's processes.

High level assessment of EUSPA's CoI Policy

An assessment of the CoI Policy of EUSPA was planned under the framework of the study as underlined by article 102 of the Space Regulation:

“The evaluation [...] shall also address the Agency's policy on conflicts of interest”.

To assess the CoI policy, the team verified first that it matched the requirements of the Space Regulation. Then, a particular attention was paid to the consistency and the exhaustivity of the policy and to its practical application (% of topics covered, number of cases detected if any etc.) in order to have a global vision of its functioning.

In its Anti-Fraud Strategy policy document, EUSPA mentions following the *“OLAF Methodology in [its] analysis, which is supported by a background check on the requirements (EU Space Programme Regulation and ICF), the review of implementation of 2015 AFS (2021), and a limited but extensive review of audit and management reports over the last three years with an anti-fraud focus”*. Moreover it should be underlined that EUSPA's Anti-Fraud Strategy has been discussed with both OLAF and the European Commission Directorate-General for Defence Industry & Space prior to presenting it for approval of the Administrative Board.

At the highest level, we can note that the requirements of the Space Regulation have been fully fulfilled. Indeed, article 79 (q) of the Regulation requires Executive Director to draw up an anti-fraud strategy and article 77(2)(l) requires the Administrative Board to approve the anti-fraud strategy. These obligations have been respected since EUSPA has updated and adopted a new Anti-Fraud Strategy on the 25 of October of 2022.

Regarding specifically conflict of interest, article 99 underlines that a declaration of interests shall be made by Members of the Administrative Board and of the SAB as well as by the Executive Director, seconded national experts and observers, to declare the absence or existence of any direct or indirect interests which might be considered prejudicial to their independence. On a procedural level, this declaration shall be renewed annually and updated whenever necessary. This obligation is taken into account in EUSPA's policy of conflict of interest since it is for example restated in the Article 3 of the Agency's Decision on implementing rules on the prevention and management of conflicts of interests with regard to staff members and external workforce.

Article 20 also states the importance of paying attention to the management of conflict of interest in procurement procedures for innovative solutions. Regarding this point, during our consultation with the Internal Control Coordinator, we noted that there were particular areas of focus and adequate processes put in place while assessing the CoI policy at EUSPA (procurement, contract management, selection of experts, recruitment boards, post-employment, administrative board members) which means that EUSPA has succeeded in identifying situations which are the most likely to lead to a conflict of interest and in mitigating the risks by paying a particular attention to them.

At a more detailed level, the Conflict of Interest policy is structured around several pillars and adequate resources are made available:

- **In relation to staff, contractors and SNE:** a policy, implementing rules, CoI boards set up (and active) and active monitoring ;
- **In relation to departing staff (post-employment, Staff Regulation) :** implementing mechanisms in place and active ;
- **In relation to Administrative Board member :** specific CoI provisions in Rules of Procedures, and active monitoring in place.

An additional document in relation to Administrative Board members (post-employment) is currently under discussion.

The Agency demonstrates its willingness to prevent and if they exist, control conflicts of interest by ensuring that an effective conflict prevention and management policy exists. It has put in place various elements to have a good coverage of the CoI topics and it is estimated that the actual coverage percentage is around 98%. Additionally, the available resources define procedures to follow in the case of a CoI suspicion.

According to the information we gathered during our desk research as well as during the consultation, EUSPA's CoI policy is well structured. Until now, no particular issue has been reported regarding the effectiveness of the policy even though it is quite often used (every 2 weeks). It should also be noted that ECA audit report did not mention any irregularities relating to EUSPA's CoI policy and that a benchmark of other institutions' CoI policies showed that EUSPA is in line with the current international practices.

Takeaways

It can be stated that EUSPA has implemented its obligation to develop a COI policy in the first place. Its CoI Policy is deemed to be broad and comprehensive, in line with global benchmarks and standards. It has several layers and the agency has put in place specific procedures to ensure that the areas representing the highest risk in terms of conflict of interest are well covered. The adequacy of this policy is also reflected in the ECA audit report of 2022 in which no fraud nor irregularity has been detected.

APPENDIX

The appendix to this report constitutes 6 excel files containing the assessment of the implementation of the entrusted interventions and the activities constituting these interventions per Space Programme component per entrusted entity. Additionally, it contains the detailed assessment of the KPIs for the performance of the Space Programme components.

HOW TO OBTAIN EU PUBLICATIONS

Free publications:

- one copy:
via EU Bookshop (<http://bookshop.europa.eu>);
- more than one copy or posters/maps:
from the European Union's representations (http://ec.europa.eu/represent_en.htm);
from the delegations in non-EU countries
(http://eeas.europa.eu/delegations/index_en.htm);
by contacting the Europe Direct service (http://europa.eu/europedirect/index_en.htm)
or calling 00 800 6 7 8 9 10 11 (freephone number from anywhere in the EU) (*).

(*) The information given is free, as are most calls (though some operators, phone boxes or hotels may charge you).

Priced publications:

- via EU Bookshop (<http://bookshop.europa.eu>).

Priced subscriptions:

- via one of the sales agents of the Publications Office of the European Union
(http://publications.europa.eu/others/agents/index_en.htm).



Publications Office
of the European Union

doi: 10.2889/520780