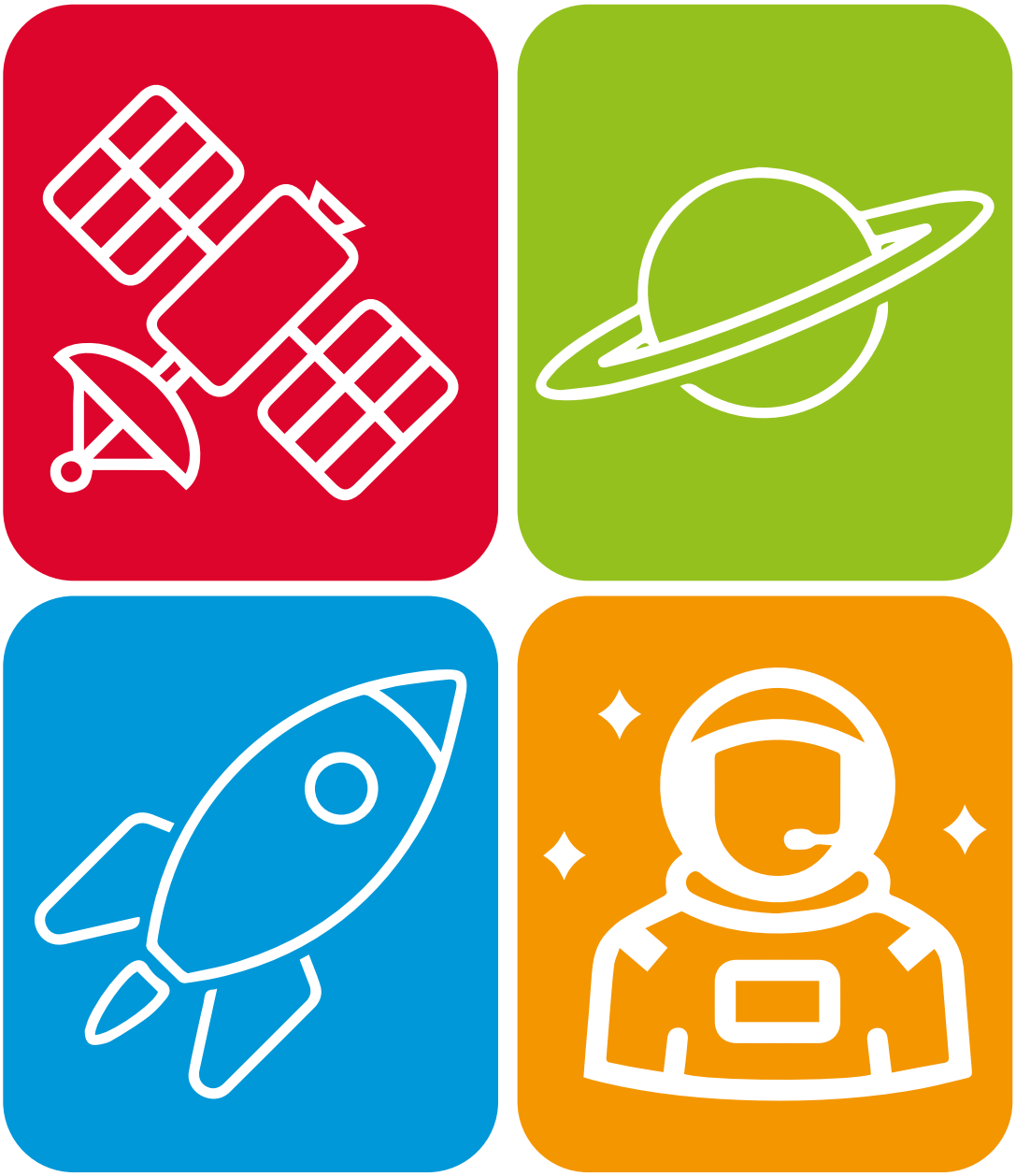
Scottish Science Advisory Council

Scotland's Space Sector: Exploring potential future opportunites



Contents

Executive Summary 3

1. Introduction 5

2. The Scottish Space Ecosystem 6

3. Scotland's current and emerging sector strengths and some weaknesses 7

4. Future Opportunities and Challenges 9

5. Competition and Collaboration 15

6. Conclusion and Recommendations 17

Acknowledgments 19

Annexes 19

Executive Summary

The Scottish and UK governments have identified the Space Sector as a significant opportunity to develop a thriving and innovative national space economy. The global space economy is projected to grow from an estimated £270 billion in 2019 to £490 billion by 2030.[1] This report is in response to a request to the Scottish Science Advisory Council, from the "New Market Clusters Team" of the Scottish Government, to help identify future opportunities (commercial and societal) for the sector in the next 10-20 years, aligned with Scotland's research and industrial strengths.

The report begins with a summary of the Scottish space ecosystem, noting that there are aspects reserved to the UK government and others devolved to the Scottish Government. We note the dual-use aspects of the sector in civil and defence, and we outline the current routes to funding for space projects and programmes.

An examination of Scotland's strengths and weaknesses reflects on heritage in contributions to space science missions and highlights the development of the "new space" sector in Scotland with its strong focus and expertise in small satellite manufacturing, data analytics, and its emerging strengths in the launch sector, potentially providing an "end-to-end" capability. Supporting the sector is an increasing number of infrastructure assets and the diverse strengths of the academic community. With an SME-dominated economy (small and medium enterprises), weaknesses noted include the difficulties in scaling our space-related businesses, the lack of a Scottish prime contractor and difficulties in accessing larger programmes.

An examination of future opportunities and challenges starts by considering areas for consolidating and stabilising the new space sector including satellite manufacture and launch. It explores areas where Scotland can provide leadership, such as in sustainable space, while acknowledging commercial constraints and how these can be alleviated. It recommends building on our expertise in data science and analytics and suggests exploring the use of satellite networking for opportunities to introduce new public and private services.

Leveraging our academic strengths is seen as a key driver of the Scottish sector, and making use of our breadth and depth in Enabling Technologies is seen as an important differentiator. Skills are seen as an area of focus with greater promotion of the sector in schools and increasing the talent pool through transferrable skills and apprenticeships. Looking longer-term, we examine opportunities in emerging themes such as in-orbit services and space resource utilisation.

Consideration of competition and collaboration looks at threats and opportunities from comparable nations such as the Nordic countries, and areas where we can learn from the use of legal frameworks in countries such as Luxembourg.

The recommendations are:

1. **National Contracts:** The Scottish Government should explore the use of national contracts to support and enable the growing Scottish space sector and associated supply chain.
2. **Co-created Research Programmes:** The Scottish Government should act to support co-created research programmes between academia and industry targeting innovation in satellite manufacture and operation, and work with relevant agencies to promote wider applicable themes in collaborative funding calls for critical and enabling technologies for Space Science Missions and Industrial Challenges.

1 https://www.gov.uk/government/publications/national-space-strategy

3. **Nordic Collaborations and Legal Frameworks:** The Scottish Government should explore collaborative opportunities with the Nordic nations in those areas devolved to it, and examine space legal frameworks, including Luxembourg's, with a view to influencing UK's own space legislation.
4. **Infrastructure and Educational Strategy:** The Scottish Government should commission Space Scotland and the Scottish Space Academic Forum to undertake an exercise covering the following areas:

    a. A mapping of the supporting infrastructure available to the space sector, examining opportunities for shared access to capital assets;

    b. A review of Scottish research activity in space "emerging themes" with a view to informing future strategic collaborative programmes; and

    c. The development of a strategy for promotion of the space sector across primary and secondary education.

5. **Entrepreneurial Programme for Space Data:** The Scottish Government should introduce a focussed entrepreneurial programme for space data start-ups linked to the existing Entrepreneurial Campus[2] and Techscaler[3] programmes. This should be promoted using Scottish space data start-ups as exemplar case studies and engaging SDI (Scottish Development International) with assistance to route-to-market.
6. **Economic Development Interventions:** The Scottish Economic Development agencies should look at using existing intervention mechanisms to help pump-prime the application sector for the use of satellite communications networks as an enabler of new innovations in service solutions for public and private services, to reduce cost and improve the quality-of-service provision for economic and societal benefit.
7. **Legislative Examination and Standards Engagement:** The Scottish Government should examine legislation already under development by Scottish and UK legislatures to explore opportunities to include the space environment, and encourage greater engagement, across the sector, with relevant standards bodies.

2 https://www.gov.scot/publications/entrepreneurial-campus-higher-education-sector-driving-force-entrepreneurial-ecosystem/
3 https://www.techscaler.co.uk/

1. Introduction

The Scottish Government has identified the Space sector as a key economic opportunity for the future through the National Strategy for Economic Transformation, the Inward Investment Plan and the recently published National Innovation Strategy.

The Scottish Space Strategy was launched in November 2021. It shares an ambition to deliver an annual contribution to the Scottish economy in excess of £4bn by 2030, with year-on-year sector growth of 26%, and a five-fold increase in the workforce. These targets reflect an evolution from the 2017/2018 figures, where Scotland's space industry contributed £245M total income (14% of UK space industry contribution), generated £880M in Gross Value Added (GVA), employed 8,500 individuals and saw a sustained annual growth rate of 12% since 2016.[4] The Scottish space workforce is approximately one fifth of all UK space jobs with 85% working in space applications, with the remaining 15% spread across space manufacturing, space operations and ancillary services. Key features of the Scottish strategy include developing space infrastructure and the research environment, consolidating Scotland as a leading UK location for space technology development, supporting the launch sector, growing the customer base for end-to-end solutions, increasing national and international collaboration, and aligning the sector with Scotland's Net Zero ambitions.

The approach adopted in preparing this report included: a) a literature review and desk research to examine the academic and industrial ecosystem in Scotland, together with a short study of comparable international markets; b) a set of survey questions informed by the desk research and completed by sector stakeholders; and c) an online roundtable of key stakeholders from industry, academia, and the wider public sector. This report draws on each of these sources of evidence and knowledge from within the SSAC to arrive at the key findings and conclusions.

4 https://spacescotland.org/wp-content/uploads/2023/11/a_strategy_for_space_in_scotland.pdf

2. The Scottish Space Ecosystem

The UK's national space strategy, published in September 2021, is jointly owned by the UK Space Agency (UKSA), the UK Government Department for Science, Industry and Technology (DSIT) and the Ministry of Defence (MoD). Areas related to national security, defence, and international relations, including regulation of satellite launches, spaceports, and membership of the European Space Agency (ESA), are typically reserved matters for the UK Government. Aspects of space policy and regulation that concern economic development, education, innovation and regional planning are devolved to the Scottish Government, although there may be some cross-over. Collaboration and co-ordination between the two governments on matters of mutual interest are accepted in areas such as space exploration, satellite technology, and the promotion of the UK space industry as a whole.

The UK Space Agency was established in 2010 and is responsible for coordinating the UK's civil space programme, overseeing strategic investments, and promoting the sector. The agency collaborates with industry, academia and international partners to advance scientific research, technology development, and space exploration. In March 2024, the agency announced that its new headquarters would be based in Harwell, Oxfordshire, with regional offices in Scotland, Wales and the Midlands. The Scottish office of UKSA will be located at Queen Elizabeth House in Edinburgh.[5]

The Scottish Space Strategy was formulated with input from the Scottish Government Space Group, Space Scotland[6] and the Scottish Space Academic Forum. Within the Scottish Parliament there is an active cross-party working group of MSPs. Enterprise agencies, including Scottish Enterprise (SE), Highlands & Islands Enterprise (HIE), and South of Scotland Enterprise (SOSE), have all assigned policy leads for space.

With over 133 Scottish space organisations, the Scottish ecosystem is diverse and expanding. A brief overview of the industrial landscape is detailed in Annex E, and a similar snapshot of the Scottish Space academic network is outlined in Annex F.

Space is a dual-use environment. With a view to having a sovereign defence space capability, the Ministry of Defence established UK Space Command (UKSC) in 2021.[7] The UKSC has three functions: space operations, space workforce generation, and space capability. It was noted that much of this is built on prior UK civil investment, and the sector would benefit from civil-defence partnerships. However, the Scottish sector is not inherently dual-use nor actively engaged with the defence and security industries as seen elsewhere in the UK. Progress in this area would amplify Scotland's contributions to national security and defence. For the most part, this report concentrates on civil space sector opportunities.

Funding routes for space-related innovation development can come from a variety of routes: government grants and funding programmes from UK Space Agency (UKSA), Innovate UK as well as the enterprise agencies; research council grants for academic institutions and researchers (UKRI, including STFC, NERC, EPSRC); European Space Agency (ESA) contracts and collaborations; EU Horizon Europe programme; private investment and venture capital; and industry partnerships and collaborations. Defence-related funding can also come from the Defence and Security Accelerator (DASA), Defence Science and Technology Laboratory (Dstl) and through collaborative funding from MoD; the Advanced Research & Invention Agency (ARIA) has funding aimed at supporting high-risk, high-reward research and innovation projects.

5 https://www.gov.uk/government/news/uk-space-agency-announces-new-headquarters-and-regional-offices
6 https://spacescotland.org/
7 https://www.gov.uk/guidance/uk-space-command

3. Scotland's current and emerging sector strengths and some weaknesses

Scotland has heritage and contributions to space missions which continue to the present day, including supplying components for lunar and deep space exploration. These come from research organisations such as the UK Astronomy Technology Centre based at the STFC's Royal Observatory Edinburgh site, and industrial companies such as WL Gore and Star Dundee, through to the optical bench system for the LISA gravitational space interferometer developed by the University of Glasgow,[8] and the HABIT ExoMars Mission instrument developed by the University of Aberdeen.[9] However, the growth in the "new space" sector can be linked to the formation of Clyde Space in 2005 and the development of small satellite manufacturing and associated supply chain, which attracted other manufacturers and start-ups in this area. Indeed, an often-quoted statistic is that Glasgow builds more small satellites than any other city in Europe.

The sector in Scotland today is still dominated by small satellite manufacture but this is being augmented and diversified by the creation of an end-to-end ecosystem including the development of five dedicated launch sites and the emergence of launch vehicle manufacturers such as Orbex and Skyrora. These elements, together with the strength of the Scottish Data Analytics academic and industrial community, centred around Edinburgh, provide the connected elements of a national end-to-end space offering. Strengths exist in specialist component design and manufacture although the relationships with systems engineering companies is an area for improvement.

In the downstream sector, there is an established cluster of companies, public and private organisations including NGOs (Non-Governmental Organisations), working in Earth Observation, many of which are targeting services in natural capital data for forestry, agriculture, land use, biodiversity monitoring and climate change monitoring and mitigation. This feeds into elements of the "sustainable space" agenda, where Scotland is acknowledged to be a leader having introduced one of the first roadmaps in this area, "The Space Scotland Sustainability Roadmap", published in 2022.[10]

Scotland's strengths in the space sector are underpinned by a significant depth and breadth in "Enabling Technologies". This catch-all term is often used to describe technologies which can be applied across multiple sectors, and which are used to derive complementary innovations in an industry, much of which is driven by outputs from university research. Examples include Photonics, Quantum Technologies,[11] Robotics and Automation, Communications Technologies, Sensing and Imaging Systems, Cybersecurity, Advanced Manufacturing, Engineering Biology and many others. For example, more than 75% of Scottish companies working in photonics are active in more than one operational sector.[12]

While the above indicates areas of the ecosystem where Scotland has strength, it is acknowledged that the "new space" sector is still nascent, and support will be required to consolidate and deliver on its potential.

8 https://www.physics.gla.ac.uk/igr/index.php?L1=detectors&L2=lisa
9 https://www.abdn.ac.uk/geosciences/departments/planetary-sciences/habit-1567.php
10 https://spacescotland.org/wp-content/uploads/2023/11/Space-Sustainability-A-Roadmap-for-Scotland-Compressed-Version.pdf
11 https://scottishscience.org.uk/publications/ssac-report-quantum-technology-opportunities-scotland
12 https://technologyscotland.scot/wp-content/uploads/2022/10/Photonics-Survey-2022-final-version.pdf

The small satellite market is maturing, and steps need to be taken to avoid Scottish manufacturers being outcompeted by larger international players who can ramp-up mass manufacture. Differentiation can be maintained by improvements to product design and specification and/or improvements in infrastructure for manufacture. Scale-up is a significant challenge for companies and current mechanisms should be examined, and if necessary evolved, to support this. Diversification will help the sector and there are promising signs of development in larger sized medium earth orbit (MEO) and highly elliptical earth orbit (HEO) satellites for satellite-enabled communications networks and cloud services by Mangata, an inward investment with a proposed space engineering R&D Centre (Research and Development) and operations hub based at Prestwick.[13]

In the space sector, Scotland is dominated by SMEs with a lack of an established prime contractor. This is in contrast to other regulated industries such as Defence or Oil and Gas, where a cascading subcontract culture is more obviously beneficial to SMEs. As such, it is difficult for these SMEs to gain access to larger programmes from ESA and elsewhere. There is also a lack of specialist venture capital, including patient capital, as compared to the "Golden Triangle" in the southeast of England. It is not yet possible to raise required finance wholly in Scotland. This is considered a risk that has led some SMEs to locate their headquarters outside Scotland. Also, with UKRI's increased emphasis on "challenge led" R&D funding, the proportion of funding coming to Scotland has seen a reduction in recent years.[14]

To counter these challenges, fostering a more supportive ecosystem for SMEs and start-ups is seen as being key. Initiatives could include the development of a Scottish space sector investment fund, tailored financial instruments for space enterprises, and enhanced mechanisms for participation in larger international space projects. Strengthening connections with global space industry networks and encouraging the establishment of prime contractors within Scotland could significantly elevate the sector's international standing and capabilities.

A more detailed review of Scotland's strengths in research and industry can be found in Annexes E and F.

13 https://www.mangatanetworks.com/
14 https://researchbriefings.files.parliament.uk/documents/SN04223/SN04223.pdf

4. Future Opportunities and Challenges

Future opportunities often rely on consolidating and building on existing strengths. There is no doubt that Scotland has built up an enviable position in the manufacturing of small satellites. Many respondents in this area have reported on the challenges associated with scaling up their businesses. Competition is growing in the small satellite sector and there are some concerns that market saturation and arrival of lower cost competitors may threaten future commercial opportunities. With that in mind, it is important that Scotland maintains differentiation through innovation and optimised manufacturing infrastructure. Co-creation of targeted research programmes between industry and academia will support the former and it is suggested that the use of shared infrastructure together with closer integration of national assets in the sector, such as the National Manufacturing Institute of Scotland (NMIS) and the National Robotarium, will help support the latter.

There is desire from stakeholders for a coherent investment strategy in Scotland to support sector growth, perhaps including a space investment marketplace, set up to create a sector-specific investment fund involving Scottish National Investment Bank and others, plus support for exporters through strategies such as "Scotland: A Trading Nation".[15]

Several respondents indicated that a move away from government support in the form of grant funding to government contracts involving the satellite end-to-end ecosystem would be highly beneficial. In this case, the Scottish Government would be a procurer of space data (Earth Observation) from Scottish companies, supplied from Scottish satellites, launched from Scottish Spaceports. This would help maintain Scottish competitiveness and provide opportunities to validate existing and emerging developments. Indeed "Advance Market Commitments (AMC)" are being promoted by Innovate UK as potential valuable mechanisms for scaling innovation in Net Zero and other areas.[16] Application areas include examples such as environmental monitoring and forestry. Long-term anchor contracts of 5 years or more to data suppliers would help attract further investment. One example of this type of model is Terra SAR-X, a public-private venture from the German Government and EADS Astrium.[17]

> **Recommendation:** The Scottish Government should act to support co-created research programmes between academia and industry targeting innovation in satellite manufacture and operation, and work with relevant agencies to promote wider applicable themes in collaborative funding calls for critical and enabling technologies for Space Science Missions and Industrial Challenges.
>
> **Recommendation:** Space Scotland should be commissioned, alongside the Scottish Space Academic Forum, to undertake a mapping exercise of supporting infrastructure available to the space sector with an examination of opportunities for shared access to capital assets such as manufacturing and test facilities.
>
> **Recommendation:** The Scottish Government should explore the use of national contracts to support and enable the growing Scottish space sector and associated supply chain.

Space sustainability is an area, raised by many respondents, where Scotland is seen to be a leader. The World Economic Forum notes that "in the near future, space debris will become a critical challenge for the global community, endangering access to space and the benefits this access brings".[18] With the orbital environment being a globally shared resource, current standards are both insufficient and unenforceable failing to prevent a significant build-up of debris and an increasing collision risk.

15 https://www.gov.scot/publications/scotland-a-trading-nation/
16 https://www.ukri.org/blog/the-innovation-demand-paradox/
17 https://earth.esa.int/eogateway/missions/terrasar-x-and-tandem-x
18 https://www.weforum.org/projects/space-sustainability-rating/

Opportunities exist to provide solutions based on multi-stakeholder public-private collaborations. Space sustainability is also seen as a mechanism to help with the delivery of the United Nations Sustainable Development Goals (SDG).[19]

The Scottish space sector's sustainable space roadmap, published in November 2022, is the first initiative of its type, addressing issues from the environmental implications of the space industry to the growing need for businesses to deploy satellite data for environmental monitoring and climate analytics. This has garnered interest from UKSA and elsewhere. Respondents referenced several points including the development of green propellants by the launch sector (Orbex is actively engaged in this area), space debris removal and mitigation, reducing the impact of space resource utilisation, and the use of Earth Observation data for climate health monitoring, where Scotland has a track record of company creation, although again the point was made about failures in scaling these companies.

Innovating in space traffic management and actively participating in international dialogues on space law and governance could further Scotland's leadership in sustainable space. Developing technologies and frameworks that enable responsible use of space resources and ensuring the long-term sustainability of outer space activities are areas where Scotland can contribute at a global level.

There is a growing international interest, notably in the US, including NASA, regarding the utilisation of biotechnologies for sustainable space exploration and the potential benefits these could offer. Scotland has significant expertise in synthetic and engineering biology and the potential to emerge as a leader in the intersection of human space exploration and space sustainability with several research groups focusing such biotechnologies to enable the circular economy, including the UK Centre for Astrobiology at the University of Edinburgh.

Having leadership in sustainable space is one thing; being able to exploit the outputs of that leadership is quite another. The challenge is that sustainable practices may be in tension with commercial exploitation if those practices are not implemented everywhere. The solution may be found in international collaboration and legislation. International legislation is not yet in place and therefore future development will be essential.

The Artemis Accords[20] are a series of non-binding bilateral arrangements between the United States Government and other world governments that sets out the norms expected to be followed in outer space, particularly with lunar development. These could be expanded upon and could act as a template for other multi-country legislation on space sustainability.

Some respondents pointed to the Scottish Government's proposed Human Rights Bill, one of the first common law jurisdictions to establish a human right to a healthy environment, and whether this could be extended to cover space, through working with the UK Government to include legal protection and a policy framework for regulation of the sustainable space environment. Wherever and whenever new regulations are formed, it was recognised that it is important that Scotland strives for increased representation on standards committees and having a "voice in the conversation". This is reinforced from experiences in other sectors such as Oil and Gas, where those who set the standards are often best placed to benefit from them (cf. Rocket Lab,[21] a California-based space system company, who have been proactive in helping to develop space standards).

19 https://sdgs.un.org/goals
20 https://www.nasa.gov/artemis-accords/
21 https://www.rocketlabusa.com/

> **Recommendation:** The Scottish Government should examine legislation already under development by Scottish and UK legislatures to explore opportunities to include the space environment, and encourage greater engagement, across the sector, with relevant standards bodies such as the National Physical Laboratory (NPL), the British Standards Institution (BSI) and others.

The use of satellite-derived space data and the use of satellite-enabled communications networks are both areas that can provide new opportunities for key application and service providers.

As an SME-dominated country, data-based solutions offer low cost of entry for start-ups and SMEs. Scotland's industrial and academic strengths in data processing and analytics suggests that this could be a significant area to develop.

There are a number of providers of free, or low cost, satellite data such as the Sentinel-3 Copernicus Online Data Access (CODA) service. SMEs already take advantage of these data, including (for example) Trade in Space Ltd, who use satellite data and distributed ledger technology (asset tokenisation) to provide micro-financial services applications globally in the agriculture sector.

Expanding the utilisation of satellite data for advanced analytics and AI-driven insights could open new frontiers for Scotland's space sector, particularly in agriculture, forestry, maritime surveillance, and urban planning. Enhancing capabilities in satellite data analytics and fostering start-ups in these domains could enhance Scotland's position in the space data economy.

By encouraging and promoting greater entrepreneurship in space data applications, Scotland can grow this part of the commercial space sector significantly.

Alongside this, the introduction of satellite communications networks (e.g. Starlink) for secure, high-bandwidth, low latency, cloud services, has opened opportunities to deliver service-based applications across a variety of sectors including maritime, aerospace, transport, healthcare, fintech, agriculture, including "Internet of Things" (IoT) services in areas not covered by terrestrial cellular networks. Prestwick-based Mangata is an emerging entrant to this market, with satellites being developed for MEO and HEO orbits, together with Edge data servers for data processing closer to the application. Respondents noted that Scotland is an ideal "sandbox" for a diverse range of space related applications having an established ecosystem alongside a varied metropolitan/rural/maritime environment.

> **Recommendation:** The Scottish Government should introduce a focussed entrepreneurial programme for space data start-ups linked to the existing Entrepreneurial Campus[22] and Techscaler[23] programmes. This should be promoted using Scottish space data start-ups as exemplar case studies (for example Trade in Space Ltd) and engaging SDI (Scottish Development International) with assistance to route-to-market.

> **Recommendation:** The Scottish Economic Development agencies should look at using existing intervention mechanisms to help pump-prime the application space for the use of satellite communications networks as an enabler of new innovations in service solutions for public and private services, to reduce cost and improve the quality-of-service provision for economic and societal benefit.

22 https://www.gov.scot/publications/entrepreneurial-campus-higher-education-sector-driving-force-entrepreneurial-ecosystem/

23 https://www.techscaler.co.uk/

The section on Scotland's sector strengths above highlighted "Enabling Technologies" as being one of our key strengths in the space ecosystem. While this has been acknowledged, to some extent, via support through the cluster organisation Technology Scotland and translational assets such as Fraunhofer CAP and CENSIS, many respondents felt that there was a lack of connectivity across the individual technologies that could benefit from greater co-ordination and sector-specific focus. This has started to be recognised at both Scotland and UK level with the proposal of a Scottish "super-cluster" of critical technologies comprising quantum technologies, photonics, semiconductors and wireless communications, and at UK level with DSIT defining five critical technologies: AI, engineering biology, future telecommunications, semiconductors, and quantum technologies.[24]

The Scottish supercluster comprises over 140 companies, generating more than £3.6 billion in turnover, £1.2 billion GVA and supporting over 10,000 jobs. This cluster is understood to be the largest in the UK, outside the East and Southeast of England. Some other adjacent technologies, which are cited as being particularly relevant to the space sector, include cybersecurity, with a focus on secure-by-design aspects across the supply chain, and technology related to the gaming sector. Cybersecurity particularly has been identified by the Scottish Government as a key enabler of the space sector with Scottish expertise in a number of areas including quantum key distribution for satellite communications.[11] Several national agencies are developing frameworks and guidelines related to cybersecurity including the USA and Germany, who have initiated the development of technical guidelines for satellite security.

While some informal cross-technology alliances are already in formation, such as "Photonics for Space"[25] special interest groups within Technology Scotland and UKRI's Knowledge Transfer Network (KTN), there is perceived to be a lack of project-related cooperation with defined outcomes, designed to secure technological advantages for the Scottish and UK space sector. Examples of such activity could include alleviation of congestion of the RF spectrum by development of secure AI-enabled photonics for ground-to-satellite or satellite-to-satellite communications, the use of compound semiconductors for novel satellite imaging components, or the use of engineering biology for space-based pharmaceutical manufacturing.

> **Recommendation:** The Scottish Government should work with relevant agencies to promote wider applicable themes in collaborative funding calls for critical and enabling technologies for Space Science Missions and Industrial Challenges.

Running through all the above narrative is the subject of skills. Representatives of the industrial space sector have observed that hiring staff with five or more years' experience in the space sector is difficult due to the limited talent pool, while sector growth is making retention challenging. It was also noted by respondents that access to experienced talent from Asia and Europe is not currently available to companies in the UK and that much of the R&D funding available (UKSA) is short duration, feeding into the overall skills shortage. Many respondents also remarked on the lack of diversity and highlighted that more could be done to encourage women and girls into the sector. Other, more established, sectors can address some of these challenges through co-investment with skills providers to develop tailored programmes matched to industry demand, which are not yet available in the Scottish space sector. While recognising that the skills required are competed for by other sectors, there exist opportunities for workers with transferable skills from other sectors to move into space, especially from regulated industries such as Oil and Gas, Subsea engineering, Nuclear and Defence. Indeed, it was pointed out that some engineering companies in these sectors could diversify into space if they had the vision and ambition to do so.

24 https://www.gov.uk/government/publications/uk-science-and-technology-framework/the-uk-science-and-technology-framework

25 https://photonicsscotland.com/photonics-for-space/

Although there was a desire to see more space-focused courses in higher education (cf. the International Space University in France) and further education (tailored Modern Apprenticeships), increasing the talent pool over the long term will require more focused effort on promotion of the sector as an available and attractive career choice from primary and secondary school age. It was also stressed that as manufacturing companies scale, the numbers of technicians significantly outweigh the numbers of HE graduates required. The use of space as a flagship sector for attracting more students into STEM education was raised as a significant opportunity. In addition to promoting space as a career choice, integrating space-related projects and competitions into the educational curriculum could inspire the next generation of space professionals. Collaborations with industry to provide hands-on experiences and internships would bridge the gap between education and employment, ensuring a steady pipeline of skilled individuals ready to contribute to Scotland's growing space sector.

> **Recommendation:** The Scottish Government should commission Space Scotland and the Scottish Space Academic Forum to develop a comprehensive strategy for promotion of the space sector in schools and the development of relevant education and training at all levels. This should be developed in partnership with relevant organisations such as Primary Engineer,[26] Stemettes,[27] and others to stimulate and inform young people about career opportunities in the sector and the skills required. This scope could be expanded to higher education levels if capacity allows.

The newly formed launch sector in Scotland is seen as being a key part of the end-to-end capability in Scotland, and support for the launch sector is a central pillar of the current Scottish Space Strategy. Success in this will depend on keeping the launch pipeline filled, with a move towards fast-track or on-demand launch services and streamlining the licencing process. Also, fundamental to this will be the establishment of supporting infrastructure to the more remote space ports such as transport, logistics and accommodation.

Looking further forward, respondents were keen to emphasise opportunities for Scotland arising in the following areas, many of which appear under "emerging sectors" in the UK National Space Strategy:

In-orbit servicing. There were of the order of 10,000 satellites launched in the last 70 years. It is expected that anywhere between 30,000 and 60,000 will be launched in the next decade. Part of space logistics, in-orbit servicing involves orbit transfer of satellites, satellite servicing, life extension and remediation, and de-commissioning. These services will rely heavily of specialist areas of robotics and automation. There are already companies operating in this field such as Italian start-up D-Orbit.[28] National assets in Scotland (e.g. NMIS, UKATC at the Royal Observatory, and the National Robotarium) could make a significant contribution here.

Active debris removal (ADR). Simulations run by ESA and NASA show that, even with the current density of objects in space, the number of debris objects would continue to grow with a forecast collision rate of once every 5-9 years. ESA's "CleanSpace"[29] initiative is looking at the required technology developments for ADR, including advanced image processing, complex guidance, navigation and control and innovative robotics to capture debris.

26 https://www.primaryengineer.com/
27 https://stemettes.org/
28 https://www.dorbit.space/
29 https://www.esa.int/Space_Safety/Clean_Space/Clean_Space2

In-space manufacturing. Environmental factors such microgravity and vacuum allow for production of materials that are otherwise difficult to produce on Earth. These may include exotic material such as superalloys, certain optical crystals, carbon nanotubes, crystallisation of protein-based pharmaceuticals, and others.[30] Production processes for these will require the use of autonomous or semi-autonomous robotics, or a human crew. In-orbit fabrication involves direct printing of materials to manufacture space structures. In-space modular assembly of assets, such as observatories and science platforms, allows for the modular construction of assets unconstrained by the specifications of a single launch vehicle.

Space travel, habitation and tourism. Programmes involving human spaceflight are increasing including NASA's Artemis missions[31] to develop a sustainable staffed base and lunar economy on the Moon. These will require innovations in areas such as engineering, energy generation, in-situ-manufacturing, life sciences, human health, and robotics. Scotland has an opportunity to contribute to these programmes given our strengths in many of these areas and our transferrable expertise from other sectors. With the prospect of future industrial activity in Earth orbit, a mix of human and robotic activity can be envisaged, with strong parallels to the remote working of North Sea oil and gas exploration. Collaboration between government agencies, industry partners, and academic institutions will be essential to drive these innovations forward.

Space resource utilisation. This includes extraction and use of resources beyond Earth. In-situ utilisation can support programmes such as Artemis, mentioned above, using resources such as water ice and mined material from the Moon (regolith) or asteroids. Water in particular can be electrolysed into hydrogen and oxygen to manufacture propellant in space. This offers the possibility of commercial propellant re-supply services to spacecraft in orbit at a lower cost than lifting propellant from the bottom of the Earth's deep gravity well. There are a number of opportunities to examine here including what may be required in terms of infrastructure and support. We also acknowledge that space resource utilisation can be a contentious area, given the Scottish Government's focus on environmental sustainability and the circular economy.

Space-based energy. There are numerous concepts for this including Solar Power Satellites (SPS) and larger orbital solar farm arrays, collecting solar energy in orbit and wirelessly transmitting that energy to Earth using microwave transmitters or lasers to ground stations for conversion to electricity. These have advantages of being free from the influence of weather patterns and nightfall and can be directed to locations not covered by terrestrial grids. There are a number of Scottish universities with research that is directly relevant to this application including the Universities of Glasgow and Strathclyde.

> **Recommendation:** Scotland has research activity in all six of the above mentioned "emerging themes". The Scottish Government Space Group should engage the Scottish Space Academic Forum and Space Scotland to undertake a mapping exercise to highlight these areas as a collective, with a view to informing future strategic programmes and collaborations.

30 https://www.nasa.gov/international-space-station/space-station-research-and-technology/in-space-production-applications/

31 https://www.nasa.gov/feature/artemis/

5. Competition and Collaboration

A brief review of competition risks and collaboration opportunities is outlined in Annex G. The key points are summarised below:

With more than 70 countries investing in space, our closest collaborations are expected to be in our relations with our UK partners and aligned with the UK Space Strategy being delivered by UKSA, and in Europe with the related association with ESA. That view was reflected by a majority of our respondents. Other opportunities may lie with participation in large lunar and Martian programmes from NASA. For security collaboration, the "five eyes" of UK, USA, Canada, Australia and New Zealand are seen as being especially important.[32] That said, there are strategic objectives and considerations from a purely Scottish national perspective that make an assessment of "comparable countries" worthwhile, including countries in Europe and elsewhere, which have economies and populations comparable to Scotland. Such countries also have comparable space ambition, timing, programs, progress, space relevant geography, and national strategies. Some of those considered include Sweden, Luxembourg, Lithuania, Belgium, Norway, Denmark, Finland, and Israel. Many of these may emerge as potential competitors or collaborators, or both.

Most of these nations showed documented ambition and commitments in the space sector, including commercial space activities, particularly in the past half-decade (2016-2022), and have declared space strategies either for the first time or published a revised version to include their current capabilities and forecasts.

The "small satellites segment" is expanding in multiple comparable countries, emerging as a high priority in their strategies with ambitions to build and promote a relevant supply chain within the nation or via collaboration. Sweden appears as a likely main competitor although also a potential source of inward investment (in 2019, AAC Clyde Space was formed following acquisition of Clyde Space by AAC Microtec). In addition, Sweden has had an ongoing focus on the launch sector in recent years (cf. Esrange Space Centre[33]) backed by its well-established aerospace and defence industry (Saab, OHB), and expanding capabilities to include satellite tracking, telemetry, and command services, as well as hosting ground stations for satellite communication and Earth observation. Sweden therefore presents strong competition to Scotland in the space sector overall. With a geographical and economic proximity, one important aspect of this competition could be in attracting relevant funding from EU programmes or private investment, which could have a significant impact on the overall growth of the sector in either country. Among other comparable countries, Luxembourg (with Société Européenne des Satellites), Israel (with Israel Aerospace Industries) and Belgium (with Thales Alenia Space) are also seen to have strong positional focus on satellite manufacturing and data services.

Beyond satellite manufacturing and launch services, Luxembourg's space activities, including its very recent legal framework for space resource exploration, may present potential competition to Scotland's space sector. Luxembourg has established an efficient legal and regulatory framework with a dedicated space law for the exploration and utilisation of space resources making it the first European country to offer such regulations in the space sector.[34] These regulations provide clarity and stability for space ventures, which can help attract international operators and investors. The legal framework in Luxembourg supports commercial space projects and space mining ventures. Scotland may gain from learnings in space law, and in technical or commercial collaborations with small countries like Luxembourg and Lichtenstein. This is relevant considering their success in the early setup and implementation of a legal and regulatory framework, which has proven useful in attracting business and investment in the space sector despite their small size.

32 https://www.cigionline.org/articles/the-five-eyes-and-space-a-new-frontier-for-an-old-intelligence-alliance/
33 https://sscspace.com/esrange/
34 https://space-agency.public.lu/en/agency/legal-framework.html

While Scotland has no immediate strategic roadmaps for space resource utilisation, energy from space or space tourism, these have started to appear in the strategies of some comparable countries, notably Sweden and Denmark. Strategic collaboration with other small countries, especially the Nordic nations, may lead to partnership opportunities in these and other areas. With limited budgets, collaborations will become more important, avoiding independent developments in areas requiring heavy investment. Engaging in joint ventures and projects with these countries could leverage Scotland's strengths and mitigate competition risks by fostering a collaborative rather than competitive environment in the niche segments of the space industry.

> **Recommendation:** The Scottish Government should explore collaborative opportunities with the Nordic nations in those areas devolved to Scottish Government, and examine space legal frameworks, including Luxembourg's, with a view to influencing UK's own space legislation.

6. Conclusion and Recommendations

The "New Space" sector in Scotland is still in the formative stage. Action taken now will have significant consequences for the stability and growth of the sector. By leveraging the strengths of our academic and industrial communities in support of the sector, Scotland can derive significant economic and societal benefits for its citizens. As a small country, collaboration will be key to ensuring that we maximise the opportunities that the space sector offers, including collaboration with the rest of the UK and Europe, collaboration in translating our academic research into industrial impact, and the formation of successful partnerships across our industrial base and with external partners.

Our recommendations cover the following areas:

1. The use of intervention mechanisms at their disposal by the Scottish Government and the enterprise agencies to support the sector;
2. The introduction of focussed academic and collaborative research programmes to benefit the space sector;
3. Promotion of space in schools and in entrepreneurship to help secure the sector's long-term future;
4. The use of sector mapping to establish opportunities for use of collaborative infrastructure and expertise; and
5. The role of legislation and standards in supporting the sector.

We recommend:

1. **National Contracts:** The Scottish Government should explore the use of national contracts to support and enable the growing Scottish space sector and associated supply chain.
2. **Co-created Research Programmes:** The Scottish Government should act to support co-created research programmes between academia and industry targeting innovation in satellite manufacture and operation, and work with relevant agencies to promote wider applicable themes in collaborative funding calls for critical and enabling technologies for Space Science Missions and Industrial Challenges.
3. **Nordic Collaborations and Legal Frameworks:** The Scottish Government should explore collaborative opportunities with the Nordic nations in those areas devolved to it, and examine space legal frameworks, including Luxembourg's, with a view to influencing the UK's own space legislation.
4. **Infrastructure and Educational Strategy:** The Scottish Government should commission Space Scotland and the Scottish Space Academic Forum to undertake an exercise covering the following areas:

    a. A mapping of the supporting infrastructure available to the space sector, examining opportunities for shared access to capital assets;

    b. A review of Scottish research activity in space "emerging themes" with a view to informing future strategic collaborative programmes; and

    c. The development of a strategy for promotion of the space sector across primary and secondary education.

5. **Entrepreneurial Programme for Space Data:** The Scottish Government should introduce a focussed entrepreneurial programme for space data start-ups linked to the existing Entrepreneurial Campus[35] and Techscaler[36] programmes. This should be promoted using Scottish space data start-ups as exemplar case studies and engaging SDI (Scottish Development International) with assistance to route-to-market.
6. **Economic Development Interventions:** The Scottish Economic Development agencies should look at using existing intervention mechanisms to help pump-prime the application space for the use of satellite communications networks as an enabler of new innovations in service solutions for public and private services, to reduce cost and improve the quality-of-service provision for economic and societal benefit.
7. **Legislative Examination and Standards Engagement:** The Scottish Government should examine legislation already under development by Scottish and UK legislatures to explore opportunities to include the space environment, and encourage greater engagement, across the sector, with relevant standards bodies.

35 https://www.gov.scot/publications/entrepreneurial-campus-higher-education-sector-driving-force-entrepreneurial-ecosystem/
36 https://www.techscaler.co.uk/

Acknowledgments

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Annexes

Annex A – Invitation and questionnaire

Annex B - Roundtable programme, attendees and breakout group notes

Annex C – Roundtable presentations

Annex D – Summary of survey responses

Annex E – Brief overview of Scottish industrial landscape

Annex F – Brief overview of Scottish academic landscape

Annex G – Brief review of competition and collaboration opportunities

Produced for Scottish Science Advisory Council by APS Group Scotland, 21 Tennant Street, Edinburgh EH6 5NA
(May 2024)

scottishscience@gov.scot

ANNEX A

SSAC REPORT – Scotland's Space Sector: Exploring potential future opportunities

INVITE LETTER AND QUESTIONNAIRE

15 January 2024

Dear colleague

Invitation to collaborate on Exploring Future Commercial Opportunities in Scotland's Space Sector

We are contacting you on behalf of the Scottish Science Advisory Council (SSAC) – Scotland's national independent scientific advisory body. The SSAC has recently established a Short-Life Working Group (SLWG) to engage with key stakeholders across Scotland. Our goal is to gather valuable insights to consider and assess the longer-term future opportunities within the global space sector.

This initiative is crucial for placing Scotland at the forefront of space industry advancements. It aims to ensure that our nation remains globally competitive and reaps both economic and societal benefits from a robust space sector. To this end, the SLWG has identified several key areas of focus, working with policy officials in the Scottish Government's (SG) Division for New Market Clusters. These include:

- Identifying prioritised future opportunities in the global space sector over the next 10-20 years, aligning with Scotland's research and industry strengths.
- Outlining actions to position Scotland's research community to support and capitalise on these opportunities, including delineating the roles of industry, academia, and government.
- Addressing challenges across these opportunities and considering potential international collaboration partners.
- Assessing comparable international markets to derive key findings.

Our methodology encompasses gathering responses from a diverse range of stakeholders through an attached questionnaire, due no later than **31 January 2024**. Subsequently, we will host a virtual roundtable on **21 February 2024**, from 10:00 to 14:00, to further explore these topics and discuss findings from the questionnaire responses.

Further details on the roundtable will be issued to those completing the questionnaire in due course.

As an esteemed expert in this sector, your insights would be immensely valuable to this national initiative. We encourage you to share your perspectives by completing the attached open-ended questionnaire. Feel free to collaborate with colleagues in

your institution or department for comprehensive responses. Please respond to the questions you are most comfortable with, if unable to address all sections.

Please note that questionnaire responses may be shared with the relevant policy team within the Scottish Government. Should you prefer to submit your responses anonymously, please indicate this in your reply, and we will ensure confidentiality.

Please send your questionnaire responses, and confirmation of your participation in the Roundtable, to Christine.lawson@gov.scot **no later than Wednesday 31 January 2024**. The insights gathered from the roundtable and questionnaire will be examined by the SLWG to inform a formal report, to be published on our website in Spring 2024 and shared with all respondents.

We appreciate your engagement in this important initiative.

Yours sincerely,

Professor Julian Jones
SSAC Chair

Dr Graham Kerr
SSAC Project Lead

Questionnaire

Respondent

Name:
Organisation:
Email:

1. Data protection

Please highlight how would you like your response to be considered:

a. Kept confidential to the SSAC and used solely for informing this study.
b. Quotes from your response could be used (in the Roundtable and/or report) but not attributed
c. Quotes from your response could be used (in the Roundtable and/or report) and attributed to your organisation.
d. Quotes from your response could be used (in the Roundtable and/or report) and attributed to you.
e. Your response could be shared in whole or part with relevant policy officials in Scottish Government.

2. Questions for consideration

i. What are the strengths of the Scottish Space sector? How can these strengths be consolidated and enhanced to maximise benefit to Scotland over the next two decades? (In your answer, please consider the strengths of the both the academic and industrial sectors).

ii. Where are the greatest opportunities for Scotland in the Space Sector in the next 10-20 years and where should we focus our priorities?

iii. What mechanisms and interventions are required to ensure Scotland maximises the benefits of the Space Sector for the Scottish economy?

iv. Which countries are going to be the most important international collaboration partners for Scotland and what is required to enable these partnerships and to ensure that Scotland is at the forefront of the sustainable space agenda?

v. Does Scotland have the skills needed to support the space sector in the next two decades? Are there sectors with transferable skills that can be retrained? How do we promote a steady conduit of graduates with the necessary skills?

vi. How can Scotland's space sector align with and contribute to broader national and international goals in areas such as climate change, AI, technology innovation, and education?

vii. What role do you see for public-private partnerships in advancing Scotland's space sector, and what models or examples could we look to for successful collaboration?

viii. In which areas of the Scottish technology industry and research community is the Space Sector already an important customer and what are the key relevant technologies.

ANNEX B

SSAC REPORT – Scotland's Space Sector: Exploring potential future opportunities

ROUNDTABLE PROGRAMME, ATTENDEES AND BREAKOUT GROUP NOTES

SSAC VIRTUAL ROUNDTABLE

21 February 2024, 11.00-14.00

Programme

11:00-11:05	Welcome and objectives	Dr Graham Kerr, SSAC Project lead
11:05-11:15	Background to SSAC	Professor Julian Jones, SSAC Chair.
11:15-11:25	Overview of Scottish Government space sector policy	Scott McClelland, Scottish Government
11:25-11:35	Emerging key questions for international space sector	Professor Colin McInnes, University of Glasgow
11.35-11.45	Scotland's space industry	Dr Hina Khan, Executive Director, Space Scotland
11.45-12.25	**Breakout Session 1 - Opportunities, risks and policies** 1. Where are the greatest economic opportunities for Scotland in the longer term (10-20 years) and what do we need to do now to position our sector to take advantage? 2. What are the risks and barriers to stability and growth in the Scottish space sector and how can these be overcome. 3. How can Government (UK & Scottish) best support the space sector in Scotland? 4. How is legislation likely to impact the space sector and how can Scotland help influence local and international policy and standards?	
12.25-12.55	**Lunch Break**	
12.55-13.35	**Breakout Session 2 - Technologies, people and working together** 1. In which relevant areas of research are we world-leading and how can we best enable the adoption of this for impact in the Scottish space sector?	

	2. How can Scotland's space sector support sustainability and contribute to broader national and international goals in areas such as climate change, AI, technology innovation, and education? 3. What skills are needed to support the current and future space sector and how can we ensure that the skills are available in Scotland? 4. Which collaborations nationally, and internationally, and between different disciplines and sectors, will become the most important for the Scottish space sector? How can we use these collaborations to further our involvement in larger space programmes worldwide?	
13.35-13.55	**Plenary**	Professor Julian Jones, SSAC Chair
13.55-14.00	Summing up and next steps	Dr Graham Kerr, SSAC Project lead

FRAMEWORK FOR BREAKOUT DISCUSSION

The project is intended to review the potential future global opportunities for the space sector. It will offer recommendations highlighting future opportunities best aligned to the existing and potential strengths of the Scottish space ecosystem, taking into consideration existing areas of industrial capability within and out-with the space sector and academic research in relevant areas. Particular consideration may be given to opportunities aligned with the other priority areas identified within the National Innovation Strategy.

The project will also seek to set out the actions that the collective ecosystem should implement to position Scotland to maximise the economic opportunities, including identifying where the respective ownership of relevant actions best sits.

Breakout Groups
Attendees will be split into two pre-determined breakout groups. While each group will discuss all of the questions outlined in the programme, they will do so in a different order to ensure each question gets sufficient consideration if some groups do not get round to discussing all four.

SSAC Working Group Members
Julian Jones – SSAC Chair
Graham Kerr – SSAC Member (Space Project Lead)
Louise Horsfall – SSAC Member
Connor Blair – SSAC associate member
Colin McInnes – University of Glasgow
Javier Martin-Torres – University of Aberdeen
Anton Dubenko – SSAC volunteer, University of Edinburgh
Shrawan Jha – CENSIS

Roundtable Attendees:

Alastair McInroy
Andrew Mount
Andy Campbell
Benjamin Wells
Bill Wood
Craig Clark
Daniel Smith
Ellie Ebrahimi
Hina Khan
Hugh Hunter
Julian Dines
Karen Wilson
Kristina Tamane
Malcolm Macdonald
Matteo Ceriotti
Matthew Warden
Paul Winstanley
Peter JW Anderson
Rosa Santomartino
Ross Donaldson
Scott Wilson
Sharon Lemac-Vincere
Stewart Miller

Roundtable Observers:
Anton Dubenko – SSAC working group
Connor Blair – SSAC associate member
Graham Kerr, SSAC Space Project Lead
Javier Martin-Torres – SSAC working group
Julian Jones, SSAC Chair
Scott McClelland, Scottish Government
Shrawan Jha – CENSIS

Breakout Group Chairs
Colin McInnes – SSAC Working Group Member
Louise Horsfall – SSAC Working Group Member

Breakout Group Scribes
Jennifer Gordon – Scottish Government
Rory McGregor - Scottish Government

ROUNDTABLE BREAKOUT GROUP NOTES

Breakout Session 1 - Opportunities, risks and policies

Where are the greatest economic opportunities for Scotland in the longer term (10-20 years) and what do we need to do now to position our sector to take advantage?

Infrastructure

- Concentrating on existing strengths, Scotland could put infrastructure in place to support existing companies, start-ups and incoming investors to create the right path to scale up.
- The Scottish space sector is made up of mainly SME's who need a more supportive infrastructure, shared spaces/labs for hardware development, scaling up satellite production etc.
- Scotland has strong expertise in satellite manufacturing and if companies here cannot keep up with the right infrastructure to cope with large constellations we will fall behind.
- Need to make better use of existing facilities – National Robotarium, National Manufacturing Institute Scotland (NMIS) and Universities that have facilities that could be used for collaboration and bringing together academia and industry.
- Main market seen to be in-situ resource utilisation, which spans both human and robotic exploration. Otherwise in the broadest sense - power networks and defence seen as core activity currently and continue to represent key opportunities for the foreseeable future.
- Defence in particular seen as a driving factor in the sector, eg Ukraine and the growth of military customers for launch capability - all equally applicable to climate resilience and net zero transition.
- Also lunar and martian economies - Scotland could use overarching NASA programmes associated with these to leverage opportunities for Scottish companies.

Sustainability

- Sustainable space is an area where Scotland is already leading following the publication of the world's first Sustainable Space Roadmap. The Environmental Taskforce are working to support the use of space data for climate mitigation and to support the space sector to be more green through innovative design. There is an opportunity here to lead the way internationally.
- Growth and sustainability need to work in tandem.
- Industry to remain mindful that while sustainability is important it should not restrict small businesses so much so that they are not commercially sustainable.

Space data applications

- Space data has applications in the commercial market and PwC recently published a report on applications of space.

Collaboration

- Better coordination between industry and academia could support spin-outs.

Parallel technology to be harnessed

- Scotland also has real strengths in photonics, laser communications, quantum communication and sensing, science missions, space robotics, cybersecurity and life sciences and there is an opportunity to harness these parallel technologies through better coordination and communication.
- Robotics was highlighted as a major opportunity given experience of UK Astronomy Technology Centre, NMIS and the National Robotarium as well as the existing intersections between space and robotics in simulation and emulation, in-orbit servicing, asteroid mining, constructing satellites at scale.

Monitoring and understanding of landscape

- Increase understanding of what exists in Scotland in design and certification.
- Opportunity to monitor what others are doing and build on this.
- Increase understanding on international research.

Universities

- Opportunity to showcase Scotland's flagship projects to attract international talent, for example University of Aberdeen has an instrument on Mars and are currently running a project with the Japan Aerospace Exploration Agency (JAXA).
- Opportunities in future space missions given strong history:
    - James Webb Telescope
    - European Space Agency's (ESA) Laser Interferometer Space Antenna (LISA) and PLAnetary Transits and Oscillations (PLATO) missions
- The move to small satellites will drive further opportunities in science missions.

In-Space Missions

- Scotland is well placed to be a gateway to developing infrastructure in space, lunar missions and in-orbit servicing etc by off-earthing workforce in construction and expertise in oil and gas sector etc. These are all opportunities that should be developed.

What are the risks and barriers to stability and growth in the Scottish space sector and how can these be overcome.

- Need to be careful that the commitment to sustainability doesn't hinder young and small companies to unsustainable levels.
- Competition of pace of development in the rest of the world
- Lack of infrastructure/facilities, or access to, for young and small companies that are looking to scale up.
- Lack of equality and diversity in the sector
- The encroachment of 5G on space, due to congestion in the RF spectrum with ever increasing demand for greater capacity. Need to protect the allocation of the electromagnetic spectrum.
- Finance - Creating a full end to end eco-system should mean also being able to raise the required finance wholly in Scotland. Cannot do this currently and is considered a risk that has led some SMEs locating HQs outside Scotland.

- Getting the mix of inward investment right - eg not bringing in other companies that undertake activity that's already happening in Scotland. We've got a lot of what we need already - we should just grow that.
- All individual ingredients to grow the space sector are here but they could perhaps be better integrated. The key is recognising the capabilities we have and connecting them together.

How can Government (UK & Scottish) best support the space sector in Scotland?

- Increased funding from the UK for infrastructure that can encourage and supplement private investment.
- More agile and a better balance of UK Space Agency investments in infrastructure across the UK.
- Investment in shared facilities (lab space particularly) for scale up.
- More support for better equality and inclusion across the sector.
- More detailed information on government needs that can be supported by space applications, to better inform research and development in the industry in creating solutions.
- Notion that concentration needs to be less on less grants tied up in unnecessary T&Cs, and move to focus on contracts for services for government.
- Government needs to be a better customer *and* a better partner with a "three pillars" approach that could build a programme of platform delivery for services undertaken with a holistic approach to the sector. That government backing would also serve as a de-risker for delivery.
- Scaling needs to be addressed and it was felt that there is a large piece missing between support provided for startups/large enterprises and those companies in the middle ready to go to next stage of growth.
- Support for space sector startups – felt to be less support at the much higher risk pre-company stage, which are more capital intensive than other sectors.
- Procurement currently a challenge around accessing to get onboard the frameworks (especially in UK level). More support felt to be needed for entering those UK level platforms.

How is legislation likely to impact the space sector and how can Scotland help influence local and international policy and standards?

- Current licencing processes in the UK are far behind those in the US in terms of timing and number of launches allowed.
- Improvements required licencing process to allow the sector to react and respond to the commercial opportunities created by more rapid launch.
- Acknowledgement that if Scotland wants to have influence, then it needs a presence in space - difficult to influence anything if not a player.
- However, also acknowledged that once the standards are set, they tend to favour the industries in the county that originated the standards. Key is working out the most constructive way for Scottish entities to interact regulation at the UK level.
- Broad consensus that sustainability is a key area where Scotland can have influence. Scotland has been successful in positioning that wider sustainability conversation - not just in the UK but at a global level. We have earned our right to

sit at table and global agencies coming to us. We should therefore be using that position to leverage policy in those areas.
- But also an awareness of the need to be careful on sustainability since there is a risk of being outcompeted by those actors less concerned in this area (eg China and Russia). Crucial at this point in the sector's development to ensure the sector is commercially successful and "wash its own face".

Breakout Session 2 - Technologies, people and working together

In which relevant areas of research are we world-leading and how can we best enable the adoption of this for impact in the Scottish space sector?

- The University of Edinburgh is one of Europe's largest centres for AI research.
- Scotland is leading in the gaming sector which can offer data visualisation for space data.
- Scotland has strengths in Quantum and Photonics, with Craft Prospect and University of Strathclyde leaders in the sector. Opportunity for funding from UK Spending Review 2025 – 28.
- Strengths in advanced manufacturing, additive manufacturing, robotics and in orbit manufacturing are all areas that can be built on.
- The University of Glasgow is researching space technologies and find that space is a rallying point for many cross over technologies.
- Existing strengths in space science and research in gravitational waves can drive technology into new applications. Scotland is involved in the 30-year funded ESA project LISA.
- Space science and research opportunities to link up with industry in satellite manufacturing to increase robustness to withstand space weather in Low Earth Orbit.
- There is a huge amount of existing IP in universities that has not been commercialised. There is a need for more IP protection, greater business support for researchers.
- There is an opportunity to create a mechanism for sharing information about what research IP is available with potential consumers.
- There is a gap in support available for getting research ready for commercialisation, which can normally be a costly and timely process.
- There is existing opportunity for more Knowledge Transfer Partnerships which are not currently utilised.

How can Scotland's space sector support sustainability and contribute to broader national and international goals in areas such as climate change, AI, technology innovation, and education?

- Space can support sustainability in 3 ways:
    - Use of space data to support climate monitoring and mitigation
    - Protecting the space environment and clearing up space debris.
    - Supporting the sector to be more sustainable on earth.

- Ultimately the space sector is a way to make everyone else net zero.

- There is a need for support and incentives from government to encourage businesses to be more sustainable and innovative in creating solutions.
- There is a need to raise awareness of how Scotland is already leading the way in terms of space sustainability but that we can change the dialogue by highlighting what Scotland is already doing.
- Defence aspects are a major threat to the space environment and there is more UK funding going to defence rather than civilian use of space.
- Need to acknowledge that we are currently in a negative point at the moment in terms of sustainability.
- The narrative of space as a leader in sustainability can act as a major attractor to future generations of skills.
- Sustainable technology and innovation can cross sectors.
- Industry already felt to be contributing to the conversation and the Scottish Sustainability Roadmap stands as a testament to that existing moral commitment.
- Work should continue to promote collective messaging around sustainability policy via the Environmental Task Force roadmap and strategy.
- Need for alignment of sustainability narratives across the UK. Strong suggestion that UKSA needs to not “re-invent wheel” in this area and instead build on work already done through Space Scotland.

What skills are needed to support the current and future space sector and how can we ensure that the skills are available in Scotland?

- Recognition that there is a disconnect between academia and industry in terms of what skills are required and communication needs to be improved through the creation of better forums.
- There are not enough technicians or young people coming through from colleges.
- There needs to be a balance of focus between Higher and Further Education to create the right mix of skills.
- Need to consider how AI will impact and influence the skills required in the future.
- Short term solutions include programmes/courses for reskilling and upskilling to be driven in partnership between industry and education.
- Longer term solutions for 20 year's time, need to focus on primary and secondary schools and college structures which can then be built into the future. Industry needs to work more closely with schools.
- Solutions need to create pathways throughout the school structure into a career and early intervention is critical.
- Promoting and raising awareness of the opportunities out there is important.
- More work required to increase diversity in the sector at primary school level.
- Speaking to parents is important as they are the biggest influencers on children.
- Education and industry to do more to encourage apprentices.
- We don't try to teach skills that individuals require in 5 years time.
- No real problems apart from Attitude Determination and Control System (ADCS) trained folk - Italy leading here. Struggle to hold on - v. competitive landscape. Don't get a ton of support through contracts?
- Cost of VISAs - costs of folk leaving for Mangata.
- Graduate programmes/CDTs - great ideas, struggle to support because trying to close gaps. City College in Glasgow - they have supported.
- Much greater collab between this and other sectors.

Which collaborations nationally, and internationally, and between different disciplines and sectors, will become the most important for the Scottish space sector? How can we use these collaborations to further our involvement in larger space programmes worldwide?

- Cross-sectoral collaboration felt to be important - Technology Scotland's Photonics for Space cited as a good practice example.
- Otherwise, ESA singled out as an entity where the priority for engagement as a collaboration partner needed to change – General agreement that the whole of the Scottish and UK eco-systems are not involved enough.
- Suggestion that UKSA could be better connected to ESA, and relationship should be more like that of NASA. Anecdotal evidence that those attending ESA events highlight a perceived lack of UK engagement.
- Scotland should also be collaborating more with individual agencies globally with Italian, German, and French national agencies all given as examples.
- Acknowledgement that post-Brexit the UKG brought UK back into Horizon and Copernicus programmes, however, the sector in Scotland is yet to feel any particular benefits.
- Scotland lacks a "proper" prime and there are benefits associated with one being located within our borders as a vehicle for generating opportunities for the wider supply chain.
- Notion was presented by one manufacturer that industrial thinking perhaps being too commercial orientated and doesn't work with "big science" community, stifling potential opportunities.

scottish science advisory council

SSAC Space Sector Roundtable
21 February 2024

Dr Graham Kerr
SSAC Project Lead

SSAC Space Sector Roundtable
21 February 2024

Professor Julian Jones
SSAC Chair

SSAC – Who are we?

scottish science advisory council

- SSAC was created in 2002

- **Council** – currently chaired by Julian Jones; along with 11 members plus 2 associate members and 4 *ex officio* CSA; Chief Scientist, Health; CSA ENRA; Chief Social Policy Adviser

- **Secretariat** – Science Advice and Engagement team within SG Industrial Transformation and Office of the Chief Scientific Adviser Division

Distinctive features of SSAC

scottish science advisory council

- a remit that cuts across all sectors and policy areas;
- we provide independent science advice at “arm’s length” to SG ;
- we have no disciplinary or sectoral “agenda”;
- we operate as a “collective” (i.e. Members have a responsibility to provide checks and balances within the Council);
- our combined knowledge of Scottish science skills and context enables us to ensure that advice commissioned from outside Scotland is appropriate to the Scottish context

Principles of engagement:

- Our focus is on *science* advice, where science includes social and economic disciplines;
- We need to be thinking of future needs and highlighting the potential value of science;
- We can be both reactive (responding to requests from within SG) and proactive (identifying topics we think are opportunities or risks for Scotland);
- In developing Terms of Reference for specific pieces of work we take into account the broader landscape of advice available (e.g. Centres of Expertise, other advisory committees and organisations, the RSE etc)

Recent reports:

scottish science advisory council

- Link to all SSAC reports can be found here

Some recent reports below:

- SSAC Report - Science and evidence for place-based adaptation
- SSAC Report - Quantum Technology: Opportunities for Scotland
- SSAC Report - Use of Science and Evidence in Aquaculture Consenting and the Sustainable Development of Scottish Aquaculture

Roundtable discussions will be focussed on opportunities for Scotland's Space sector over the medium to long term (10-20 years).

The outputs from the roundtable will be considered by the SSAC working group to inform a formal report for Scottish Government which will be published on the SSAC website Scottish Science Advisory Council in Spring 2024

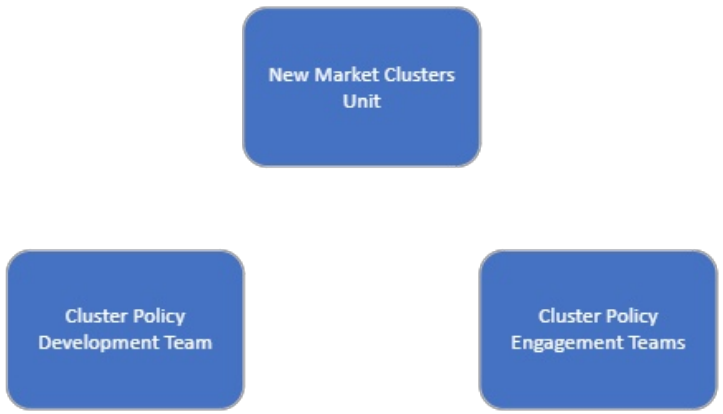
Exploring the potential future commercial opportunities for Scotland’s Space Sector

Scott McClelland
Hd New Market Clusters
Directorate for Economic Development

New Market Clusters Unit

To support the emergence of clusters of excellence by 2026

- Establish NMCU as home of SG cluster development policy
- Establish and grow NMCU remit clusters
- Establish SG cluster building capacity



Establish a framework approach to cluster development

- Cluster framework development
- Cluster accreditation
- Cluster data: baseline, E&M, dashboard

Engage and support priority areas to deliver growth

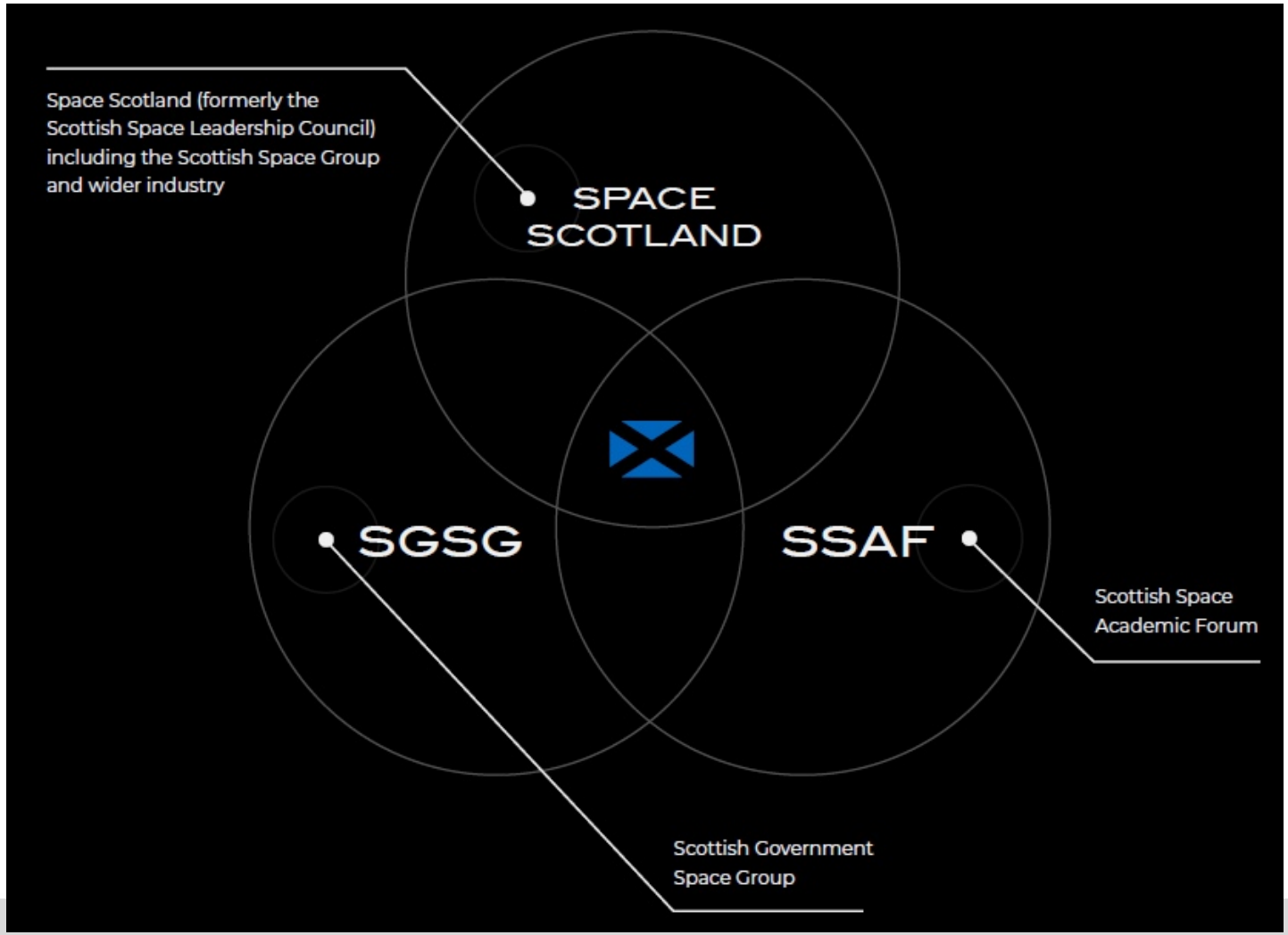
- Specific priority cluster engagement
- Implementation of cluster framework

RESPONSIBILITIES

- Cluster development policy (including cluster framework)
- Space
- Critical Technologies (Quantum, Photonics, Semiconductors)
- Robotics and Autonomous Systems
- Aerospace and Defence manufacturing
- Industrial Biotechnology
- Michelin Scotland Innovation Parc

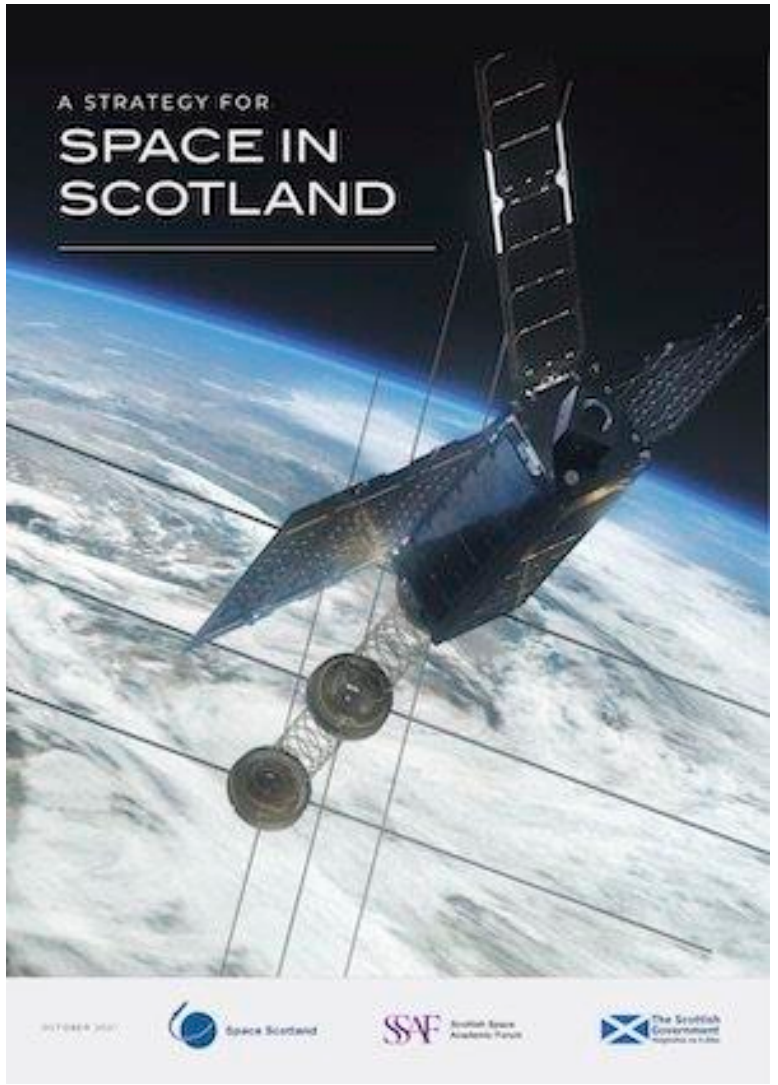
GOVERNMENT AMBITION

Our ambition is for Scotland to lead Europe in end-to-end capability for small satellite design, manufacture and launch, including earth observation data solutions that are critical in tackling climate change.


Space Scotland (formerly the Scottish Space Leadership Council) including the Scottish Space Group and wider industry
SPACE SCOTLAND
SGSG
SSAF
Scottish Space Academic Forum
Scottish Government Space Group

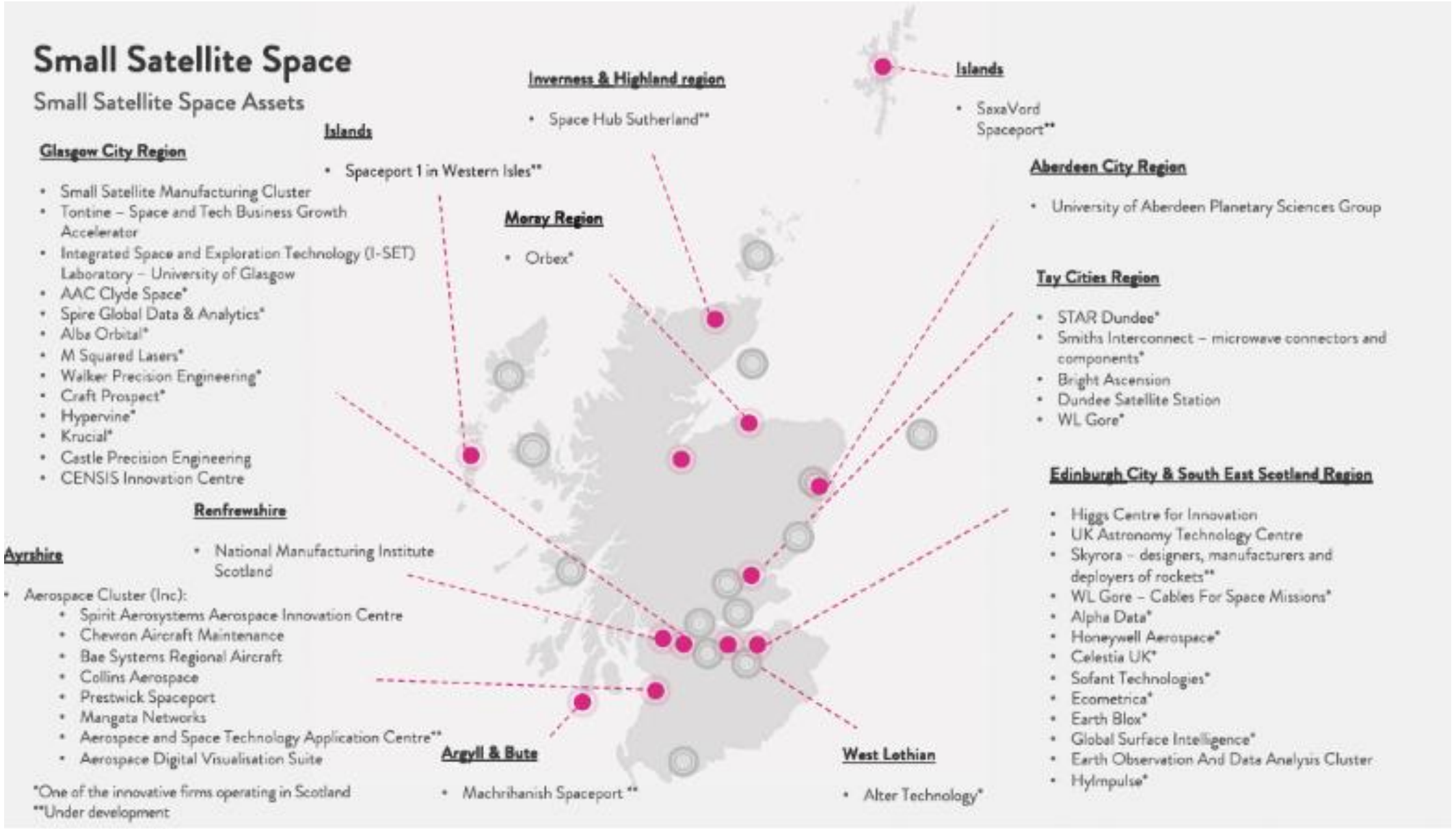
Scottish Space Strategy

- Targeted Inward Investment Plan
- International Opportunities
- Sustainable Launch Capability
- Space Infrastructure
- Skills and Equality of Access
- Sustainable Space
- Future Commercial Opportunities



Small Satellite Space

Small Satellite Space Assets



Glasgow City Region

- Small Satellite Manufacturing Cluster
- Tontine – Space and Tech Business Growth Accelerator
- Integrated Space and Exploration Technology (I-SET) Laboratory – University of Glasgow
- AAC Clyde Space*
- Spire Global Data & Analytics*
- Alba Orbital*
- M Squared Lasers*
- Walker Precision Engineering*
- Craft Prospect*
- Hypervine*
- Krucial*
- Castle Precision Engineering
- CENSIS Innovation Centre

Ayrshire

- Aerospace Cluster (Inc):
  - Spirit Aerosystems Aerospace Innovation Centre
  - Chevron Aircraft Maintenance
  - Bae Systems Regional Aircraft
  - Collins Aerospace
  - Prestwick Spaceport
  - Mangata Networks
  - Aerospace and Space Technology Application Centre**
  - Aerospace Digital Visualisation Suite

Renfrewshire

- National Manufacturing Institute Scotland

Islands

- Spaceport 1 in Western Isles**

Inverness & Highland region

- Space Hub Sutherland**

Moray Region

- Orbex*

Argyll & Bute

- Machrihanish Spaceport **

West Lothian

- Alter Technology*

Islands

- SaxaVord Spaceport**

Aberdeen City Region

- University of Aberdeen Planetary Sciences Group

Tay Cities Region

- STAR Dundee*
- Smiths Interconnect – microwave connectors and components*
- Bright Ascension
- Dundee Satellite Station
- WL Gore*

Edinburgh City & South East Scotland Region

- Higgs Centre for Innovation
- UK Astronomy Technology Centre
- Skyrora – designers, manufacturers and deployers of rockets**
- WL Gore – Cables For Space Missions*
- Alpha Data*
- Honeywell Aerospace*
- Celestia UK*
- Sofant Technologies*
- Ecometrica*
- Earth Blox*
- Global Surface Intelligence*
- Earth Observation And Data Analysis Cluster
- Hylmpulse*

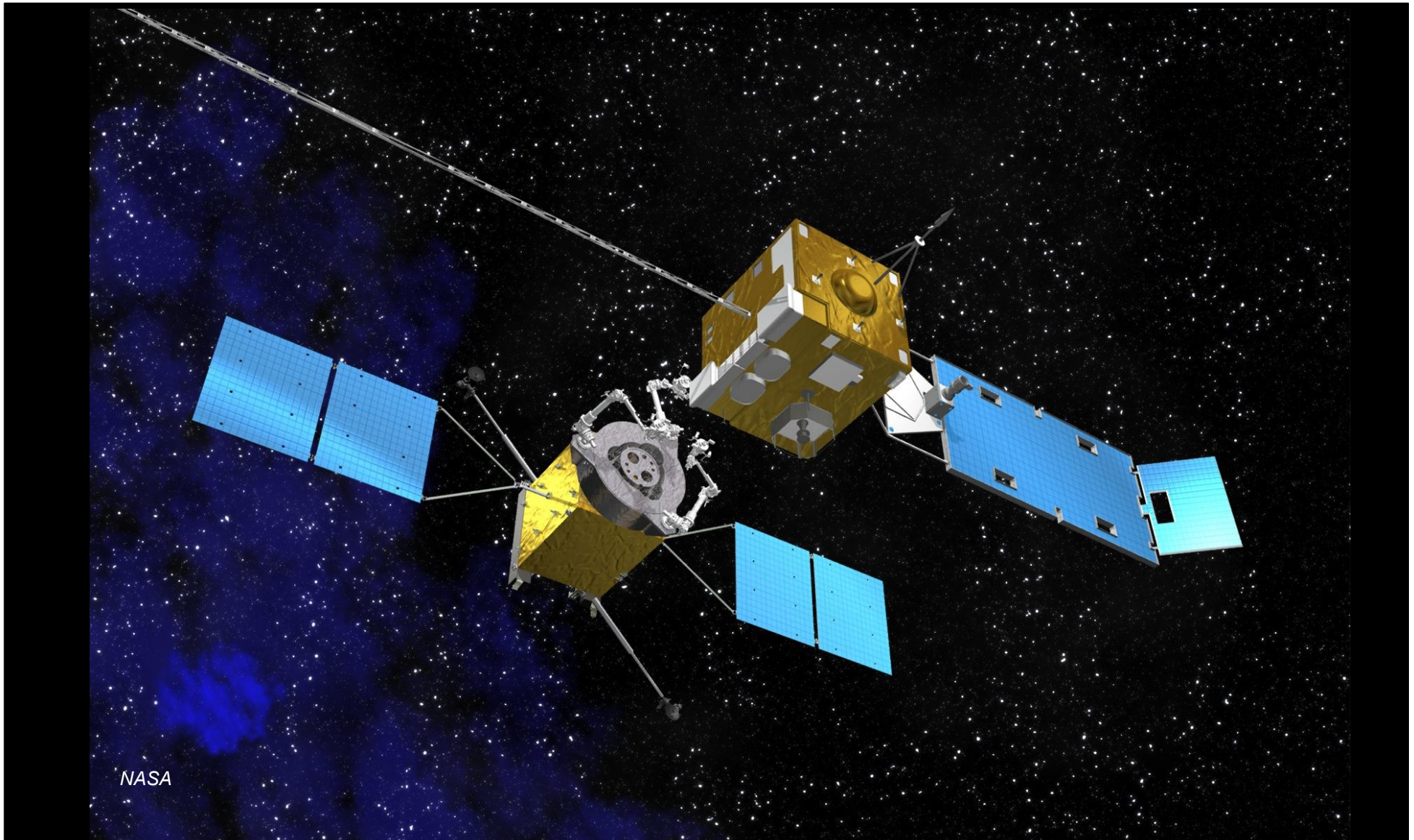
*One of the innovative firms operating in Scotland
**Under development

Emerging opportunities for the global space sector

Colin McInnes

Space and Exploration Technology Group

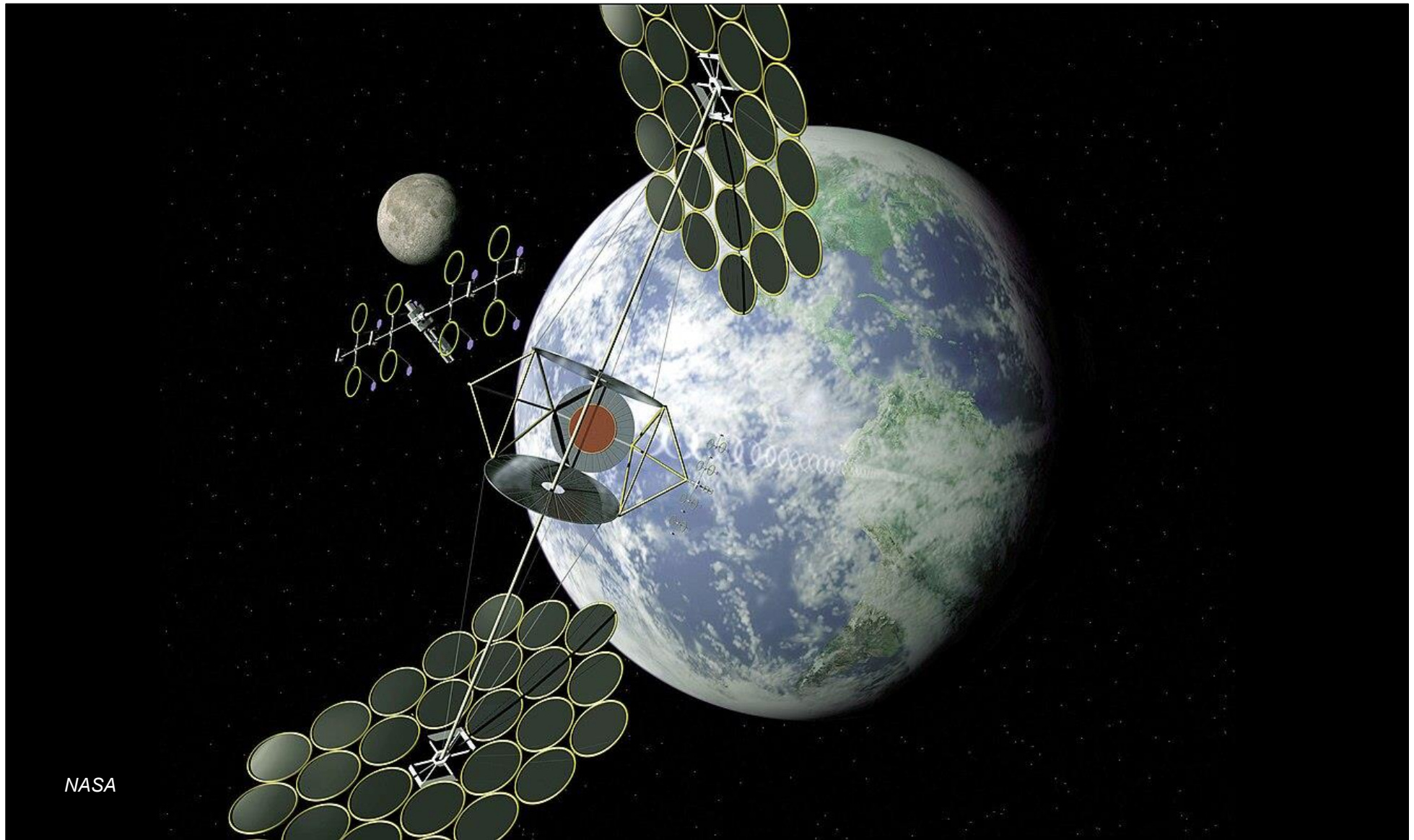
University of Glasgow


NASA

SpaceX

NASA

NASA JSC



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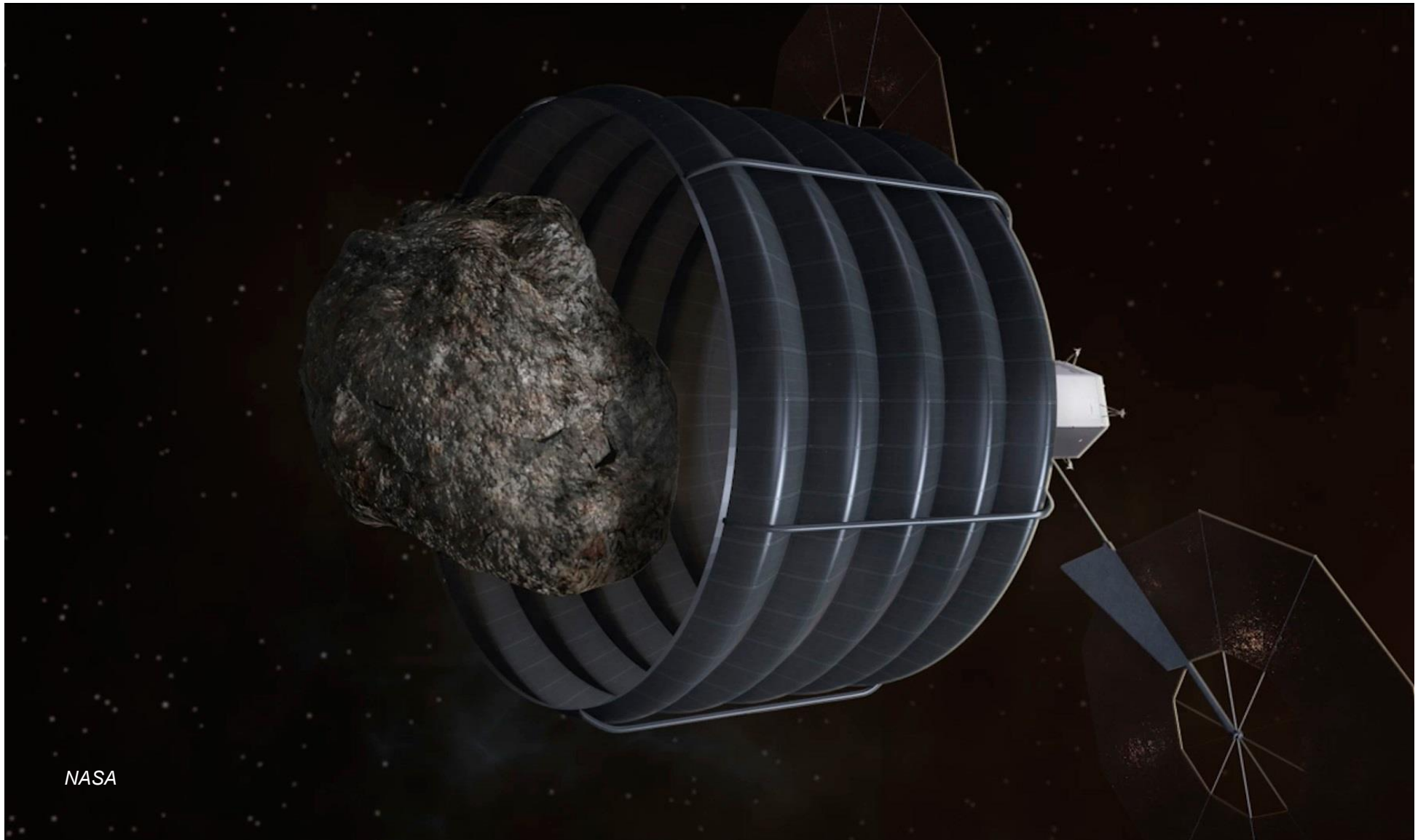

NASA

SpaceScotland

Scotland Space Sector

Dr Hina Khan
Executive Director

spacescotland.org

21 Feb 2024

SpaceScotland

Space Scotland

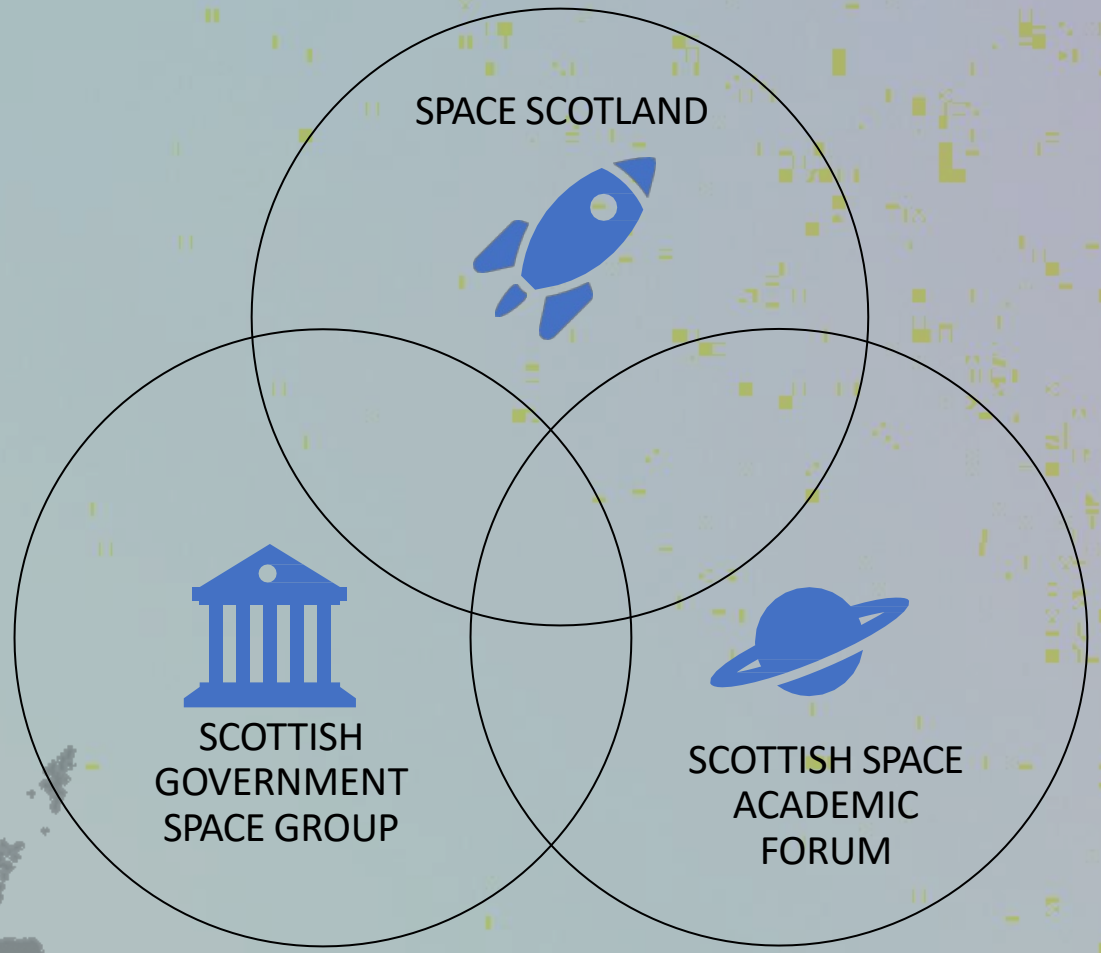
- A collective voice for the Scottish Industrial Space Sector
- Industry voice in the Scottish Space Strategy
- Actively supporting the growth of the sector
- Comprises Industry representatives from Satellite Manufacturers, Downstream Exploitation Companies, Spaceport Operators, Launch Platform and Service Providers and Traditional Payload/Avionics Suppliers, Academia, Catapults and Facilities

Aims

- To form a community of Scottish Businesses with an involvement in Industrial/Commercial Space to establish the conditions to increase business opportunities, efficiencies, effectiveness and economic impact through collaboration, partnering and mutual support.
- To raise the profile of Scotland as the home of Agile Space and to become a leading global destination to access space and space services, including locating or establishing businesses in a supportive environment.
- To work collectively and with partners such as the investment community, academia and Government to enable such an environment

Scottish Space Sector

SpaceScotland



Scotland space hubs

- Glasgow
  - Satellite design, manufacturing, testing, deployment of full mission services
  - Strong academic links to drive innovation
- Edinburgh
  - Long heritage in data science and earth observation
  - Melting pot for space data companies
- North Coast & Islands
  - Launch providers and services
  - Vertical launch sites on North Coast and Islands
- Dundee
  - World leading subsystem development
  - Leading in areas of data and computational science
- Prestwick - West Coast
  - Heritage of research excellence in aerospace
  - Horizontal spaceport site at the only rail linked airport in Scotland

SpaceScotland

Scottish Value Chain

A

Scottish Small Satellites

Design, development, prototyping, manufacture, test, certification & operation of Small Satellites.

A connected supply chain supporting the satellite sector

B

Scottish Launch Services

Launch services for Scottish Space Industry & Businesses.

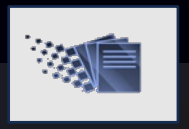
A cost-effective means of getting Scottish Payloads and other offerings into orbit, and beyond.

C

Scottish Launch Vehicles

Design, development, manufacture, test, certification and operation of a Scottish Launch Vehicle capable of orbital entry and space operation

D

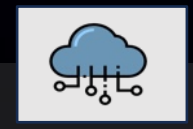


Downstream Industry

Making & Delivering a Globally Distinctive Scottish Proposition

Development of globally distinctive data & information analyses and product provision. The application of algorithms and other image and signal processing to offer new and novel products to a global market

E



Future - New Applications / Non-Traditional Payloads

Research, design, development, and manufacture of payloads, technologies, systems and services as part of an overall growth in Space – including, energy production, zero-G manufacture, habitats, Lunar Projects, asteroid prospecting

spacescotland.org

Component & Sub-System Supply	Long heritage in fundamental component development for space missions, supplying critical material and subsystems to deep space missions and the global space manufacturing industry
Space Exploration	Science grade expertise in space exploration missions and NASA/ESA flagship programmes on deep space tech, planetary exploration and fundamental science mission to advance human curiosity

SpaceScotland

Scottish Space Ecosystem

180 companies

8500 employees across the sector

Diverse range of industries:

Small satellite manufacturing

Rocket and launch vehicle manufacturing

Vertical and horizontal launch

Data analysis

Earth observation

- Sustainability at the heart of the sector
  - Up to 90% less carbon is produced by green rocket fuels used by Scottish companies.
  - The world's first carbon-neutral spaceport is in progress at Sutherland in the Scottish Highlands.
  - A 50% drop in space sector emissions will be achieved by 2030 — with a goal to reach net zero by 2045.

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SpaceScotland

Small Satellite Capability

CRAFT PROSPECT
a space engineering practice

albaorbital

AAC CLYDE SPACE

spire

Images courtesy of Spire Global

SCOTTISH EARTH OBSERVATION SPACE DATA COMPANIES

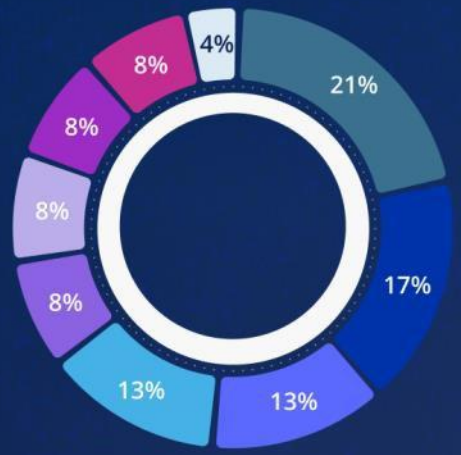
The use of space data from Earth Observation satellites is a Scottish success story, with a growing ecosystem of Scottish companies using this space information to improve our world.

Companies Capabilities

29 are directly involved in the Earth Observation space downstream sector

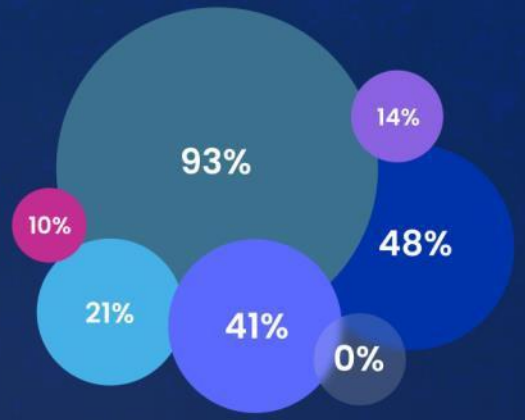
130 companies indicating space activity in Scotland

Number of Scottish Earth Observation Data Companies by City or Region



Scottish EO Company Applications

21% Natural Capital · 17% Environmental · 13% Meteorology · 13% Energy · 8% Geological prospecting · 8% Sustainability · 8% Humanitarian · 8% Agriculture · 4% Waste



Scottish EO Company Waveband Use

Optical; 93% · SAR; 41% · FAR IR; 21% · Near IR; 48% · LIDAR; 10% · IOT; 14% · UV; 0%

Scottish Enterprise · SCOTTISH DEVELOPMENT INTERNATIONAL · ASTROAGENCY · scottish-enterprise.com

UrbanTide · Carbon360 · S2C · tradeinspace · TOPOLYTICS · Resilience Constellation · Hypervine.io · manos nalytics · spire · EARTH BLOX · AAC CLYDE SPACE · Brainnwave · weather2 · Adrok · EOLAS · Symbios · gsi · SPACE INTELLIGENCE · TREEMETRICS · PLANETARY AI · WEATHER STREAM · DCAT · ASTROSAT · Ecometrica · Terrabotics · earthwave · NIRAS · Dundee Satellite Station Ltd

acescotland.org

Scotland's Space Strategy

SpaceScotland

Over the next decade, we aim to help deliver:

- An annual contribution to the Scottish economy in excess of £4bn.
- An increase in the workforce by five times the current level.
- A globally recognized strategic location and European leader for commercial space developments.
- A range of managed launch and orbital services, supporting the highest launch cadence in Europe.
- An increased and diverse workforce with improved participation that is fully reflective of Scottish society and ensures space is open for all.

Emerging Capabilities

SpaceScotland

- Innovative technologies from satellite design and manufacturing links to other sectors
- Incorporating novel research ideas into commercial opportunities
  - e.g. Craft Prospect working closely with academics on quantum technology for the next level of data security
- Use of data services for non-space sectors – fintech, biotech, agritech etc
- The National Robotarium is leading innovation in robotics in all sectors
  - In Orbit manufacturing is a key area that requires intricate robotic technology to build infrastructure of exploration and lunar mission
- Sustainable and responsive action towards space technology and launch capabilities

Space Scotland

spacescotland.org

QUESTIONS?

@ScottishSpaceLC

Space Scotland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ANNEX D

SSAC REPORT – Scotland's Space Sector: Exploring potential future opportunities

SUMMARY OF SURVEY RESPONSES

Note: the text below reflects the views of the respondents with no edits other than removing repetitive views and personal identity information. Not all respondents have provided a response to every question asked.

1. What are the strengths of the Scottish Space sector? How can these be consolidated and enhanced to maximise benefit to Scotland over the next two decades?

Scotland's strength in space is often characterised as an 'end-to-end capability' – from design to launch to data exploitation. This is a reasonable way of describing our unique selling point (USP) as we are not focused on one particular aspect, but due to history and geography we can address the entire chain. This could however lead to spreading ourselves too thinly, and thus not making a significant impact in any particular aspect, and also creates a difficulty in articulating our uniqueness (to external investors for example). The 'end-to-end capability' tagline does help with the latter, but to address the former we can show specific areas of particular strength in Scotland:

- NanoSats
- Components and subsystems for larger sats
- Launch vehicles and launch sites – this is a new but growing area for Scotland. With 5 potential launch sites in Scotland, and the only three vertical launch sites in the UK, we are well placed to win future launches from Scottish soil.
- SaxaVord became Europe's first licensed vertical launch site in December 2023 and hopes to start launch operations later in 2024. Being able to launch from Scotland is the last piece of the 'end-to-end capability' needed.
- Environmental considerations – one related aspect that should be kept in mind is Scotland's growing reputation for incorporating environmental considerations into the growth of commercial space activities.
- Science missions – The UK Astronomy Technology Centre in Edinburgh is the Science & Technology Facilities Council (part of UKRI) UK national centre for the design and build of astronomy instrumentation.
- Data exploitation (applications) – this is a major part of Scotland's space sector that is likely to generate the largest commercial revenues in the longer term.

As space eventually becomes another tool to deliver services to customers it is the applications that differentiate commercial offerings. There are academic research areas in data applications, and this ties strongly into the Edinburgh University aim to be the ‘space data capital of Europe’ but also the strong heritage in data analytics in Scotland.

Full value chain capability (a rare end-to-end ecosystem that will involve the addition of orbital launch services in the near future) covering:

- Satellite manufacturing (particularly cube / nanosatellites and below made by Spire, AAC Clyde and Alba Orbital although soon to grow with the arrival of Mangata to manufacture larger satellites)
- Orbital launch vehicle developers (launch companies employing hundreds of people and gaining significant private and public sector investment)
- Developing launch sites (the “missing piece of the jigsaw”)
- Thriving downstream data analysis segment with thirty-three earth observation companies commercialising space data and more looking at wider geospatial / IOT etc.
- World-class universities underpinning the sector.
- Proven heritage in space research and contributing to deep space missions, via the likes of STFC / ATC but also through private companies such as Star Dundee and WL Gore
- A collaborative environment, from Space Scotland acting as an enabler and platform for engagement / sectoral representation, closely aligned with ‘A Strategy for Space in Scotland’ and combined with the Space Scotland ‘spin out’, Scottish Space Academic Forum, to the likes of HIE, SE and SOSE sharing knowledge via the Scottish Government Space Group feeding directly into SG
- Developing wider USPs that include space sustainability, an organised movement in Scotland that culminated in ‘Space Sustainability - A Roadmap for Scotland,’ the world’s first sustainability strategy for a nation that has drawn engagement from space agencies around the world and led to engagement at UN level.

In order to merge and enhance, the strong level of collaboration between industry, academia and government must continue. This engagement is encouraged and helped by organisations such as Space Scotland and Scottish government agencies, all of whom have been valuable supporters and ambassadors for our fast growing (but still formative) commercial space industry. It is important to highlight Scotland’s space strengths and ambitions, as outlined above, in a uniform, considered manner that is amplified by industry ambassadors, MSPs and MPS, as well as Global Scots.

There are two parts of this question. Firstly, space deployed assets and secondly, products and services that can be enhanced with data derived from space e.g. GPS or earth observation. Academically we are stronger in the second area. Interestingly,

I see in the industrial landscape the reverse of this scenario with satellite manufacture and launch. My belief is that Government policy is more aligned to the second area. Strengthening could be achieved by closer linking of both of these areas.

Scotland has key strengths in the Space Sector:

- Satellite manufacturing
- Launch
- Ecosystem
- Governmental / Enterprise Agency support
- History and Heritage in innovation
- Academic prowess

Other areas have highly complementary sectors of great capability in Scotland from Fintech to Gaming but we need to actively strive strategy that collaborates where the output is greater than the sum of the parts.

Clyde Space Ltd was set up in 2005 in Glasgow, and whilst now owned by parent company AAC Clyde Space AB, headquartered in Sweden, still represents the group's largest site, employing one hundred people by the end of 2023. The company has been designing and building subsystems for small satellites for 20 years, with a range of academic, industrial, and institutional customers all over the globe. The company also built the UK's first CubeSat, UKube-1, launched in 2014, for the UK Space Agency

2. Where are the greatest opportunities for Scotland in the Space Sector in the next 10-20 years and where should we focus our priorities?

There are identified opportunities looking forward, where Scotland has a good or reasonable change of having some traction. In a very rough priority order (high to low) in terms of likelihood of Scottish success / impact. *Note - there are areas of overlap (e.g. laser-comms and quantum comms, or space mining and space robotics), however we have simply included these to avoid missing potential future opportunity areas:*

- Photonics, including laser-comms
- Quantum communication
- Science missions, particularly those using smaller satellites / spacecrafts
- Quantum sensing
- Space robotics, including autonomous systems
- ISRU (in-situ resource utilisation)
- Space mining
- RF spectrum utilisation / optimisation, including Software Defined Radio (SDR) & phased array antennas
- Space based solar power
- Debris removal / mitigation
- Nuclear power
- Space tourism

By building upon the industry-led space sustainability movement in Scotland, the country can cement its position as a world-leader in this increasingly key area. From supply chain sourcing, the development of green propulsion, environmentally conscious launch site developments and the ability of space data coming from Scottish satellites and being analysed by Scottish space data firms, Scotland can lead by example as part of the wider UK proposition around space sustainability in orbit (active debris removal/ space situational awareness).

Scotland can also use its reputation as being Europe's main producer of small satellites to encourage inward investment and further grow the skills pipeline/ new businesses in this area. If Scotland can offer a compelling, comprehensive launch proposition and remain internally collaborative, the opportunity is there to be the European home of spaceflight. In such a broad industrial market, one that plays a key role in every sector imaginable, it is difficult to say where we should focus priorities beyond the importance of continued knowledge-sharing, awareness-raising, and collaboration to build upon the impressive sectoral development to date.

Space data, however, feels like the area of the industry with the greatest level of growth opportunity. Scotland's expertise in this area, from university to the businesses commercialising satellite data from Scotland all over the world, is a huge opportunity due to the increasing need of information from space to support our environment, economy (insight for businesses in most sectors) and society in general (via the everyday space applications we all access, such as weather forecasting or logistical information).

I would be interested to see international benchmark data relating to the evolution of the satellite and launch capability here and this being used to define how we can be a global leader / significant player. This should consider how we can develop our capabilities e.g. satellites of higher payload. Consideration should be given to launch and maximisation of asset value. The applications area is still ripe for exploitation and how we can become a significant player in the development of space-based infrastructure and applications. This should consider broad benefits – economic, societal, and environmental. Building on the latter point, are there opportunities for us to apply our ability and reduce the impact of space utilisation and build this as a strong underpinning theme?

Scotland is recognised for its powerful reputation in the satellite market, and I believe that the obvious next step would be to provide leadership in developing cyber security resilience in this area. To achieve this, Scotland should adopt an initiative-taking and forward-thinking approach which goes beyond simply adapting existing frameworks, it should focus on building and implementing secure-by-design principles across the entire supply chain and ecosystem of the Scottish Space Sector and seeking new methods of cyber resilience. This will require innovative fresh ideas, and pressure testing across the ecosystem. But Scotland is still small and agile and as such this is the right moment rather than trying to retrospectively address issues later. Furthermore, I believe a focus on cyber security in the sector may also provide potential benefits for our young people. There is currently a global skills shortage in both the space and cyber domains, and this shortage is expected to continue. By positioning Scotland as a leading nation in both domains, we can

create opportunities for our young people to fill these gaps and become global leaders themselves. The intersection of space and cyber presents untapped entrepreneurial potential for Scotland as a nation but also our young people and entrepreneurs. Additionally in developing end to end capabilities with innovative cyber resilience building into the ecosystem, Scotland could develop enhanced national security measures and protect data sources used to inform decision making and commercial activity. One such example from public data is that that Chinese researchers have claimed that they can hack into Elon Musk's Star link network and change data and also change the positions of orbiting devices and disrupt data traffic. The veracity of these claims is unknown, but these risks are real and developing at a pace. There is an urgency in this field which cannot be overstated.

Areas of opportunity are outlined in the space strategy. Areas which align to / leverage distinctive Scottish University strengths / strategic activities are of real interest (e.g. downstream space data driven innovation activities, strategic net zero / sustainability initiatives) and should provide competitive advantage in a fast developing sector worldwide. Although the economic value to be extracted from earth observation data alone will diminish, as it becomes ubiquitous, value will come from combining these data with other sources of (proprietary) data that a customer owns.

Scotland as the employee gateway to the construction of New Space. The North East's Oil and Gas sector has developed great capability at sending workers offshore to hazardous environments, looking after them, having them conduct their job to exacting standards in dangerous environments, feeding them, caring for their health and wellbeing, and bringing them hope safely. This sector needs to pivot. Off-Earthing is the next step – as we start to build in space (labs, datacentres, hotels) or Lunar settlements on the moon or the mining of asteroids etc – Scotland can realign its ability from off shoring to off earthing. Rather than helicopters flying offshore, rockets will launch taking personnel off earth. The entire supply chain in this proposition from spaceship construction, to launch to health & safety and so much more is well within our reach and expertise. Come to Scotland – Go to space – do you job safely – come home.

Scotland has a long history of innovation and manufacturing, and it has an established space sector, delivering £180M of income in 2020/21 and employing 8,568 people in 183 space organisations, according to the Size and Health of the UK Space Industry 2022. Clyde Space Ltd e. in 2005 in Glasgow, and whilst now owned by parent company AAC Clyde Space AB, headquartered in Sweden, still represents the group's largest site, employing one hundred people by the end of 2023. The company has been designing and building subsystems for small satellites for 20 years, with a range of academic, industrial, and institutional customers all over the globe. The company also built the UK's first CubeSat, UKube-1, launched in 2014, for the UK Space Agency, pivoting the company from being a spacecraft subsystems supplier to providing full missions for its customers. The Glasgow site is now AAC Clyde Space's nucleus for satellite manufacture and is part of its satellite operations service.

Satellite manufacturers are now also set up in Glasgow, including Spire Global, and Alba Orbital as well as multiple other upstream companies such as Craft Prospect

and Bright Ascenion It has been well quoted that Glasgow builds more satellites than anywhere else in Europe. This strength is undisputed, and with the continued support of Scottish Development International to attract inward investment, and Scottish Enterprise to back growth of the sector, this trend should continue. There is also a large downstream sector in Scotland, and AAC Clyde Space is focussing its future on Space Data as a Service, delivering access to high-quality, prompt data from space to its customers, from weather forecasting to precision farming to environmental monitoring, essential to improving our quality of life on Earth. Again, we are not alone in this endeavour in Scotland. The central belt is fast becoming a 'space corridor' connecting the west to the east coasts and there is a wealth of companies analysing and delivering insights and services from space data to their customers, including Global Surface Intelligence, Astrosat, Trade in Space, Krucial and more. This is potentially where there is the biggest opportunity for Scotland as the global demand for communications, Earth observation, maritime services and even quantum services from space are set to increase.

With globally recognised Universities and Higher Education bodies in Scotland specialising in related disciplines including AI and ML, the country is poised to use the space applications opportunity. Finally, of course, the spaceport and launch offering has been tantalisingly close for some time, with funding having been invested into no less than 5 spaceports across the nation. There is no denying the opportunity is real, but the real market demand for such small satellite launchers and launch facilities is still to be realised. Aims of launching multiple times per year from multiple sites seem overestimated, while the rideshare market for small satellites is already well established, trusted, and dominated by SpaceX in the US. To maximise benefit for Scotland, we propose that the Scottish Government becomes an active user of space data derived from Scottish-built satellites, using skills from Scottish universities and Scottish data companies to process and analyse such data into services and insights. This requires dedicated focus, coherence, and funding within Scotland and with the wider UK.

Space is, by-default, a dual-use environment. The Ministry of Defence has made significant steps towards re-establishing a sovereign defence space capability. Much of this, by necessity as well as logic builds on prior UK civil investment, and, logically, future developments should pre-emptively seek out such civil-defence synergies. However, the Scottish sector is not well positioned to benefit from this investment trend as it is neither as intrinsically dual-use or as engaged with the defence and security industries as the sector elsewhere in the UK. Academia, in Scotland, should be supported to enable Scottish SME engagement in the space defence and security sector. Cyber security in the space sector is attracting significant international attention. The US recently launched a consultation on their proposed Hybrid Satellite Network framework. Germany has launched technical guidelines for satellite security, and the European Space Agency (ESA) has increased its focus on cyber security and resilience launching a 'Space Shield' tool to collect adversary tactics and techniques to develop an evidence base of attack types to enable ESA to strength it is security actions. This trend to build cybersecurity into the space ecosystem from a 'secure-by-design' perspective arises at a time when internationally there is a global shortage of skilled cyber security experts (currently estimated at, at least, 3.5 million).

The Scottish government has already found cyber security as a critical enabler of space sector growth; for example, working with ScotlandIS, a membership organisation for Scotland's digital technology industry, to begin identification of activities to enhance the cyber security stance of the Space sector. Given Scotland's global reputation in the satellite market, there is an opportunity for Scotland to lead in ‘secure-by-design’ cyber security resilience. This would, in-effect, create a competitive advantage for Scottish space businesses and, simultaneously, create a skilled workforce in the dual emerging domain of cyber: addressing skills shortages in both sectors.

Sustainability of the space environment will be a key sector-wide challenge, and opportunity, in the coming decade. Similar to the terrestrial environment, this is more than wealth creation and must be viewed in the context of losses incurred in an unsustainable space environment. Space has the potential to become a trillion-dollar sector in the 2030’s, with Scotland well positioned to secure a significant share of that if future investment is astutely targeted at ‘moving the dial’. Failure to preserve another natural environment from irresponsible human actions jeopardises this opportunity, alongside the vital contribution space makes in mitigating the impact of humans on the Earth’s ecosystem, and, to the NetZero transition.

The regulation of space is a reserved matter. Notwithstanding this, the ambition of the Scottish Government’s proposed Human Rights Bill to become one of the first common law jurisdictions to establish the human right to a healthy environment provides an opportunity for Scotland and the UK to provide further leadership through ambitious and strong legal protection and policy initiatives for environmental and sustainable protection by extending this human right into space. Enabling Scotland, and hence the UK, to provide global leadership and vision in the regulation of a sustainable space environment. It could be perceived that Earth observation continues to underdeliver on promised commercial potential. The new space Earth observation sector lags the rest of new space in Scotland. However, in Europe as a whole the new space Earth observation market is significantly outperforming the rest of the Earth observation sector. Scotland, and the UK, has proven a track-record of company creation but has failed to scale those companies, with market share significantly below pro-rata levels in comparison to leading ESA member states. Earth observation needs to look beyond its traditional core community, to engage with adjacent technology sectors where Scotland, and the UK, also has significant strengths, and to engage as a solution provider across the economy into challenge owner sectors such as FinTech and HealthTech.

Globally, the space sector is transitioning away from the concepts of ‘up’ and down’ stream. The sector is becoming more integrated, more ‘cross’ stream. This is clear in Scotland’s manufacturing (upstream) capability, with companies acting as service providers (downstream), who also build spacecraft, rather than as merely manufactures. This shift is not only higher margin, but it also enables the rapid deployment of novel capabilities that provide unique commercial advantage, often from within Scotland’s leading academic community which is itself a key attractor to inward investors in the sector. However, the lack of access to suitable finance, both private capital within Scotland and Scottish government investment into sector capability rather than singular companies that often merely drive staff movement

between companies rather than sector or economic growth, risks loss of potential as companies exits in pursuit of opportunities elsewhere.

There is already a bountiful photonics sector in the central belt of Scotland. That sector will be critical to future growth and capability in the near future for a range of applications (space situational awareness, earth observation, optical communications, amongst other things). In addition, that photonics sector is also breading a quantum technology sector, which itself will be critical to future directions of the space industry.

Edinburgh has a huge global network of collaborators and partners in the space sector. In order to continue to accelerate and maximise such initiatives, we would call upon both the Scottish and Westminster governments to find ways to ease the movement of international students and scientist, and to grow the opportunities for bilateral projects and novel space missions, such as GLAMIS. A key strategy for Scotland must also be to exploit the existing successful sectors. Beyond the technical and economic, we should not forget the social. Scotland's Inward Investment Plan sets out "our ambition for Scotland to be a leading destination for inward investment aligned with our values as a nation." Strengthening those values offers a further route to a USP. At Edinburgh we like to imagine a space nation that becomes the #1 choice for 50% of the population (i.e. women) because it provides a professional culture that allows them to succeed. Edinburgh University looks to do just that as a means to differentiate ourselves and unlock the transformation we aspire to achieve.

The Scottish space sector stands as a formidable force within the UK, yet its potential could be further realized by expanding its vision into sectors that are not only unique to Scotland but also overlooked within the broader framework of the UK Space Agency (UKSA). A particularly promising avenue lies in the domain of Space Sustainability, an area that has recently piqued the interest of UKSA, albeit with a limited focus on terrestrial debris and orbits. Crucially, there is a growing international interest, notably in the US, including NASA, about the utilisation of biotechnologies for sustainable space exploration and the potential benefits these could offer to Earth. This presents a unique opportunity for Scotland, given its vision toward sustainability and its remarkable ability in biotech and synthetic biology.

With significant funding predicted from the UK government over the next decade, Scotland has the potential to appear as a leader in the intersection of human space exploration and space sustainability. Edinburgh, in particular, stands out as a hub for this vision, hosting one of the only space biology research groups in the UK, spearheaded by myself as the principal investigator. The research group not only boasts a robust focus on space circular economy but also actively collaborates with esteemed entities such as NASA, ESA, and the Italian Space Agency (ASI). By using this expertise and fostering strategic collaborations, Scotland can position itself at the forefront of pioneering initiatives that redefine the landscape of human space exploration and contribute significantly to the overarching goals of space sustainability.

Looking at developing an ability in the use of robotics for space applications. These include opportunities in manufacturing of payloads, construction in orbit, debris

removal, in orbit maintenance, lunar habitat creation, lunar habitat sustainment and planetary (and other bodies) exploration.

The key opportunities for the Scottish space sector lie in the integration of university R&D, industrial satellite manufacture, satellite launch and downstream satellite data services with the advent of small satellite launch facilities.

3. What mechanisms and interventions are required to ensure Scotland maximises the benefits of the Space Sector for the Scottish economy?

Scotland's economic impact is dominated, particularly in the space sector, by SMEs – therefore we need to focus on how to improve creating and supporting the growth of SMEs. We have reasonable provision of support for spinouts and start-ups in the space sector (though more support would always be welcome), however where we noticeably fall down is the scale-up part of the journey – from say 10 FTE to 50 FTE. In particular the provision of mixed lab/office spaces for scale-ups. Access to labs (including cleanrooms, shared facilities, etc) collocated with offices is available for start-ups (e.g. via the ESA BIC UK), however there is limited availability for scale-ups – who obviously need more space but cannot (yet) afford their own dedicated facility. This is an area where intervention would support economic growth in Scotland. This should be geographically dispersed, not just in one location, as the need is spread across Scotland, albeit in concentrated hot spots. Another aspect is improving support for component and subsystem suppliers into the (world-wide) supply-chain for larger satellites / spacecraft. There are often complaints from the community that, for example, we do not get as much return to Scotland from ESA subscriptions as we should – which is dominated by where the primes are located (none being in Scotland). Therefore, the way to address this is to support the indigenous subsystem & component suppliers to join the wider European / world-wide supply chains and be part of consortium bids into ESA. This support could come from a combination of SDI, UKRI and UKSA:

- Skills mapping and development
- Support to space companies in order to guide more sustainable practices.
- Gov staying informed and engaging with the industry (due to the fast-changing priorities, challenges, and opportunities)
- Support with exporting products and services
- Support with UK gov and ESA procurement portals, which can be cumbersome and overly administrative, disadvantaging the SMEs that make up our sector and preventing access to government contracts
- A move from funding to government contracts at Scottish and UK level (particularly around earth orbit and geospatial insights)

I would explore further the potential divergence of industrial and academic capabilities and strengthen this through mechanisms to support new / sustain ongoing industrial / academic collaborations. Funding and delivery of collaborative R&D could be extremely beneficial here. I would also look at what translational assets we have to bridge the academic and industrial gap. Academic institutions income comes from teaching and research and quite rightly this will be their priority.

Industry is focused on delivering shareholder value through robust financial performance of their products and services. There is a gap here. Recently, a good game has been talked about the roles of universities in delivering innovation. I do not see this, and we should consider a translational asset supported by public-private partnership.

The interventions needed to ensure Scotland maximises the benefits of the Space Sector are:

- Cyber security skills development: Currently there are skills gaps in cyber security c. 3.5 million. When considering acceleration in technology and new markets such as space, this figure is likely to increase.
- Sector market positioning. I realise that the UK campaign 'Space for All' is developing the narrative that space is not just for scientists and engineers. However, I teach and supervise students in business schools on space entrepreneurship, and consistently these young people claim that space was not for them as they did not take a traditional (science and engineering) route. But when they are presented with the opportunity to explore space, they relish the opportunity and enjoy the experience. It would be beneficial to have funding to develop HE and Executive courses in Space Entrepreneurship, cyber security, and technology. There also needs to be more people working across Space Educations with a non-STEM background. I have analysed job adverts in the 'Space' sector and they by default include technical skills for jobs that do not necessarily require technical ability. One such example a job advert for education outreach in January 2023, specifically sought high level technical skills.
- Funding support for young entrepreneurs and women looking to run a business in the sector.
- Developing ambitious plans for manufacturing with end-to-end capability across the space ecosystem to be prioritised at speed to realise the potential of the sector.

Place based impact acceleration activities built around and using Scotland's ecosystem strengths and civic partnerships (e.g. in the central belt) would be highly UK competitive and timely in developing cluster activities to impact. The Scottish sector is based around SMEs, whose cluster development requires more support and can contribute overall less leverage. Training and capacity building (an effective multidisciplinary skills development pipeline across all relevant disciplines, from early career to leadership) is needed to deliver the stated strategic growth. Continuity of support is crucial at a time of the funding cycle when government funding is tight, and commitments are in danger of being short term. Unclear – Company creation and job creation are the obvious go to's but keen to understand and develop more. Investment and academic leadership and direction.

Scotland is a unique global jewel from geographical. environmental and technological leadership perspective. As a country we should pioneer the technology to capture data, analyse and show to the rest of the world how we can improve our life here on earth.

Linked to above either government as a customer or the direct introducer to larger global corporates who will co/fund the development for the likes of cyclops etc. Scotland offers its space companies an ideal ‘sandbox’ to develop and demonstrate services, from urban areas to remote settlements, from oil & gas to renewable, from protecting our fish stocks to our water. These services can both directly help our people and environment but also be exported globally to the multiple other countries that share similar challenges.

It is proposed that the Scottish Government would develop a national programme through which public and private entities could explore what space can offer and similarly allow space companies to understand the challenges faced. This would be further catalysed through a government-as-a-customer programme designed to make available data to the market for development, obtained from our very own Scottish space-based assets. This approach would bring coherency and stability to the ecosystem resulting in significant inward investment.

The space sector is R&D intensive: the UK’s space industry’s R&D investment is more than five-times the UK business average. However, both government stagey and the commercial nature of the sector distorts the nature of R&D investment towards the mid- to high-Technology Readiness Levels (TRL). Consequently, the sector is under-represented and under-active in the lower TRL range. This predisposition is repeated throughout the sector, in its representations and its governmental support with, for example, a tendency to focus on the commercially valuable outputs of the innovation pipeline rather than the inputs. This has created a disconnect within the sector. The Scottish government includes experienced users of satellite data, including agencies such as Marine Scotland, Nature Scot, and Scottish Environment Protection Agency (SEPA). These users should be supported to work with academia to inform and co-create future research programmes to address user needs with, for example, development of new sensors or data processing techniques to ensure enhanced impact and social value from publicly funded research.

Academia needs to be viewed as a key enabler and core part of the sector that is integral to future growth. Further recognition should be given to the value of basic research as the pipeline of future commercial innovations, and that engineering science underpins the technical innovations of the future. To this end, steps should be taken to encourage an increase in sector engagement in low-TRL research and consideration given to how academia might better support government with the identification of longer-term opportunities. This could include, for example, secondment into the civil service.

Training - Specific STEM national action/activity to push people towards the technological area of the space sector. There is an abundance of focus on astronauts and astronomy, but in reality, there are limited jobs. We need more of a focus on the technological side of space to promote those career routes. There is a critical lack of technical level workers for to support and grow the sector. There needs to be an intervention to bring more technical apprentices into the sectors. There used to be a technical graduate programme in the central belt that supplied technical graduates to aerospace companies in the past. The government could initiate a new joint programme bringing together the sector stakeholders.

Collaboration - Accessing space can be heavy on capital/infrastructure costs that spin-out, start-ups, and small-to-medium enterprises simply cannot afford. Many of those capital/infrastructure needs can be common and only needed intermittently. The creation of a “Scottish hub” that gives those unpractised players access to facilities will give them a significant boost over international competitors. Such a “Scottish Hub” would provide essential facilities such as space qualification machines, but also look to support the future sector such as optical test and measurement facilities (including an optical ground station). While the facility could also support the growing need of current “big industry” who themselves require more facilities for test and measurement.

Building space heritage – bringing together teams who want to space-qualify components and create space heritage through a series of funded (or co-funded) CubeSat missions.

Growth - Infrastructure to grow – currently a lack of places attracting the space-sector where manufacturing can take place at scale. National support for those looking to provide that infrastructure/real-estate.

One major challenge that University of Edinburgh staff are addressing is “the congestion in the RF spectrum with ever increasing demand for greater capacity, [which] is leading a drive to develop technologies that operate at higher and optical frequencies, including inter-satellite links.” Scotland has a concentration of expertise in photonics and optical communication system development at both academia and industry, which can be exploited to target future opportunities in developing high-speed satellite communications with less impact on the EM Spectrum. Scotland has to ensure we engage in UK-level bandwidth allocation and proactively lobby to ensure that protections are implemented, but simultaneously we support research in areas related to maximising the use of available EM Spectrum. Another key challenge in Scotland is that investment capital is expensive – investors take a higher share for the same capital as compared to London, and especially North America. Startups and spinouts therefore at once start with a disadvantage in global markets. Furthermore, growth capital is very scarce in Scotland. We must find ways to support our successful companies to become larger and even more successful. We consider it a priority for both the Scottish and Westminster governments to find ways to support such companies to scale and grow internationally. It is also vital that such support recognises the impact on the universities when staff members start a company. By way of example, we fully support the Royal Society of Edinburgh Enterprise Fellowship scheme (currently on hold), as that recognises the need to provide financial support for HEIs to host such endeavours. We need more initiatives like this.

The strategic priorities for the Scottish government in advancing the space sector are well-outlined and encompass a comprehensive approach. The Scottish government should focus on a) Invest in research and development to foster innovation and maintain a skilled workforce, this include provide appropriate and consistent funding for research, b) Establish partnerships with global space agencies for joint projects and knowledge exchange, c) Implement supportive policies and incentives for space-related businesses and research, particularly from the human exploration and the space sustainability perspective, d) Strengthen collaboration between academia and

industry to facilitate knowledge transfer, e) Foster education and training programs tailored to the evolving needs of the space industry.
There needs to be a coherent space sector industrial strategy that ensure time, money and effort is used to best impact:

- A Scottish CubeSat programme would support STEM outreach to deliver a pipeline of talent for the future. The provision of training by Scottish universities could be integrated to transition new graduates into the space sector, both for upstream and downstream activities.
- Bespoke funding opportunities for training and education related to the space sector will help support and keep a strong workforce. A critical pathway for skilled researchers would be through Centres for Doctoral Training (CDTs) in all aspects of the Space Sector.

4. **Which countries are going to be the most important international collaboration partners for Scotland and what is required to enable these partnerships and to ensure that Scotland is at the forefront of the sustainable space agenda?**

Space is inherently an international business; however, Scotland's closest collaborators will continue to be (in priority order): the rest of the UK; Europe; USA. There are individual projects/areas where specific international partners are important, whether that be Australia, or Singapore, or Japan, or elsewhere – but it is not clear we can really focus this down further. We need to keep our focus international, but also collaborate with our closest neighbours – particularly across the UK – to enable efficient delivery.

Aligning with other ambitious, fast developing nations make strong partners as there are emerging areas of constructive collaboration for knowledge sharing (e.g. skills development/ sustainability) but also mutual gaps that can be found. Switzerland, Portugal, Australia, Gulf nations, Malaysia, Singapore, etc. Despite improved cluster engagement across the UK, more could be done with wider UK nations.

For space data, Astro Agency's work on the UKSA funded International Bilateral Fund programme demonstrated the opportunities to export our capabilities to countries that need our support in local challenges (in this case the Gulf nations, but identifying other government departments around the world that have challenges that are suited to the capabilities of Scotland's EO companies would work well – Astro Agency completed a report for SDI on this very topic).

The US will always remain a clear partner for collaboration, enhanced by the TAA between the UK and USA, but again on the EO side I would suggest widening that to North America due to the huge EO segment in Canada.

There are huge opportunities in transferring skills from adjacent sectors right across the supply chain, from part manufacture to data scientists. The key is to build awareness in Scotland's space sector as not only an exciting place to work, but an industry that offers job security. The challenge around skills again comes back to the "challenge" of Scotland's strengths being so broad. It is difficult to say at this time whether launch vehicle manufacturers will be needed more than other areas of the

sector until the launch proposition has not only been developed but can deliver long-term security and results. Whereas more assured areas, such as satellite manufacture and data analysis are less of a risk, but again broad and diverse kinds of skillsets.

UK, Nordic, and smaller, technically strong EU counties such as the Netherlands. It is also worth noting that the competitor/collaborator/partnership space includes USA and Europe; in the latter case exploiting strategic partnerships post-Horizon association could present further opportunity and there has been a huge commercial shift in the nature of the US space industry which presents both a competitive challenge and a potential opportunity.

America, Middle East. Continual and persistent high level relationship building and strategic commercial development – Incentivised where possible.

Scotland should continue to work with the rest of the UK to use the relationships across industry and academia, cohered by UK Space Agency and other funding institutions. ESA is still one of the key partners to Scottish organisations too. In terms of specific countries, we expect that collaborations with Portugal, USA, Netherlands, South Africa, Sweden, New Zealand, Australia, and Canada will be valuable.

Given the heavily integrated nature of the sector across Europe, the European sector will remain vital. Moreover, the growth and investment of the sector in Ireland and their desire to work closely with and learn from the Scottish sector offers a unique ‘Celtic’ opportunity.

The “Five Eyes” – UK, Canada, America, Australia, and New Zealand will be critical for cybersecurity and telecommunications (inc. optical / quantum communications). Japan/Korea – scientific and components supply. America – big science and optical communications, EU – access to ESA funding for R&D.

Finland has a highly active tech ecosystem that has a good record of feeding into the space sector globally (e.g. Iceye). Within Europe, Finland is the most similar country to Scotland in terms of space activities and ecosystems. India has proven that they are a space nation at the forefront on the new space race. We should ensure we integrated with their progression. Australia, given its size and low population density, will soon rely even more heavily on satellite Earth observation: for agriculture, insurance, mining, Environmental, Social, and Governance (ESG), environmental impact, and early warning. There are clear synergies and alignments with Scotland and Australia’s space ambitions, and it make sense to build on that.

Cultivating collaborations with key international players is crucial for the growth and success of the Scottish space sector. Regarding the EU, Scotland should a) Establish and strengthen partnerships with EU space agencies, institutions, and industry players, b) Advocate for Scotland's participation in EU space programs and projects, c) Actively engage in Horizon Europe and other EU funding programs to enhance research and development opportunities, d) Work towards regulatory alignment to facilitate smoother collaboration post-Brexit.

Italy is becoming particularly active in the space sector, and collaborations are encouraged. I recommend strengthen ties with the Italian Space Agency (ASI) through joint projects and initiatives, collaborate with Italian space industry players like Kayser Italia, both in Italy and its twin branch in England, explore opportunities for knowledge transfer and joint research ventures.

Collaborations with India and China India should explore joint ventures and collaborative projects with local space agencies, leverage on each other's ability for mutual benefit, participate in bilateral space cooperation agreements to help knowledge exchange, identify areas of mutual interest such as satellite technology, long-term human space exploration, and Earth observation.

By strategically positioning Scotland as an active participant in international collaborations with the EU, India, China, and Italy, the Scottish space sector can use diverse ability, resources, and opportunities, contributing to its global standing and fostering innovation and growth.

5. **Does Scotland have the skills needed to support the space sector in the next two decades? Are there sectors with transferable skills that can be retrained? How do we promote a steady conduit of graduates with the necessary skills?**

We do not have enough STEM skills in Scotland. However, focusing on trying to poach skilled people from parallel sectors is entirely the wrong approach – but is one that people across sectors seem to keep promoting – this approach will fail as there are few parallel STEM-heavy sectors in actual decline where skilled people will be made available. Even the often reference oil & gas sector is in a bit of a revival and not shedding skilled people. The correct approach is to focus on building the general STEM skills base, not focusing on a particular sector – however we can use space as one of the 'poster child' sectors to attract more people into STEM education. This is a slow-burn activity as it needs to go all the way back to schools to encourage more children to study STEM skills at school to be able to study STEM courses at university/further-education. And we need to have a broad view of skills to include not just graduates but also for example technicians. This also crosses over into inclusion – particularly gender inclusion – as we can help alleviate the STEM skills shortages by encouraging more girls at school (including primary) to see STEM subjects as something they should seriously consider, as STEM subjects (and jobs) are not just for boys!

There are huge opportunities in transferring skills from adjacent sectors right across the supply chain, from part manufacture to data scientists. The key is to build awareness in Scotland's space sector as not only an exciting place to work, but an industry that offers job security. The challenge around skills again comes back to the "challenge" of Scotland's strengths being so broad. It is difficult to say at this time whether launch vehicle manufacturers will be needed more than other areas of the sector until the launch proposition has not only been developed but can deliver long-term security and results. Whereas more assured areas, such as satellite manufacture and data analysis are less of a risk, but again extremely broad and various kinds of skillsets.

Graduate skills yes. From recent experience undergraduates may have challenges in connecting with the Scottish space business base. If showed to be valid we should look at how we can bridge this gap and build a deeper mutual understanding. One approach could be to create a jointly sponsored academic competition – something like formula student. Manufacturing skills I doubt this given the competitive pressure in the employment sector from areas such as Scot Wind, Hydrogen etc. Again, I would like to see data here and seek the views of entities such as Scottish Engineering. Transferrable skills are an interesting area. Space is a regulated industry. I would start here and look at adjacent areas where we have a regulated sector. Oil and gas could be a useful start.

Skills Needed: Scotland currently has gaps in the skills pipelines needed to support the space sector's growth potential and ambition over the next two decades. The skills focus should include the following areas - AI and Data analysis, Cyber Security and risk management, Business, Innovation, and problem solving and Regulatory and Legal Knowledge.

Steady Flow of Graduates: The sector needs to continue to focus on young people from primary school through their education journey. In terms of FE and HE students, a wider offering of opportunities to study space across non-traditional routes, disciplines such as entrepreneurship and cyber security and a Space Summer Leadership programme. I have a podcast: 'Space: No Rocket Required' to try to open up the conversation about alternative careers opportunities are available in space.

The potential is there for a skills pipeline, building on Scotland HE (and FE) sectors. Iain has articulated potential existing activities/disciplines that could be used to produce the required multidisciplinary skills mix. A challenge is that the disciplines needed (e.g. robotics, systems engineering, computer science/informatics, sustainability) are extremely attractive to high growth sectors. The attraction to train/retrain to go into the Space sector is clear, and the Scottish strategy and signature activities in widening participation/early career development provide a useful signpost to opportunity. Sustained commitment to the development and support of the capacity building needed for space as a sector is needed; support needs to factor in the reduced leverage capacity/increased complexity in SME cluster development (see iii), as recognised by e.g. UK research councils for doctoral training.

Oil and Gas sector, video game development. We need to do a better job at promoting and educating about the sector and the opportunities. It needs to be a bold country wide endeavour – 'Your Country needs you' type of thing, Scotland's 'Moonshot' made by someone with credibility… We need to inspire primary school children to reach for the stars and S1 and S2 student to choose more STEM subject – especially girls. Organisations like the International Space School Education Trust should be signed up wholesale to deliver this in Scotland and significant investment made without forgetting underrepresented or socially economically deprived regions. We will also need space apprenticeships with a focus on vocational, practical capability.

Scottish Universities are world renowned, and certainly generate high calibre graduates with skills suited to the space sector, including mechanical engineering, aerospace/aeronautical engineering, systems engineering, software engineering electronics and electrical engineering, and various data disciplines such as data engineering, data analytics, Artificial Intelligence and Geographical Information Science.

Clyde Space Ltd certainly hires graduates from the University of Strathclyde and the University of Glasgow, we have excellent pipeline of talent and skills available in Scotland, however the current challenges of investing and developing skills for the Scottish space industry limits our talent prospects and opportunities. We could promote our skills capability by providing more specific space-focussed courses such as Space Science or Space Engineering, or even entire space departments at universities, the value of this would be to attract more talent into the country and internally develop our own skills pipeline for the sector. In England, the University of Leicester, UCL and the Open University all have dedicated space science courses, feeding the sector locally. The International Space University puts France in a helpful position with regards to space sector skills, and there are countless others in Europe such as TU Munich and TU Delft who feed the space sector in their countries. In the US, dozens of universities such as Caltech, Embry-Riddle, University of Colorado Boulder offer space science and engineering courses. Scotland pales in comparison. In addition to this, we could receive help from tailored Modern Apprenticeships, Graduate Apprenticeships, and advanced courses for qualified professionals to continue to develop skills development for the sector. It would support our local talent eco-system with strengthening the skills capability, especially for more niche skillsets. It is, however, important to acknowledge that there is a greater demand for experienced, skilled resources in Scotland at the moment, rather than graduates. With the current challenges around skills shortage within the UK, 20% of our workforce are educated, non-UK nationals. The talent pools from Europe and Asia provide experience and skills that are currently not available in the UK, or scarcely available given the competition for skills in our established Scottish Space industry. By developing a Scottish ecosystem for talent, the industry would be better placed to deal with future challenges. There are certainly other sectors with transferable skills – there is of course a large dependency on engineering skills, the space sector needs financial, HR, administrative and marketing skills like any other sector. Any manufacturing industry will have personnel suitable for satellite design, assembly, integration, and testing – especially from tightly regulated industries such as defence or pharmaceutical. Data engineering is the most transferrable – whether data comes from satellites or from other sources is immaterial. There may be opportunities to upskill or retrain from other sectors which has not been considered or aware of at this time. Members of the team at Clyde Space Ltd transferred from sectors as diverse as engineering, IT, nuclear, and oil and gas. Scotland has the foundation of skills to support the space sector with the capability to provide the skills for the future, with the right support and investment at a national level. Space is an inter-disciplinary sector that draws on a broad range of skills and capabilities, all of whom correctly identify as part.

6. **How can Scotland's space sector align with and contribute to broader national and international goals in areas such as climate change, AI, technology innovation, and education?**

There are huge opportunities around supporting net zero as mentioned already, but just to reiterate, this is both on the upstream manufacturing side but also in the ‘space data for our environment’ side. Scottish universities offer a wide range of space related courses, and this looks to be further improving. Whereas key enabling technologies like AI, quantum and areas like photonics have enormous potential to enhance Scotland’s space sector for years to come. There are significant opportunities here for space derived applications.

Areas which align to/leverage distinctive Scottish University strengths/strategic activities, including our recently published Research & innovation strategy, include climate change/net zero and AI and data.

Space needs to have a seat at the table to lead. Initiatives like TechScaler need to be more openminded, inclusive and collaborative. Industry and international partners need to evangelise about the importance. Barriers need to be removed. The sector needs representation in policy and strategy like NSET and we need vocal supporters akin to Mark Logan for Tech in the space sector.

Clyde Space Ltd specializes in small satellite technologies and services that enable businesses, governments, and educational organizations to access high-quality, prompt data from space. This ‘space data’ has a vast range of applications, from weather forecasting to precision farming and environmental monitoring. It is essential for improving our quality of life on Earth. Small satellites are critical for understanding our planet better and addressing pressing global challenges such as climate change. Small satellites can detect trends in key climate change indicators, such as ocean health or the size of the polar ice caps. With that data, we can make better decisions for our future. The combination of more cost-effective technology, ever-improving capability (e.g. Moore’s Law) and innovative commercial models such as Space Data as a Service, it has become practical for companies to use space without needing to invest large Capex or time.

For space to deliver its promised potential it needs to transition to an outward looking, underpinning sector of the economy that is ubiquitous across a vast range sector in a similar fashion to things like artificial intelligence, communications, and data analytics. Strategy and policy must accelerate this transition.

Involvement in Earth Observation missions through UKSA and ESA to allow more engagement in climate change and AI. Technology innovation is about collaboration. Creating stronger networks between industry and academic institutions will help the capability to apply for funding to conduct innovative R&D. At the end of the day, money is the key to all of this. More investment is needed to align and grow the sector. Industry needs to feed into university education to set the skills needed by students. Offering high school industrial placement options – something like the “Year in Industry.”

Scotland's commitment to addressing climate change through space technology can be further strengthened by expanding its focus on space sustainability and the circular economy. This strategic shift not only aligns with the United Nations' Sustainable Development Goals but also positions Scotland as a pioneering force in using space activities for the benefit of Earth. Initiatives such as the Bio-based

manufacturing in space group exemplify existing efforts that can be built upon. Exploring innovative approaches to reduce space debris and promote sustainable resource use will contribute to the region's leadership in these areas. Emphasizing the role of space activities in achieving UN SDGs (quoting the UN: “space activities are essential tools for realizing the achievement of the Sustainable Development Goals”), including environmental protection, poverty alleviation, and technological innovation, will highlight the broader societal impact of Scotland's advancements in the space sector. Integrating artificial intelligence and innovative technologies into satellite systems and data analytics will enhance efficiency and accuracy, fostering research and development in AI applications for space sustainability. Educationally, Scotland's commitment to providing high-quality programs, such as the recently established MSc in Astrobiology and Planetary Sciences in Edinburgh, ensures the continual development of skilled professionals in space-related disciplines. Public outreach initiatives, engaging schools, communities, and the general public, will further raise awareness about the societal benefits of space activities, emphasizing the link between space technology, sustainability, and environmental protection. This approach aligns with global priorities and underscores Scotland's dedication to using space technology for the betterment of Earth and the international community.

Work in harmony with the existing UK agencies (Catapults, Harwell etc) who are already pursuing activities aligned to these goals.

7. **What role do you see for public-private partnerships in advancing Scotland's space sector, and what models or examples could we look to for successful collaboration.**

Science missions are a good example of public-private activities that can work well – when strong project management and systems engineering drive the overall activity. The reason for Scotland’s space industry success to date is down to collaboration between public bodies (whether research or enterprise agencies) and industry stakeholders (established local on inward investment firms). The more collaboration the better and PPPs have proven to work in many nations. I would add that it is not all about money, there are ways that the public sector can support industry growth.

The preponderance of SMEs and the timescale and nature of the development opportunity requires public-private partnership and co-funding (see iii). The alignment of academia, industry government strategies, government, and relevant development agencies and the now combined National Space Strategy provides the driver for such integrated partnership programmes; the challenge is ensuring this connectivity by addressing the barriers which hinder such long-term support. UKRI Harmonised Impact Acceleration and Place Based Investments

Would need to consider more but Public 100% needs to be pump priming this sector and making it easy (especially on the investment side) for Private to get involved. The Scottish Space Network is regularly active in its plans to create a space investment marketplace leading to the creation of an investment fund. Players like SNIB and Seraphim are already expressing interest to SSN. Gov needs to de-risk. Furthermore – The government needs to start buying, as a customer, services from the sector – from upstream to downstream.

As with any Public Private Partnership (PPP) model, the main benefit is risk sharing. Risk sharing leads to a host of other benefits including the promotion of innovation and creativity, local supply chain development, alignment between academia and industry, more efficient delivery of public initiatives, diversity and equality, and increased exports. Space infrastructure programmes are inherently more risk laden than an average large scale terrestrial programme owing to the environment and lack of access to the assets once in place. Often considered to be working at the bleeding edge of technical development, it has become increasingly difficult to secure the necessary funding to realise plans with investors wishing to see proof of concept (or indeed, market). These are areas that the PPP model directly addresses and can be an effective way to mitigate these challenges. The UK Space industry, including Scottish companies, are running under this model with ESA and the UKSA. The perfect example of this success is xSPANCION, where AAC Clyde Space lead a trio of businesses in collaboration with ESA.

Within Europe, sub-national governments are supporting local space economies by acting as a contracted customer for space services deployed by new satellites. The Scottish & UK government both commission vehicles in other domains to support government business. Consideration should be given to acting as a contracted customer for novel space services, in support of core government business, developed and launched from Scotland. This must not be a ‘space for the sake of space’ approach and must ensure a focus on value for money in delivery of government business. As such, developed services would deliver significant export value. Government users of satellite services should be supported to work with the academic sector to inform and co-create future research programmes to address user needs and drive value for money in tax-payer services. On the commercial side, the tendency for government to issue grants rather than contracts hinders company growth. Government should look to function as a customer, supporting both the creation and delivery of new services for the government customer within a single contract. This will support the development of commercially practical, scale-able products, and investable companies. Increasing the offering of Graduate apprenticeships, Doctoral training programmes, and MSc – industry placements. Specialised MSc programmes within the space sector could be subsidised if a student were employed or to be employed by a space sector company on completion of the MSc.

A key area of potential improvement lies within the procurement processes within the space sector. A considerable proportion of Scotland’s current space industry is driven by Earth observation data – much of the hardware companies in Scotland are building satellites to collect data about the Earth. It is therefore prudent of the Scottish government to find ways to provide long-term (5+ years) anchor contracts to data suppliers who can then secure investment on the back of this committed contracts. Good examples of this model include TerraSAR-X, a public-private venture from the German government (via DLR) and EADS Astrium.

Enhancing collaboration among government agencies, academia, and private companies is pivotal for elevating the ability, impact, and transferable skills within the Scottish space sector. To achieve this goal, Scotland can draw valuable insights from successful international models of public-private partnerships in the space sector, learning from their effective strategies and implementation approaches. By adopting

best practices and tailoring them to the local context, Scotland can foster a dynamic ecosystem that maximizes the collective potential of all stakeholders involved in space-related endeavours.

Scotland's public finances will never justify such a partnership for Scotland to flourish in this sector it is all about private investment.

8. **In which areas of the Scottish technology industry and research community is the Space Sector already an important customer and what are the key relevant technologies.**

The main area that comes to mind is environmental testing, with the Higgs Centre in Edinburgh offering space companies shared resources to support SMEs at a crucial stage of their development. Similarly, the incubators and accelerators are hugely important for the space sector.

Cube satellite development. Emergent environmental monitoring applications. Increasingly, delivery of public services (such as social care) into highly remote locations.

Includes access to talent, relevant equipment/infrastructure, research/innovation, consultancy to support (predominantly) SME creation/development. Innovative technology developments and testing designed to meet the challenges of extreme conditions and e.g. payload, sustainability, data science technologies.

Would need to know more personally – a platform for understanding this and a spotlight shone on this nationally would be helpful.

As a cornerstone of the Scottish Space Sector, our organization has been instrumental in the development and manufacturing of micro satellites. We have had the privilege of seeing firsthand the remarkable growth and evolution of this industry. The success of the sector within our community can be attributed to the existing skills in the area. The Space Sector has given an opportunity to those with experience in 'Silicon Glen' to repurpose their world-leading manufacturing skills for space-related applications, thereby laying a robust foundation for the sector's development. Furthermore, the supply chain in Scotland that supports the industry is experiencing growth, a testament to the success and contracts being secured within the country. This growth is not only strengthening the entire supply chain within the country but also providing a plethora of technological partners for SMEs like AAC Clyde Space to collaborate with on countless opportunities.

These partnership opportunities enable us to support our collaborations with academic and research institutions. For instance, we have enjoyed a productive relationship with Strathclyde University for over three decades, with a project or program in progress every day since our first collaboration. While this is a specific task, we also engage with Glasgow University, keeping a functional relationship centred on product testing. This allows us to see both early technology development and final product testing. Research institutions play a crucial role in the space sector and continue to contribute to and support the growth of this industry in Scotland.

Those involved in Earth Observation, astronomical work, or creating their own CubeSat missions for in-orbit demonstrations.

Crucial components within the space sector encompass data analytics, remote sensing, materials science, and engineering, all of which are fundamental for satellite construction and launch vehicle development. Additionally, satellite communication technologies play an essential role, contributing significantly to the overall infrastructure and capabilities of the space sector. These key areas collectively form the backbone of advancements and innovations within the space industry, underscoring their integral nature in shaping the present and future landscape of space exploration and technology.

ANNEX E

SSAC REPORT – Scotland's Space Sector: Exploring potential future opportunities

A brief overview of the Industrial Strengths of the Scottish Space Sector

Introduction

The Industrial Space Sector in Scotland has been established over the last twenty years and, while still young, is rapidly expanding and diversifying. Largely dominated by SMEs, it is a mixture of hardware, mainly small satellites, and software companies offering products and services in the sector's upstream and downstream technology areas.

This document is not intended to be a comprehensive record of all relevant companies and organisations in the Scottish Space sector but rather a snapshot of the main areas of activity and focus with examples used to emphasise the areas of strength on the industrial side of the ecosystem. The introduction/summary is followed by a more detailed listing of some of these companies and their capabilities and expertise.

Definitions

"Upstream" sector refers to the transportation of objects into space and their operation, ground stations and space exploration.

"Downstream" sector refers to data and services derived from the upstream sector.

"Enabling Technologies" are general-purpose or "building block" technologies, arising from advanced science and engineering that allow the creation or improvement of products and services across a wide range of applications and sectors.

Upstream

The upstream sector in Scotland is heavily weighted towards small satellite manufacture. Starting with the formation of Clyde Space in 2005 (now **AAC Clyde Space***) designing and manufacturing nanosatellites such as CubeSats and then supplemented by multinational **Spire** locating a European office in Glasgow in 2015, also designing and manufacturing small satellites. **Alba Orbital** was founded in 2012 in Glasgow and manufacture picosatellites (<1kg).

**Clyde Space was acquired by Swedish company AAC Microtec AB in 2018.*

Several companies support the development of Ground Station technologies, especially in areas such as antenna design and manufacture. These include **Celestia**, **Sofant Technologies** and **Infinect**.

Supporting the upstream sector are launch sites. There are currently 5 sites being built across Scotland:

> **Saxavord Space Port** in Shetland will launch rockets with payloads up to 1.5 tonnes into Sun-Synchronous, Polar and High Inclination orbits (30 per year). Launch services will be supported by **Lockheed Martin** and **ABL Systems** along with **Hyimpulse UK**, a Shetland-based subsidiary of a small orbital launcher developer from Germany.
>
> **North Uist Space Port 1** is based at the former **Qinetiq** missile test site in the Outer Hebrides. It will offer vertical launches – mainly sub-orbital with payloads less than 100kg.

Prestwick Space Port in Ayrshire will offer horizontal launch within an established commercial airport. The launch partner is **Astraius**. Services will include air launch of satellites up to 800kg, microgravity flights and hypersonic flight services.

Machrihannish Space Port in Argyll will offer horizontal and vertical launch with variable payloads mainly for Sun-Synchronous and Polar orbits.

Sutherland Space Port in the north of the Scottish mainland aims to be the world's first carbon neutral spaceport offering vertical launch with payloads less than 500kg.

There are two manufacturers of small vertical launch vehicles in Scotland. The Launch partner for Sutherland Space Port is **Orbex**, based in Forres, who manufacture two-stage rockets capable of taking 150kg payloads using bio-propane fuel.

Another Scottish company, manufacturing small vertical-launch vehicles, is **Skyrora** based in Edinburgh and Cumbernauld. They are developing the XL rocket, which will stand 22m high, with 3 stages, and capable of taking 315kg payloads to Low Earth Orbit.

A new entrant to the upstream sector in Scotland is Mangata Networks. Originally targeted for £84 million in collaborative funding, this large inward investment was expected to create 600 jobs at Prestwick Aerospace Park to manufacture telecoms satellites for MEO and HEO orbits providing 5G connectivity across the world, including the manufacture of edge-processing data centres. While latest reports suggest that the manufacturing centre is unlikely to proceed, there are still plans for a dedicated R&D Centre, and to manage the satellite operations and cloud services, in Scotland.

Downstream

Currently the downstream space sector in Scotland can be broadly separated into companies working with Earth Observation data and companies offering specialist software services for space applications.

Mainly based in Edinburgh and the East of the country, examples of companies working in Earth Observation include **Econometrica**, who use EO data to inform clients about climate impact; **Global Surface Intelligence**, who's management platform is used to assess and measure natural resource data for forestry, agriculture and land use; **Space Intelligence**, providing data on forest coverage and carbon storage for climate change mitigation; **Trade in Space**, who use remote sensing data and machine learning for smart contracts and commodity trading; **Earth Blox**, who offer a EO data software analysis platform for climate and nature reporting requirements; and **Hypervine**, who use satellite data to monitor construction and mining assets across the globe.

Examples of companies providing speciality software services for the Space sector include **Bright Ascension**, offering software for satellite mission development and operation; **AstroAgency**, a marketing intelligence and communications company specialising in commercial space applications, **Craft Prospect**, offering space engineering services and Quantum Key Distribution solutions; **Scotspace**, an infrastructure development and operations company; **Responsive Access**, offering launch brokerage and consultancy; and **ThinkTank Maths**, who provide space traffic management solutions.

Supply Chain

The Scottish supply chain for space hardware manufacturing is very varied with many companies providing products and manufacturing services for the sector. Some examples include **Alter Technology** in Livingston, who provide specialist integration, assembly and packaging solutions for

optoelectronics, microelectronics and MEMS technologies; **Honeywell Aerospace**, a leader in production of space-qualified passive microwave and electronic sub-systems; and **WL Gore**, a manufacturer of cable and interconnects for spacecraft.

Compliance & Testing Services

There are several locations in Scotland offering testing services to the Scottish Space sector. **Smiths Interconnect** in Dundee have a dedicated testing lab simulating the extreme conditions of space to assure they can withstand launch and orbit. Other examples of test facilities include **Eurofins Electrical & Electronic UK Ltd** based at Grangemouth, who provide compliance, certification and testing for electrical and electronic products including aerospace/defence EMC testing. EMC testing is also available at **Forth EMC** in South Queensferry. The **Higgs Centre for Innovation** (part of STFC-UKRI) has cleanroom test and integration facilities including environmental and functional testing aimed at satellite manufacturers. Many of the universities offer commercial access to specialist test and laboratory equipment. A searchable and bookable database for this is available online at **ULab** (www.ulabequipment.com). Some of the companies working the Defence sector have test facilities including accelerated life testing which can be accessible to other organisations. For example**, Leonardo UK Test House** in Edinburgh.

Enabling Technologies

An area of significant strength for the Scottish Space ecosystem is in Enabling Technologies which feed both directly and indirectly into the Space sector.

Examples of this include **Photonics**, **Quantum Technologies**, **Robotics & Automation**, **Communications Technologies**, **Sensing & Imaging Systems**, **Signal Processing and Data Analytics**, **Nanotechnology** & **Compound Semiconductors**, **Advanced Manufacturing**, **Industrial Design**, **Cybersecurity**, **Engineering Biology** & **Industrial Biotech**, **Sustainable Food Production** (including **Hydroponics**), plus a thriving **Human Health & Life Sciences** sector.

Examples of supporting organisations in Enabling Technologies include **the Fraunhofer Centre for Applied Photonics, Technology Scotland**, **National Manufacturing Institute of Scotland**, the **Lightweight Manufacturing Centre**, **The Data Lab**, **CENSIS**, the **National Robotarium**, **James Watt Nanofabrication Centre**. In biotechnology, support can be found at **iBioIC;** In human health at **Digital Health Institute**, and **Precision Medicine Scotland**.

Defence

In Scotland the Defence sector is largely multi-national with companies such as **Leonardo**, **Thales** and **Raytheon** all working on space-related developments although most of this activity is outside of Scotland. **Lockhead Martin** is partnering with ABL Space (California) for launch services in Shetland. The UK is setting up **UK Space Command**, based at RAF High Wycombe, which will utilise Scottish launch sites.

Cluster Organisations

Space Scotland is the main industrial cluster organisation for the Space sector in Scotland based at the Royal Observatory in Edinburgh and promoting the interests of stakeholders. Publications of Space Scotland include “The Space Scotland Sustainability Roadmap”. Academic interests are represented by the **Scottish Space Academic Forum**. There is a grassroots online network for news sharing and information called the **Scottish Space Network**. The **Scottish International Space Advisory Committee** (SISAC) consists of members of the Scottish Government’s GlobalScot

programme – a network of Scots in business around the world – who have come together voluntarily to provide advice and identify opportunities in the sector.

Scottish Space Strategy

Produced in 2012, the Scottish Space Strategy aims to secure a £4 billion share of the global space market for the Scottish economy. The main features of the strategy include the development of the space infrastructure and research environment, consolidation of Scotland as a UK location for space technology development, supporting the Scottish launch sector, alignment with Net Zero ambitions, growing the customer base for end-to-end solutions locally and globally, and collaborating with agencies in the UK and worldwide.

Scottish Space Cluster:

Key Stakeholders:

Space Scotland, Scottish Government Space Group, Scottish Space Academic Forum, Scottish Enterprise, Scottish Development International, UK Space Agency, European Space Agency, Innovate UK, Skills Development Scotland, Highlands and Islands Enterprise, Scottish International Space Advisory Committee, Scottish Affairs Committee, UK Space Agency, Satellite AppIlcations Catapult, Aerospace Defence Security Space.

Launch:

- SaxaVord (Vertical Launch Site and Ground Station)
- Orbex (Small Vertical Launch Vehicle Manufacturer)
- Space Port Sutherland (Vertical Launch Site)
- Skyrora (Small Vertical Launch Vehicle Manufacturer)
- Glasgow-Prestwick Space Port (Horizontal Launch Site)
- Astraius (Horizontal Launch Vehicle Manufacturer)
- Spaceport Machrihanish (Horizontal, Vertical and High-Alititute Platform Launch Site)
- Spaceport 1 (Vertical Launch Site)
- HyImpulse (Hybrid Propulsion Launch Technology/Capabilities)

Upstream:

Satellite Production:

- Mangata
- AAC Clyde Space
- Spire
- Alba Orbital

Ground Stations:

- Celestia
- Sofant Technologies
- Infinect

Upstream Supply Chain:

- Star Dundee
- WL Gore
- Smiths Interconnect
- M Squared Lasers
- Alpha Data

- Walker Precision
- ALTER Technology
- Rhea Space Activity
- Plexus Corp

Downstream:

Earth Observation:

- Ecometrica
- Global Surface Intelligence
- Space Intelligence
- Trade in Space
- Earth Blox
- Hypervine
- SpaceAye
- EarthWave
- Weather Stream

Software and Services:

- Bright Ascension
- ThinkTank Maths
- Scotspace
- AstroAgency
- Responsive Access
- Craft Prospect
- Krucial (R3 IOT)
- Brainnwave
- Niras UK

Aerospace and Defense:

- Leonardo
- Thales Grou
- Raytheon

LAUNCH

SaxaVord Limited:
Company No: #SC306164
Enterprise Size: Medium
Incorporation/Registration: 2006/Scotland
Company Website: https://saxavord.com/
Company (current) Status: Private
Contact: Scott Hammon, Operations Director, scott.hammond@shetlandspacecentre.com
Additional Information:

Description:
SaxaVord is an operator of a developing vertical launch site and ground station, based on Lamba Ness in Unst – Shetland (Scotland) [1]. Having received ~£100 million GBP in investment (over 5 year period), SaxaVord aims to launch small rockets (payloads up to 1.5 tonnes) into sun-synchronous, polar and high inclination orbits. SaxaVord, and its partners, estimate ~30 launches per year, with the first planned to take place at the end of 2023 [2]. Beyond its launch site capabilities, SaxaVord's ground station will also provide storage facilities (fuel, pyrotechni, etc.), control centres (launch and range), off-site offices, the ability to transmit and receive ground station 5M SX and KA bands, and space situational awareness [3]. Scottish-based Hylmpulse, a launch company working SaxaVord and Orbex, has recently been awarded £3 million GBP in funding from the UK Space Agency, supporting spaceflight activities [4]

References:

1. SaxaVord UK Space Port Webpage: https://saxavord.com/
2. Rocket Factory Augsburg's first launch to take place from SaxaVord Spaceport [Link]
3. LAUNCH UK: A guide to UK spaceports: [Link]
4. UK Space Agency funding boosts plans for launch from SaxaVord Spaceport and Sutherland Spaceport [Link]

Orbex (Orbital Express Launch Limited):
Company No: #09580714
Enterprise Size: Medium
Incorporation/Registration: 2015/England
Company Website: https://orbex.space/
Company (current) Status: Private
Contact: sutherlandspaceport@orbex.space
Additional Information: Orbex is formerly known as Moonspike Limited (May 2015 – Jan 2016).

Description:
With headquarters and manufacturing faciltiies in Forres (north-east Scotland), and design facilities in Denmark, Orbex is Europe's leading orbital launch services company and has raised over £38 million GBP to date [1]. Orbex offers a low cost launch service for the small, micro and nano satellite industry and has developed Orbex Prime: a low carbon, high performance micro-launch vehicle. Orbex Prime is a two-stage rocket that is ~19 meters in height and capable of carrying payloads up to 150 kg into a 500 km sun-synchronous orbit (i.e., LEO). Orbex Prime utilises a more sustainable fuel known as BioLPG (bio-propane). Orbex has partnered with Sutherland Spaceport Ltd (*see additional information below*), using their vertical launch site in Sutherland (northern Scotland) to facilitate up to 12 orbital rocket launches per year for the deployment of satellites into Earth's orbit [2]. They aim to be the world's first carbon neutral spaceport. An example of how they plan to achieve this is through re-using the peat lifted during construction to repair other large already degraded peatland in different areas. Orbex will direct the construction and hold full operation management of this facilitiy, expected to support ~ 250 new jobs (40 high-quality on-site jobs and > 200 jobs in the wider region including manufacturing and supply chain opportunities) [3]. Orbex has recently received £3.3 million GBP from the UK Space Agency aimed at ensuring their space-related activities are environemntally sustainable [4].

Sutherland Spaceport Ltd:
Company No: #SC682509
Incorporation/Registration: 2020/Scotland
Contact: sutherlandspaceport@orbex.space
Additional Information: Space Hub Sutherland has a payload capacity of < 500 kg. This Spaceport houses a launch control centre, launch integration and assembly facility, antenna farm, and launch pad with commodity farm [3]

References:

1. Orbex Webpage: https://orbex.space/
2. Construction Begins at Sutherland, the UK Mainland's First Vertical Launch Spaceport [Link]
3. LAUNCH UK: A guide to UK spaceports: [Link]
4. UK Space Agency funding boosts plans for launch from SaxaVord Spaceport and Sutherland Spaceport [Link]

Skyrora:
Company No: #SC569511
Enterprise Size: Medium
Incorporation/Registration: 2017/Scotland
Company Website: https://www.skyrora.com/
Company (current) Status: Private
Additional Information: Previously known as Space Alba (Jun 2017 – Aug 2017)

Description:
Skyrora is private launch vehicle services company capable of designing, manufacturing and deploying small vertical launch rockets/vehicles [1]. Skyrora have developed the XL rocket, a ~22 meter – three-stage rocket, capable of carrying a payload (up to 315kg) into sun-synchronous LEO. The third stage of Skyrora's XL rocket features an Orbital Transfer Vehicle (OTV). This OTV can relight up to 15 times in space, allowing for the vehicle to navigate in space and maintain/replace orbiting satellites. Once payload has been delivered, the OTV can subsequently be used as a 'space tug' that can latch to non-operational satellites, de-orbitting them and reducing space debris. Skyrora's rockets use Ecosene rocket fuel, a high-grade kerosene made of waste plastics. Skyrora have also developed a recycling method for this fuel, further highlighting their sustainability efforts. Skyrora has a multi-launch agreement in place with SaxaVord Spaceport to launch their XL rockets in Shetland (Scotland). They aim to carry out 16 launches per year by 2030.

References:

1. Skyrora webpage: https://www.skyrora.com/
2. Skyrora Ecosene Rocket Fuel: https://www.skyrora.com/ecosene/
3. SKYRORA AGREES MULTI-LAUNCH DEAL WITH SHETLAND SPACEPORT FOR THE NEXT DECADE [Link]

Glasgow Prestwick Spaceport (part of Glasgow Prestwick Airport Limited):
Company No: #SC135362
Enterprise Size: Very Large
Incorporation/Registration: 1991/Scotland
Company Website: https://www.glasgowprestwick.com/business/spaceport/
Company (current) Status: Acquired/Merged
Contact: Mick O'Connor, Prestwick Spaceport Programme Director, mick@haelo.io
Additional Information: Company information relates to Glasgow Prestwick Airport Ltd, and not specifically Prestwick Spaceport. Zoe Kilpatrick is the commercial director at Glasgow Prestwick Airport.

Description:
Glasgow Prestick Spaceport offers horizontal launch services within an already well established commercial airport near Glasgow (Scotland), connected by air, road, train and sea [1]. Prestwick is therefore a well connected base and over 50% of Scotland's aerospace workforce are already being employed at Prestwick. With launch partner/service provider Astraius, the first commercial launch is planned for late 2023 [2-4]. By 2035, this spaceport plans to provide air launch of satellites up to 800kg, as well as microgravity and hypersonic flight services. Not only is Glasgow Prestwick Airport an infrastructure that supports more than 4,000 jobs in the west of Scotland already, but Prestwick Spaceport is considered to play a vital role in the creation of up to 4,000 more jobs (locally) associated with the aerospace and space sector in Scotland; supporting by £80 million GBP in investment. This site will also house several R&D and manufacturing companies in the space industry, adding to its strong existing aerospace presence (BAE systems, Collins Aerospace, GE, National Air Traffic Services, Spirit Aerosystems) [5].

References:

1. Glasgow Prestwick Spaceport Webpage: https://www.glasgowprestwick.com/business/spaceport/
2. "Ready for take-off" as Prestwick Spaceport takes a giant leap forward in rocket launches [Link]
3. Astraius Webpage: https://www.astraius.com/
4. South Ayrshire Council – Prestwick Spaceport Episodes: 1 [Link], 2 [Link], 3 [Link], 4 [Link], 5 [Link]
5. LAUNCH UK: A guide to UK spaceports: [Link]

Astraius Limited:
Company No: #12853584
Enterprise Size: Small-Medium
Incorporation/Registration: 2020/England
Company Website: https://www.astraius.com/
Company (current) Status: Private
Contact: Webpage 'Contact Us' Page: https://www.astraius.com/contact/
Additional Information: See Glasgow Prestwick Spaceport section (above) for complementary information, including relevant contact detail(s).

Description:
With its global headquarters based in Glasgow Prestwick Spaceport (Scotland), Astraius are a horizontal launch services company with already proven launch capabilities [1]. Utilised succesfully by the US Government, Astraius are using the C-17 Globemaster transport aircraft as their horizontal air-launch platform – facilitating the safe delivery of satellites (up to 800 kg) to a sun-synchronous low-earth orbit. Collaborating alongside Spirit Aerosystems (also based within Prestwick's space cluster) to advance/accelerate the development of the Astraius horizontal launch platform, Astraius are estimated to begin launching satellites in 2025 from Prestwick Spaceport [2]

References:

1. Astraius Webpage – Launch Services: [Link]
2. Spirit AeroSystems, Astraius join forces to boost UK launch ambitions: [Link]

Spaceport Machrihanish (Discover Space UK Limited):
Company No: #SC499199
Enterprise Size: Small-Medium
Incorporation/Registration: 2015/Scotland
Company Website: www.discoverspaceuk.com
Company (current) Status: Private
Contact: enquiries@maccdl.co.uk
Additional Information:

Description:
Based out of Spaceport Machrihanish in Argyll & Bute (Scotland), Discovery Space UK Ltd is a commercial launch service operator supporting small-scale rocket launches and spaceflight operations [1-2]. This spaceport offers the potential for horizontal, vertical and high-altitute platform vehicle launch into both sun-synchronous and polar orbits (i.e., LEO). Negotiations with launch providers are on-going.

References:

1. Discover Space UK Webpage: www.discoverspaceuk.com
2. LAUNCH UK: A guide to UK spaceports: [Link]

Spaceport 1:
Company No: #SC573404
Enterprise Size: Small
Incorporation/Registration: 2017/Scotland
Company Website: *in development*
Company (current) Status: Private
Contact: Allison MacCorquodale - alisonmaccorquodale@cne-siar.gov.uk, Mark Roberts - mark@reflectsolutions.com
Additional Information: Commiunity Interest Company (CIC)

Description:
Spaceport 1 represents a commercial sub-orbital vertical launch spaceport at Scolpaid in North Uist (Scotland) [1]. Compared to other previously described spaceports, Spaceport 1 is at an early phase in development. However, this spaceport aims to provie permanent infrastructure for the launch of sub-orbital sounds or research launch vehicles; a class of vehicle that does not enter Earth's orbit but is capable of operativing above the stratosphere. This site to be designed in a way that is daptable and flexible to customers, providing access to: sub-orbital launch vehicles, working accommodation, assembly facilities, licensed storage, range services and launch communciations networks [1]. Spaceport 1's project is to be supported by up to £1 million GBP from the Scottish Government [2].

References:

1. LAUNCH UK: A guide to UK spaceports: [Link]
2. Spaceport 1: [Link]

Hyimpulse UK Limited:
Company No: #SC684332
Enterprise Size: Medium (parent company, set up in 2018)
Incorporation/Registration: 2020/Scotland
Company Website: https://www.hyimpulse.de/en/
Company (current) Status: Private
Contact: contact@hyimpulse.de
Additional Information:

Description:
Hyimpulse is an aerospace launch company focused on enabling (cost-effective and rapid) access to space through development of mini-launchers for satellites, orbital launchers, sounding rockets, hybrid rocket motors and other related products that support acess to space. Hyimpulse are enabling access to space (sub-orbital and orbital) utilising their hybrid rocket propulsion technology. Hyimpulse successfully tested a full scale 75kN flight rocket motor in 2020 and 2021, the largest and most advanced hybrid motor to ever be tested in Europe (currently in operation worldwide). The role of the UK office, based in the Bayes Centre at Edinburgh University, is to support development of this technology as well as support operations at the SaxaVord spaceport in Shetland – receiving over £3 million GBP in funding from the UK Space Agency [2-3].

References:

1. Hyimpulse Webpage : https://www.hyimpulse.de/en/
2. UK Space Agency funding boosts plans for launch from SaxaVord Spaceport and Sutherland Spaceport [Link]
3. New Member: aerospace company HyImpulse [Link]

UPSTREAM

SATELLITE PRODUCTION

Mangata Networks Limited:
Company No: #12484210
Enterprise Size: Medium
Incorporation/Registration: 2020/England
Company Website: https://www.mangatanetworks.com/services
Company (current) Status: Private
Contact: brian@mangatanetworks.com (CEO), more@mangatanetworks.com
Additional Information:

Description:
The nature of Mangata's business is wireless telecommuncations activities [1]. Mangata is a satellite-enabling cloud services company that aims to facilitate high-speed, continous connectivity to everyone on the planet through its constellation/network of medium and high earth orbit (MEO;B2 / HEO;B1) satellites. Compared to lower earth orbit (LEO), MEO/HEO is believed to give Mangata a more optimal cost/coverage advantage, with edge processing (carried out by MangataEdge™ micro data centres) offseting any latency associated with MEO/HEO. Mangata signed a partnership in December 2022 with public sector partners worth ~£83.7 million GBP, including Scottish Enterprise, Scottish Government, UK Government and South Ayrshire Council [2]. This investment enables Mangata to build a manufacturing facility at Prestwick International Aerospace Park (Scotland), where they plan to manufacture and deploy ~ 80 medium class satellites (< 625 kg in mass, 10-year mission life) every year, over a 10-year timeline. Mangata will also manage/operate its satellite systems and global network from Prestwick. This operation is estimated to create 575 new jobs in Scotland, the majority of which are considered highly skilled technical engineering positions.

References:

1. Mangata Network Limited Website: https://www.mangatanetworks.com/services
2. Mangata Networks announces new space engineering, manufacturing, and operations hub in Prestwick. [Link]

Clyde Space Limited (part of the AAC Clyde Space AB Group):
Company No: #SC285287
Enterprise Size: Medium
Incorporation/Registration: 2005/Scotland
Company Website: https://www.aac-clyde.space
Company (current) Status: Private
Contact: Peter.JW.Anderson@AAC-clydespace.com (Peter Anderson – Chief Commercial Officer, AAC Clyde Space), aac.spacequest@aac-clydespace.com
Additional Information: AAC Clyde Space is a public company (STO:AAC), HQ – Sweden (Luis Gomes – CEO). In addition to Clyde Space Limited (Scottish Operations), AAC Clyde Space AB Group has five other reportable Operational) segments: AAC Clyde Space (Sweden), Hyperion Space (Netherlands), SpaceQuest (USA), Omnisys Instruments (Sweden), and AAC Space Africa (South Africa).

Description:
AAC Clyde Space specialise in small/nanosatellite technologies (CubeSat) and services. Utilising the satellites radio and laser communciation capabilities, AAC provide businesses, government and educational organisations access to high-quality real-time data from space (including precision farming, tracking of commercial shipping, weather forcasting, climate change observations) [1]. Small satellite manufacturing (particularly CubeSats) is a focus of the Glasgow operations, as well as providing turnkey space mission services and enabling space data communcation.

References:

1. AAC Clyde Space AB Group Webpage: https://www.aac-clyde.space

Spire Global UK:
Company No: #SC493745
Enterprise Size: Large (Spire Global Inc.)
Incorporation/Registration: 2014/Scotland
Company Website: https://spire.com/
Company (current) Status: Private
Contact: Peter@spire.com (CEO), Contact Us: https://spire.com/about-us/contact-us/
Additional Information: Spire Global UK are part of Spire Global Inc, a public company with headquarters in the USA (NYSE:SPIR, CEO – Peter Platzer).

Description:
Spire Global are a California satellite data company that has set up nanosatellite (CubeSats) design/manufacturing in Glasgow, Scotland [1-2]. Spire's global constellation of 'next-generation' weather satellites utilise radio communications to provide high-quality real-time data that can accurately monitor and predict weather forecasts, as well as track maritime and aviation patterns. Spire currently have 100 nanosatellites in operation providing earth obseration data to over 30 grounds stations globally.

References:

1. Spire Global Inc. Webpage: https://spire.com/
2. Why California satellite data company Spire chose to set up in Scotland: [Link]

Alba Orbital Limited:
Company No: #SC434130
Enterprise Size: Small
Incorporation/Registration: 2012/Scotland
Company Website: https://www.albaorbital.com/
Company (current) Status: Private
Contact: tom.walkinshaw@albaorbital.com (CEO), contact@albaorbital.com
Additional Information:

Description:
With the aim of 'demoncratising' access to space, Alba Orbital manufacture and support pico-satellite (PocketQube satellites) development [1]. Satellites provide real-time data through collecting earth observation information at intervals of minutes (as opposed to conventional satellited data capture, taking hours or days). PocketQube satellites developed thus far: Unicorn-1 (1P, 5x5x5 cm) and Unicorn-2 (2P, 5x5x10 cm) – weighing less than 1 kg. Alba Orbital has successful launched > 5 picosatellite missions into low earth orbit, working with multiple space companies including SpaceX [2].

References:

1. Alba Orbital Inc. Webpage: https://www.albaorbital.com/
2. Alba Orbital: News and Press Releases: https://www.albaorbital.com/

UPSTREAM

GROUND STATIONS

Celestia Technologies Group (UK) Limited:
Company No: #10756220
Enterprise Size: Celestria (UK) – Small, Celestia Parent Company – Medium
Incorporation/Registration: 2017/England
Company Website: https://celestia-tech.com/
Company (current) Status: Private
Contact: contact us page: https://www.celestia-uk.com/contact-1
Additional Information:

Description:
Celestia has a site in Edinburgh (Heriot-Watt University's enterprise park), developing electronic scanning antennas (active phase arrays) for ground stations. Celestia has built its own radio-frequency (RF) anechoic chamber hosting a spherical far field measurement capability. Celestia UK are part of the Celestia Tech Group and are focused on providing technical/cost-effective solutions in Satcoms, 5G, Position Navigation & Timing, and Software-defined Radio domains [1].

References:

1. Celestia UK Info Webpage: https://www.celestia-uk.com/

Sofant Technologies Limited:
Company No: #SC409777
Enterprise Size: Small
Incorporation/Registration: 2011/Scotland
Company Website: https://www.sofant.com/
Company (current) Status: Private
Contact: Contact us page: https://www.sofant.com/contact
Additional Information:

Description:
Utilising their radio-frequency microelectromechanical system (RF-MEMS), Sofant are focused on solving power consumption and heat dissipation issues associated with current satellite communications antenna systems (including electronically scanned antenna arrays) [1]. The development of Sofant's low power – low cost platform is being supported by ESA/UKSA funding (£6.2M) [2], aimed at commercialising their technology as a new generation of low-latency, super-fast satellite networks, enabling global wireless communications/connectivity.

References:

1. Sofant Technologies Webpage: https://www.sofant.com/
2. Sofant Technologies signs €7.3 million European Space Agency contract [Link]

Infinect Limited:
Company No: #14001369
Enterprise Size: Small
Incorporation/Registration: 2022/England
Company Website: https://infinect.space/
Company (current) Status: Private
Contact: info@infinect.space [Samuel Rothenberg, CEO/co-founder]
Additional Information:

Description:
Infinect have developed a flat panel antenna, knonw as INFINECT antenna [1]. INFINECT antenna is estimated to be 2x smaller, 3x faster and 10-15x cheaper than current comparable technologies/solutions. INFINECT antenna is capable of providing high-speed wireless connectivity to remote areas across the globe, supporting many sectors including IoT, maritime, rail, avionic, and national security (defence). Technology is 'patent pending' and is anticipated to be market ready in 2024.

References:

1. Infinect Limited Webpage: https://infinect.space/
2. Samuel Rotenberg, INFINECT – Enterprise Fellowships presentation September 2021: [Link]

UPSTREAM

SUPPLY CHAIN

STAR-Dundee Limited:
Company No: #SC230143
Enterprise Size: Medium
Incorporation/Registration: 2022/Scotland
Company Website: https://www.star-dundee.com/
Company (current) Status: Private
Contact: stuart.mills@star-dundee.com (CEO)
Additional Information:

Description:
STAR-Dundee is an aerospace engineering company that designs network (and related data handling technology) for use on-board of spacecrafts. A Dundee University spin-out (2002), STAR-Dundee support SpaceWire and SpaceFibre network standards (i.e., for spaceflight applications) through delivery of test and development equipment, chip designs and IP cores. SpaceWire is a spacecraft on-board data-handling network which connects instrumnets to the mass-memory, data processors and control processors. SpaceFibre is a multi-Gbits/s, on-board network technology for spaceflight applications, running over eletrical or fibre-optic cables. SpaceWire technology is current being used/designed for over 100 space missions already in orbit.

References:

1. STAR-Dundee Webpage: https://www.star-dundee.com/

WL Gore and Associates (UK) Limited:
Company No: #00856254
Enterprise Size: Large
Incorporation/Registration: 1965/England
Company Website: https://www.gore.co.uk/
Company (current) Status: Private
Contact: Contact Page: https://www.gore.co.uk/contact
Additional Information:

Description:
WL Gore is a materials science company that has been active in the space industry since the 1960's. Dundee is the location of Gore's Space Centre of Excellence, where they design and develop many materials capable of supporting the space sector. Examples include ultra-durable insultated wires that are used as transmission lines in space exploration. Also includes expanded ePTFE, a key material in the space sector due to it being lightweight, having a high tensile strength, low dielectric constant, UV resistance and high thermal resistance. Gore's cables have even been used in the International Space Stations and for many NASA missions, including the Perserverance Rover on Mars.

References:

1. WL Gore and Associates Webpage: https://www.gore.co.uk/

Smiths Interconnect Group Limited:
Company No: #06641403
Enterprise Size: Large
Incorporation/Registration: 2008/England
Company Website: https://www.smithsinterconnect.com/
Company (current) Status: Private
Contact: Contact us page: https://www.smithsinterconnect.com/contact/contact-us/
Additional Information:

Description:
With a facility in Dundee, Smiths Interconnect carries out both R&D and manufacturing. To ensure Smiths' products are fit for use in space, this facility contains its European Qualification and Test Laboratory. Smiths offers a wide range of radio frequency (RF), microwave, mmW systems and components, connectors and cable assemblies, and has had its products used in > 600 satellites. Smiths was recently awarded ~£2million GBP in funding from the UK Space Agency [2]. Said funding will support its Space Qualification Laboratory, where their space components will be tested in extreme conditions akin to that experience in space.

References:

1. Smiths Interconnect Webpage: https://www.smithsinterconnect.com/
2. Smiths Interconnect awarded c.£2m in funding from the UK Space Agency. [Link]

M Squared Lasers Limited:
Company No: #SC243330
Enterprise Size: Medium
Incorporation/Registration: 2003/Scotland
Company Website: https://m2lasers.com/
Company (current) Status: Private
Contact: Contact us page: https://m2lasers.com/contact.html
Additional Information:

Description:
M Squared Lasers are based in Glasgow and are developing leading edge photonics/quantum technology for the space sector (as well as many other sectors, including manufacturing, oil and gas, medical). M Squared have already supported many Earth Observation missions, including CNES/UK Space Microcarb mission (CO_2 monitoring), and ESA's Sentinel 4, 5 and 5P missions. M Squared have made an agreement with Thales Alenia Space to develop/provide their highly advanced laser system technology (spanning visible to short-wave infrared region) to support the monitoring of CO_2 and NO_2 emissions from space (part of Europe's Copernicus program) [2].

References:

1. M Squared Webpage: https://m2lasers.com/index.html
2. M SQUARED ANNOUNCES AGREEMENT WITH THALES ALENIA SPACE TO PROVIDE ADVANCED LASER SYSTEMS TO CALIBRATE ESA'S COPERNICUS CO2M SATELLITES [Link]

Alpha Data Parallel Systems Limited:
Company No: #SC147524
Enterprise Size: Medium
Incorporation/Registration: 1993/Scotland
Company Website: https://www.alpha-data.com/
Company (current) Status: Private
Contact: Contact us webpage: https://www.alpha-data.com/about-alpha-data/contact-us/ , support@alpha-data.com
Additional Information:

Description:
With HQ based in Edinburgh, Alpha Data provide embedded systems and data centre products for digital signalin proessing (DSP), imaging systems, communcations, military, aerospace and high performance computing industries [1]. Alpha Data's hardware supported/powered NASA's climate change mineral dust detector on the International Space Station [2].

References:

1. Alpha Data Webpage: https://www.alpha-data.com/
2. Alpha Data powers NASA's climate change mineral dust detector on Space Station [Link]

Walker Precision Engineering Limited:
Company No: #SC068820
Enterprise Size: Medium
Incorporation/Registration: 1979/Scotland
Company Website: http://walkerprecision.com/
Company (current) Status: Private
Contact: Contact us page: http://walkerprecision.com/contact-us/ , enquiries@walkerprecision.com
Additional Information:

Description:
Walker Precision is a contract manufacturer that produces precision equipment and complex parts for the aerospace, defense and industrial sectors. Walker has NADCAP gold status, demonstrating their commitment to the highest standards [2]. Walker has a facility in Glasgow, Scotland, as well as centres of excellence in England and Poland.

References:

1. Walker Precision Webpage : http://walkerprecision.com/
2. Walker Gains Nadcap Gold Status: [Link]

ALTER Technology TUV NORD UK Limited:
Company No: #SC244596
Enterprise Size: Medium
Incorporation/Registration: 2003/Scotland
Company Website: https://www.altertechnology-group.com/en/home/
Company (current) Status: Private
Contact: Contact us page: https://www.altertechnology-group.com/en/company/contact/ , info@uk.altertechnology.com
Additional Information:

Description:
Part of the TUV Nord Group, ALTER Technology UK Ltd has development and manufacturing facilities in Scotland. ALTER caters for many industries, including space, aeronautics, automotive, medical, defence, and nuclear (among others). ALTER's specialised products are suitably packaged for space and other harsh environment applications. This includes, contact package design and precision assemnly services for a wide range of optoelectronic, microelectronic and MEMS devices. Also includes highly integrated, miniaturised, robust photonic products for quantum enabled positioning, nagivation, timing systems, and photonic-based satellite optical communications. ALTER also provide complete turn-key solutions, covering water testing, assembly, packaging, final test and qualification.

References:

1. ALTER Technology TUV NORD Webpage: https://www.altertechnology-group.com/en/home/

Rhea Space Activity UK Limited:
Company No: #14635288
Enterprise Size: Small
Incorporation/Registration: 2023/England
Company Website: https://www.rheaspaceactivity.com/
Company (current) Status: Private
Contact: contact us webpage: https://www.rheaspaceactivity.com/
Additional Information: subsidiary of Rhea Space Activity, an Astrophysics start-up based in Washington DC.

Description:
Rhea Space (RSA) speciaise in reliable navigation and secure communication technologies, designed to support national security objectives. Support includes the development of technologies in the fields of infrared satellites, directed energy, AI, astroparticle physics, small satellites, autonomous underwater vehicles, and more. RSA's Jervis Autonomy Module (JAM) is an autonomous guidance and navigation capability adaptable for systems operating in space and on the ground. JAM's underlying software is state-of-the-art for onboard optical navigation and originates from proven software used on NASA's Deep Impact mission. RSA is also developing a secure quantum communication capability called the Quantum Lovelace Optical Augmentation Kit (QLOAK). QLOAK enables covert communication and information sharing with the strongest possible encryption. RSA are applying these advanced and disruptive technologies to solve the world's security challenges. Founded in 2018, RSA is headquartered in Washington, DC, with a wholly owned subsidiary in the United Kingdom. RSA is actively growing its Edinburgh-based UK team.

References:

1. Rhea Space Activity Webpage: https://www.rheaspaceactivity.com/

Plexus Corp (UK) Limited:
Company No: #SC146948
Enterprise Size: Large (*part of Plexus Corp. parent company*)
Incorporation/Registration: 1993/England
Company Website: https://www.plexus.com/en-us/market-sectors/aerospace-defense/space
Company (current) Status: Private
Contact: contact us webpage: https://www.plexus.com/en-us/contact
Additional Information: subsiduary of Plexus Corp.

Description:
A significant Tier 2 supplier to the space industry, Plexus Corp provide end-to-end development and manufacturing support to small, medium and large space sector companies [1]. Said support includes, Design and Development, Supply Chain Solutions, New Product Introduction, Manufacturing, Aftermarket Services, Regulatory Expertise & Compliance, Healthcare and Life Sciences Expertise, Industrial and Commercial Expertise, Communications Expertise, and Aerospace and Defense Expertise. Plexus Corp is the UK's largest Electronics Manufacturing Services company, with a Design Centre in Livingston, Scotland [2].

References:

1. Plexus Corp Webpage: https://www.plexus.com/en-us/market-sectors/aerospace-defense/space
2. Plexus' investment in Livingston Engineering and New Product Introduction facility: [Link]

DOWNSTREAM

EARTH OBSERVATION

Ecometrica Limited:
Company No: #SC339323
Enterprise Size: Medium
Incorporation/Registration: 2008/Scotland
Company Website: https://ecometrica.com/
Company (current) Status: Private
Contact: Contact us page: https://ecometrica.com/contact-us/
Additional Information:

Description:
Ecometrica Ltd is an expert in climate metrics (part of EcoOnline Global), basd in Edinburgh, Scotland. Ecometrica enable businesses and governments to accurately and transparently calculate their climate impact, subsequently supporting them in complying with the latest legislation. Ecometrica utilises their software platform that combines Earth Observation data from multiple sources including free optical data (Sentinel-2), Landsat and MODIS, high-resolution optical data, and radar (Sentinel-1). Climate and sustainability monitoring/reporting is focused on forests, commodities, land use change, emissions, supply chain risk and disaster response. Reports produced include figures that are compliant with the Streamlined Energy and Carbon Reporting (SECR) framework for annual reporting.

References:

1. Ecometrica Webpage: https://ecometrica.com/

Global Surface Intelligence Limited:
Company No: #SC439031
Enterprise Size: Small
Incorporation/Registration: 2012/Scotland
Company Website: https://www.surfaceintelligence.com/
Company (current) Status: Private/Public
Contact: Contact us page: https://www.surfaceintelligence.com/contact
Additional Information:

Description:
Based in Edinburgh Scotland, Global Surface Intelligence Ltd utilises a natural resource management platform that provides accurate insights into changes in land use, forestry and agriculture for global energy brands, retail, insurance, government and assurance. GSI's platform harnesses artificial intelligence to transform satellite optical and radar data, UAV, drone and ground survey data into commercially valuable information. With >4,500 satellites in space today, GSI's 'ultra fast platform' aims to tackle very large datasets associated with downstream earth observation, reducing processing time from months to minutes.

References:

1. Global Surface Intelligence Webpage: https://www.surfaceintelligence.com/

Space Intelligence Limited:
Company No: #SC595836
Enterprise Size: Medium
Incorporation/Registration: 2018/Scotland
Company Website: https://www.space-intelligence.com/
Company (current) Status: Private
Contact: Contact us page: https://www.space-intelligence.com/contact-us/ , enquiries@space-intelligence.com
Additional Information:

Description:
Space Intelligence are an Edinburgh based company, focused on developing satellite data analysis technologies. Said technologies leverage advanced machine learning, artificial intelligence and big data capabilities to provide information on land-use and land-use change, ecosysem carbon storage for monitoring and protecting forests (and nature-based investments). Therefore, through interpreting large volumes of satellite data and landscape information, Space Intelligence are supporting nature-based solutions and sustainability-linked financial instruments.

References:

1. Space Intelligence Limited Webpage: https://www.space-intelligence.com/

Trade in Space Limited:
Company No: #SC576433
Enterprise Size: Small
Incorporation/Registration: 2017/Scotland
Company Website: https://tradeinspace.com/
Company (current) Status: Private
Contact: Contact us page: https://tradeinspace.com/contact-us , hello@tradeinspace.com
Additional Information:

Description:
Trade in Space are a Glasgow based company who utilise geo-spatial and distributed ledger technologies to enable agriculture supply chains to be more sustainable, ethical and accesible [1]. Trade in Space offer a satellite-activated smart contracting solution and provide the tools to enable satellites to act, in real-time, as an autonomous commercial actuary, broker or dealmaker; or from a legal stand-point as trusted regulatory compliance auditors. In 2020 they completed the first satellite-brokered direct trade between coffee producers in Colombia and roasters in the UK, recording transaction details and supply chain events on their distributed ledger [2].

References:

1. Trade in Space Webpage: https://tradeinspace.com/
2. COFFEE FROM SPACE: the future of sustainable coffee: [Link]

Earth Blocks Limited:
Company No: #12711439
Enterprise Size: Small
Incorporation/Registration: 2020/England
Company Website: https://www.earthblox.io/
Company (current) Status: Private
Contact: team@earthblox.io
Additional Information:

Description:
Based in Edinburgh, Earth Blox provides climate and nature analytics from satellite imagery to help businesses accelerate their sustainability transition. Earth Blox's earth observation software allows users to turn satellite data into highly accurate risk assessments for all their economic assets and facilities worldwide. Earth Blox customers include ADM Capital Foundation, Climate Impact Partners, ForestRe, Ecologi, MercyCorps, The Nature Conservancy, and Veritree. Earth Blox is a Google Cloud Advantage Partner, Earth Engine Expert, and a member of the TNFD (Taskforce on Nature-Related Financial Disclosures) Forum. Earth Blox is the trading name of Quosient Ltd.

References:

1. Earth Blox webpage: https://www.earthblox.io/

Hypervine Limited:
Company No: #SC596608
Enterprise Size: Small
Incorporation/Registration: 2018/Scotland
Company Website: https://www.hypervine.io/
Company (current) Status: Private
Contact: Contact us page:
https://webforms.pipedrive.com/f/ceenOCBuIQx7Bgnjgrd6mIAC2CC9xnET6aY03BBDqtF9IfWjSETrmDQnEVkGWRAcsb
Additional Information:

Description:

Hypervine are a Glasgow-based start-up utilising earth observation and blockchain technology to enhance productivity within the construction and mining industries. High-resolution satellite imagery is used to analyse and interpret specific ground operations, providing comprehensive, large-scale monitoring capabilities irrespective of weather or daylight, enabling timely insights for industries, environmental conservation, and disaster management. The wide reaching nature of Hypervine's satellite surveys ensures consistent data acquisition over vast and inaccessible regions, enhancing decision-making and safety across various sectors.

References:

1. Hypervine Webpage: https://www.hypervine.io/

Space Aye Limited:
Company No: #SC422229
Enterprise Size: Small
Incorporation/Registration: 2012/Scotland
Company Website: https://spaceaye.com/
Company (current) Status: Private
Contact: info@spaceaye.com
Additional Information:

Description:
SpaceAye are a Glasgow-based company that specialise in merging user generated content and Internet of Things Data with real-time satellite imagery to provide more in-depth information surrounding satellite imagery.

References:

1. SpaceAye Webpage: https://spaceaye.com/

Earthwave Ltd:
Company No: #SC610006
Enterprise Size: Small
Incorporation/Registration: 2018/Scotland
Company Website: https://earthwave.co.uk/
Company (current) Status: Private
Contact: info@earthwave.co.uk
Additional Information:

Description:
Based in Edinburgh (Scotland), Earthwave is an operator of a satellite data science startup designed to provide earth observation, spatial data structures, system engineering, and data visualization services. The company's platform is a part of multiple Europe-wide consortiums, delivering reproducible scientific research and algorithm development using a range of satellite data, enabling users to create a fusion of large datasets, and facilitating machine learning and other computations.

References:

1. Earthwave Webpage: https://earthwave.co.uk/

Weather Stream Ltd:
Company No: #10817398
Enterprise Size: Small
Incorporation/Registration: 2017/England
Company Website: https://weatherstream.com/
Company (current) Status: Private
Contact: https://weatherstream.com/contact-us/
Additional Information:

Description:
Weather Stream is an operator of an earth weather data platform intended to improve weather forecasting. The company's platform (GEMS: Global Environmental Monitoring System) empowers the delivery of analysis-ready, accurate, and malleable datasets within minutes of observation, enabling customers to get timely, actionable insights requiring minimal processing in a device-agnostic, driven delivery model. Headquartered in the USA, Weather Stream has a hub dedicated to data science and commercial operations within the UK.

References:

1. Weather Stream Ltd Webpage: https://weatherstream.com/

Niras Group (UK) Ltd:
Company No: #01250443
Enterprise Size: Medium
Incorporation/Registration: 1976/England
Company Website: https://www.niras.com/
Company (current) Status: Private
Contact: niras@niras.com
Additional Information:

Description:
With a hub based in Edinburgh, Niras UK are a value-driven, multi-disciplinary engineering consultancy fundamentally committed to sustainable progress and service delivery. Niras are a global partner in earth observation and geographical information services, working alongside governments and space agencies on a broad range of sustainability projects, including monitoring of GHG emissions in developing countries, biodiversity management in developing countries, satellite monitoring for forest management, climate change adaptation/risk management of climate disaster(s), and much more [2]

References:

1. Niras Webpage: https://www.niras.com/
2. Niras News/Publications: https://www.niras.com/sectors/development-consulting/publications/

DOWNSTREAM

SOFTWARE & SERVICES

Bright Ascension Limited:
Company No: #SC407753
Enterprise Size: Small
Incorporation/Registration: 2011/Scotland
Company Website: https://brightascension.com/
Company (current) Status: Private
Contact: Contact us page: https://brightascension.com/about-us/contact-us/
Additional Information:

Description:
Bright Ascension are a Dundee based space software specialist company, offering consulting and engineering services aimed at simplifying/optimising space mission; from cube-satellite to larger, space craft. Bright Ascension offer complete end-to-end space mission solutions, capable of supporting/leading space-based projects from blue-sky resaerch throgh to development and delivery. Bright Ascension received a £1.5million bridging loan to further support their satellite software infrastructure, HELIX Suite [2-3].

References:

1. Bright Ascension Webpage: https://brightascension.com/
2. WE SECURED FURTHER INVESTMENT TO SUPPORT HELIX LAUNCH: [Link]
3. HELIX: [Link]

ThinkTank Maths Limited:
Company No: #SC343621
Enterprise Size: Small
Incorporation/Registration: 2008/Scotland
Company Website: https://www.thinktankmaths.com/
Company (current) Status: Private
Contact: Contact us page: https://www.thinktankmaths.com/contact/
Additional Information:

Description:
ThinkTank Maths are an Edinburgh based IT services and IT consulting company that work with clients/partners in the Space/Energy, Space Situation Awareness (SSA) and Space Surveillance and Trackin (SST) sectors. ThinkTank Maths 'DeepTech / Intelligent Systems' offer the ability to assess complex engineering processes beyond the limitations of AI/ML and statistical analysis, levaraging mathematical data fusion of heterogenous data sets. One example includes optimising the real-time monitoring of satellite localisation/congestion within space. Given the anticipated influx of satellites within LEO is to rapidly increase (5-year forecast in LEO is 11,500 to > 70,000), accurate and real-time monitoring of satellite space situational awareness is crucial, not least for the security of global satellite services and our Earth Observation capabilities [2]. ThinkTank Maths work with a large number of clients and partners, including Shetland Space Centre, UK MoD, BAE systems.

References:

1. ThinkTank Maths Webpage: https://www.thinktankmaths.com/
2. Under The Surface of Scotland's Space Industry = The Royal Society of Edinburgh: [Link]

Scotspace Limited:
Company No: #SC653831
Enterprise Size: ???
Incorporation/Registration: 2020/Scotland
Company Website: https://scotspace.scot/
Company (current) Status: Private
Contact: Bernard Farkin, Director of ScotSpace Ltd: bfarkin@scotspace.scot, info@scotspace.scot
Additional Information:

Description:
Located in Prestwick (close proximity to Prestwick Air and Spaceport), Prestwick Aerospace Park, Machrihanish launch site, and other academic/industrial aerospace R&D centres in localised in/near Glasgow. ScotSpace Ltd (Scottish Space Corporation) aims to plan, design, coordinate, operate and promote NewSpace infrastructure development in Scotland. Their mission is to provide operational design and support for commercial space transportation services at Scottish spaceports, including assembly integration and test, pre-launch, launch, in-orbit, decommissioning and de-orbit operations. ScotSpace is also focused on orbital resources and microgravity, including the commercial applications of microgravity and other environemntal resources (e.g., sunlight, pressure, radiation, temperature, electromagnetic gradients). Following the European Space agency contractual agreement with a European Consortium (focused on prividing end-to-end response space transportations services) ScotSpace and the Prestwick Spaceport are to act as a logistics, integration and operations support hub for the Scottish launch sites [2].

References:

1. ScotSpace Webpage: [Link]
2. D-Orbit signs contract with the European Space Agency [Link]

AstroAgency Limited:
Company No: #SC640997
Enterprise Size: Small
Incorporation/Registration: 2019/Scotland
Company Website: https://astroagency.co.uk/
Company (current) Status: Private
Contact: liftoff@astroagency.co.uk
Additional Information:

Description:
Located in Edinburgh, AstroAgency Ltd is a strategic marketing firm dedicated exclusively to the commercial space sector, working with the private sector and governments globally. With established space companies, AstroAgency build awareness and engagement for space companies and public bodies. This includes translating capabilities, hihglighting expertise and showcasing achievements to deliver new business opportunities. AstroAgency also support companies that are not yet within the space sector, guiding their transition into the supply chain, securing new revenue streams via market intel, key introductions and framing their offer to suit the space sector. Further, AstroAgency work with space start-ups, helping them articulate their vision/message to generate interest, leads and investment.

References:

1. AstroAgency Webpage: https://astroagency.co.uk/

Responsive Access Limited:
Company No: #SC614798
Enterprise Size: Small
Incorporation/Registration: 2018/Scotland
Company Website: https://www.responsiveaccess.com/
Company (current) Status: Private
Contact: contact us page: https://www.responsiveaccess.com/about
Additional Information:

Description:
Based at the Royal Observatory Edinburgh, Responsive Access Ltd provides launch brokerage and consultancy services to the space industry. Their aim is to provide complete space logistics solutions that cover all aspects of mission assurance, enabling their customers to remain 'focused on their payload'. With respect to logistics, Responsive Access provide assistance with initial planning, manufacturing and testing, and delivery of payload(s) to launch site(s).

References:

1. Responsive Access Webpage: https://www.responsiveaccess.com/

Craft Prospect Limited:
Company No: #SC557385
Enterprise Size: Small
Incorporation/Registration: 2017/Scotland
Company Website: https://craftprospect.com/
Company (current) Status: Private
Contact: hello@craftprospect.com
Additional Information:

Description:
A space engineering company based in Glasgow, Craft Prospect deliver mission-enabling products, services, and develop novel mission applications. Craft Prospect aim to unlock the potential of Earth-observing nano-satellites for onboard autonomy and delivery a higher mission return. Craft Prospect are to lead the OPS-SAT Versatile Optical Laboratory for Telecoms (OS2-VOLT) Mission for the European Space Agency. This 12 million Euro mission, led by Craft Prospect, will incorporate a range of their technology within a Low Earth Orbit environment [2].

References:

1. CraftProspect Webpage: https://craftprospect.com/
2. Craft Prospect to lead the OPS-SAT Versatile Optical Laboratory for Telecoms (OS2-VOLT) Mission for the European Space Agency [Link]

Krucial:
Company No: #SC600268
Enterprise Size: Small
Incorporation/Registration: 2018/Scotland
Company Website: https://www.krucial.com/
Company (current) Status: Private
Contact: Contact us page: https://www.krucial.com/contact
Additional Information: *previously known as R3 IOT Limited*

Description:
Krucial are a Glasgow (Scotland) based IoT-based satellite connectivity technology company [1]. Through Krucial CONNECT, Krucial supports businesses resilient, reliable and continuous connectivity – combining satellite communications and cellular technology with IoT. Krucial's technology can be deployed anywhere, supporting industries with minimising downtime and data loss across highly remote and hard to reach locations/data sources. Wireless remote technology enables these organisations to access, collect and transmit their real-time information through automating the collection of data. An example can be seen from Krucial's on-going role in supporting the mitigation of risks in aquaculture [2]

References:

1. Krucial Webpage: https://www.krucial.com/
2. Mitigating Risk in Aquaculture with Connected Seafarm: [Link]

Brainnwave Group Ltd:
Company No: #11786277
Enterprise Size: Small
Incorporation/Registration: 2019/England
Company Website: https://brainnwave.ai/about-us/about-brainnwave/
Company (current) Status: Private
Contact: Contact us page: https://brainnwave.ai/contact/
Additional Information:

Description:
With head offices in London and Edinburgh, Brainnwave is a developer of a decision intelligence platform (Mosaic) designed to enrich and analyze data (e.g., derived from satellite imagery to analyse data associated with climate, weather forecasts, oil & gas, etc.) by making it usable and profitable. The company's platform provides cutting-edge visualization tools powered by artificial intelligence, enabling leadership, management executives, and local sales teams to make the right strategic business decisions.

References:

1. Brainnwave Webpage: https://brainnwave.ai/about-us/about-brainnwave/

AEROSPACE & DEFENSE

Leonardo UK limited (subsidiary of Leonardo S.p.A.):
Company No: #02426132
Enterprise Size: Very Large
Incorporation/Registration: 1989/England Leonardo UK Limited (Leonardo itself, 1948/Italy)
Company Website: https://www.leonardo.com/en/
Company (current) Status: Private
Contact: automation@leonardo.com
Additional Information: Leonardo S.p.A (parent company) is a public multinational company (LDO:ITA) focused on aerospace, defence and security (Rome, Italy – HQ). Formerly known as Leonardo-Finmeccanica and originally Finmeccanica. Clive Higgins is the current UK Chair and CEO ad interim of Leonardo UK Limited.

Description:

Leonardo UK is one of the UK's leading aerospace companies and a major supplier of defence/security equipment to UK MOD [1]. Employing over 8,000 employees across 8 sites in the UK (~2000 in Edinburgh alone), Leonardo contributes significantly to UK enconomy – with revenues of ~£1.9 billion GBP – directly supporting the UK's Space Sector.

References:

1. Leonardo UK Webpage: https://uk.leonardo.com/en/home

Thales UK Limited (part of Thales Group):
Company No: #00868273
Enterprise Size: Very Large
Incorporation/Registration: 1966/England
Company Website: https://www.thalesgroup.com/en
Company (current) Status: Private
Contact: patrice.caine@thalesgroup.com (Patrice Caine, CEO), alex.cresswell@thalesgroup.com (Alex Cresswell, CEO/Chairman Thales UK Ltd)
Additional Information: Thales Group are a public aerospace and defense company (PAR:HO), HQ – France.

Description:
Thales Group is a French aerospace and defense company. As one of Europe's largest defense contractors, Thales is involved in defense & security (including providing sensors, mission systems, communications, and control systems to EU and export defense customers), avionics and satellites (for civil, defense and governmental markets), and digital identity/cyber security/data protection. Thales UK Limited therefore serves its 'customers' throughout the UK and is supporting the UK's Space Sector.

References:

1. Thales UK Webpage: https://www.thalesgroup.com/en/countries/europe/united-kingdom

Raytheon UK Limited (part of Raytheon Technologies):
Company No: #00337167
Enterprise Size: Very Large
Incorporation/Registration: 1938/England
Company Website: https://www.rtx.com/
Company (current) Status: Private
Contact: corporatecommunications@raytheon.co.uk
Additional Information: Raytheon Technologies (RTX) is a public aerospace and defense company (NYSE:RTX), HQ – USA. Jeff Lewis – CEO and Managing Director – Raytheon UK, Gregory J. Hayes - CEO of Raytheon Technologies.

Description:
Raytheon is an aerospace and defense company (a merger of United Technologies and Raytheon). Operating in three segments: Collins Aerospace (an aerospace supplier), Pratt & Whitney (an aircraft engine manufacturer) and Raytheon (a defense contractor providing missiles, missile defense systems, sensors, hardware, and communications technology to the military). Through these activities, Raytheon is supporting the UK Space Sector.

References:

1. Raytheon UK Webpage: https://www.raytheon.co.uk/

ANNEX F

SSAC REPORT – Scotland's Space Sector: Exploring potential future opportunities

Brief overview of Scottish academic landscape

A review and mapping exercise on the strengths of academic R&D in Scotland relevant to the Space Sector. This should include directly relevant R&D such as space structures and systems, as well as indirect relevant R&D such as data analytics. Analysis completed for:

Universities	
N/A	Abertay University
X	Edinburgh Napier University
X	Glasgow Caledonian University
X	Heriot-Watt University
N/A	Queen Margaret University
N/A	Robert Gordon University
X	University of Aberdeen
X	University of Dundee
X	University of Edinburgh
X	University of Glasgow
X	University of St Andrews
X	University of Stirling
X	University of Strathclyde
X	University of the Highlands and Islands
N/A	University of the West of Scotland

Supporting Institutions	
X	Fraunhofer Centre for Applied Photonics
X	National Manufacturing Institute for Scotland (NMIS)
X	CENSIS
X	The Data Lab

X	Royal Observatory Edinburgh
X	The Satellite Applications Catapult
X	Asteria

SUMMARY

Strong academic research is one of the pillars of industrial progress, especially in the sectors of the future, such as Space technologies. Scholars based in Scottish universities are top specialists in the fields relevant to the space sector. They participate in numerous international programmes contributing to organising and maintaining space missions and analysing data obtained through them. Despite the long-term nature of space exploration, the government should support research and development-driven innovation now to secure capturing a fraction of the newly emerging markets of on-demand launches, Earth observation, satcomms, the lunar economy, etc. This document presents information on existent scientific strengths relevant to the space sector in Scotland.

The government's view set out in the Science and Technology Framework (https://www.gov.uk/government/publications/uk-science-and-technology-framework) identifies five critical technologies of the future: Artificial Intelligence (AI), Engineering biology, Future telecommunications, Semiconductors, Quantum technologies. These technologies are key drivers of the development of the UK space economy, as well. In its turn, space research and space applications can be an inspiration for breakthroughs in science. Also, the Space sector provides a global scale for innovations in these critical technologies increasing their positive impact. There are 10 priority areas stated in the National Space Strategy (www.gov.uk/government/publications/national-space-strategy-in-action). This report reflects the alignment between these areas and identified scientific expertise in Scotland's academia.

1: Capture the European market in commercial small satellite launch

The industry of commercial small satellites is complex, consisting of launch, upstream and downstream components. The work undertaken in Scottish universities, such as the University of Strathclyde, was in the foundation of the first commercial CubeSats. The researchers continue delivering innovation in this sector supporting existing collaborations with the space business companies and working on improving the properties of satellites and

their manufacturing pipeline with the support of institutions, such as NMIS. Universities with a large number of scholars working on space technologies, such as the University of Glasgow, maintain big centres to stimulate long-term future thinking for developing new methods in satellite network communication, satellite equipment and satellite data analysis. Growing its existing strengths, the University of Edinburgh aims to position Edinburgh as the space data capital of Europe.

In addition to the currently possible commercial usage, small satellites can be platforms for testing emerging technologies in quantum computing, applied photonics and innovative telecommunication.

2: Fight climate change with space technology

Multiple Scottish universities have research groups working on improving and more efficient usage of Earth observation technologies. This research area has direct application to the assessment of the anthropogenic impacts, monitoring and tackling climate change. It is also important to understand the ecological, economic and societal impacts of developing space economy infrastructure. This information can be used in numerous commercial and public services: monitoring farming, fishing and construction infrastructure, as well as bridge and road damage, preventing and mitigating the impacts of natural disasters. It is important to continue the programmes, such as the Centre for Satellite Data in Environmental Science, to train high-class environmental scientists. It is important for the innovation hubs, such as the Data Lab, to continue connecting satellite data analysis and high-tech companies to develop new profitable services.

3: Unleash innovation across the space sector

There are emerging technologies, which require a focus of the academic community to become applicable in the space sector. Some examples, where there is strong expertise of Scottish scientists are photonics and quantum technologies. Robotics and AI technologies play a significant role in developing autonomous systems, assistive technologies and operation systems in space. It is a positive practice, that Scottish universities cooperate in such initiatives as the National Robotarium.

A prospective area of space innovations is bio-based techniques for mining, in-situ resource generation and recycling in space, which should enable space explorations for humanity and make our operation more sustainable in space and on Earth. Considering the number and international recognition of research groups, Engineering Biology is one of the areas of research strength in Scotland.

4: Expand our horizons with space science and exploration

There is a large number of Scottish scientists working on astrophysics research, on studying geological aspects of extraterrestrial objects and Earth. A lot of scholars are involved in projects such as the LISA mission, Rosalind Franklin Mars Rover. Missions like this can not only answer fundamental scientific questions, but also be a test-bed for prospective technologies in robotics motion and control, extraterrestrial mining and in-situ resource usage. Supporting this research would make Scotland a valuable stakeholder in global projects such as the Artemis lunar programme. These projects set a foundation for far-future space exploration.

5: Develop our world-class space clusters

The Scottish Space Academic Forum (SSAF) is an initiative aimed at ensuring collaborative ties between university researchers and industry. Big space research centres, such as Space Glasgow, the Bayes Centre, the Aerospace Centre of Excellence, etc., are already actively working with space-oriented businesses. In the past, there was an example of the Space Technology Centre at the University of Dundee, which gave rise to a constellation of world-impactful spin-offs. It is important to ensure the sustainability of research at the academic centres and significant support to long-term projects.

It will be beneficial to spread information about the world-leading space research ecosystem present in Scotland to attract more talented experts and collaborators/customers. It is also crucial to inform about positive examples of profitable space companies emerging in Scotland.

6: Lead the global effort to make space more sustainable

There is demand for developing technologies to manage and measure space debris, improve our ability to repair satellites and improve the sustainability of the space supply chains. Numerous research groups in Scottish universities work on the topics of debris removal,

satellite orbital modifications and optimising production processes. The work of these groups should be supported and used in various demonstrative missions to set standards in these key areas of the space economy.

Space economy infrastructure exists not only in outer space, but on the Earth as well. There are numerous research groups of ecologists and environmentalists in Scotland. Their studies are not directly related to the space industry applications, but their expertise is important to evaluate risks and mitigate any negative consequences of developing space capabilities in Scotland, for example, at space ports.

7: Improve public services with space technology

Earth observation, as mentioned above, can provide tremendous benefits to support construction works, farming, energy sector. There are Scottish scientists, who work on developing models that allow to translate satellite data into impactful information for business and the public. International collaboration, for example, to achieve UN SDG or to mitigate the consequences of natural disasters, could position the UK and Scotland as a global leader in this humanitarian sphere.

8: Deliver the UK Defence Space Portfolio (www.gov.uk/government/publications/defence-space-strategy-operationalising-the-space-domain)

A lot of technologies developed by Scottish scientists in space research can have dual applications in the civilian and defence sectors. Defence Space portfolios priorities are a) Secure Satellite Communication, b) Space Domain Awareness which works in conjunction with the civil Space Surveillance and Tracking programme, c) Intelligence, Surveillance and Reconnaissance which comprises usage of Earth observation techniques, d) Space Command and Control which is focused on data analysis and training professional in it, e) Space Control to develop adequate resilience of space infrastructure, f) Position, Navigation and Timing which focused on precise navigation and timely delivering, g) Launch.

9: Upskill and inspire our future space workforce

Due to its frontier science, Scottish universities attract the best talents to work on various topics including the space sector-related ones. Scottish universities offer a competitive career ladder for early-career researchers in space topics to pursue. In addition, several universities

participate in public engagement events, that promote STEM education and in particular Space research among school students. These activities can be inspiring for both academics and students. International collaborations and addressing global challenges are beneficial for established researchers to learn new techniques and approaches.

10: Use space to modernise and transform our transport system

I have not found many laboratories that link together the transport system and space research in Scotland. The space sector is closely connected to launch and aircraft transport. Thus, it is possible, that work in the transport area is done by businesses and charities at the Scottish Space clusters. There are also clear applications of satellite communication in the control and navigation of drones and optimisation of railway and car transport. UKSA and ESA can provide funding in these areas.

EDINBURGH NAPIER UNIVERSITY

Edinburgh Napier University does not have any study programmes specifically related to the space sector.

There is a Centre for Artificial Intelligence & Robotics (CAIR) – human-robot interaction, the design of robots to operate in unknown environments (such as space exploration). They mention collaboration with the National Robotarium and partners at NASA Jet Propulsion Laboratory on their website. However, it might be possible that the person, who has previously worked in the NASA JPL has left Napier University and became a Senior Strategic Partnerships Manager in Edinburgh Innovations.

Also, there is a Centre for Cybersecurity, IoT & Cyberphysical Systems.

Several scholars were identified to be directly involved in manufacturing, data analysis for the space sector, analysis of the data acquired through space technologies or theoretical studies of space-related topics:

Prof Robert Briers – ecologist, who uses Geographical Information Systems and remote sensing techniques to research conservation and carbon flows;

Prof Sally Smith – the Director of the Centre for Computing Education Research at Edinburgh Napier University. Her research interests are mobile and pervasive computing. She has previously worked in the telecommunications and aerospace industries in the UK and Europe;

Dr Naser Ojaroudi Parchin – an electrical engineer interested in antennas currently focused on microwave power transfer. In the past, he was a research fellow in SATNEX V project, funded by ESA.

Connections:

The National Robotarium.

GLASGOW CALEDONIAN UNIVERSITY

The Glasgow Caledonian University has no study programme directly related to the space sector, but space applications are a part of BEng (Hons) Electrical and Electronic Engineering, Meng Electrical and Electronic Engineering.

In 2023, there was founded a space forum group “Research into the Space Economy”, which aims to inform practitioners, academics, etc. about the current developments in space business and the Space Economy and to offer insights about the future. The representative of the forum is Prof D Edgar

Several scholars were identified to be directly involved in manufacturing, data analysis for the space sector, analysis of the data acquired through space technologies or theoretical studies of space-related topics:

Dr Godwin Enemali – electronics engineer. His work is focused on laser-based sensing and instrumentation systems for environmental monitoring, industrial process tomography, green transportation, engine diagnostics and fuel research;

Dr Andrew Wilson – specialist in space sustainability with a focus on life cycle assessment, carbon accounting and energy systems of engineering projects;

Dr Firdous Ul Nazir – electrical engineer working on power system operation and optimisation, renewable energy integration;

Dr Keith J Baker – a policy specialist with an interest in energy and the built environment. He leads the partnership of the Built Environment Asset Management (BEAM) Centre at the Glasgow Caledonian University with the Aerospace Centre for Excellence at the University of Strathclyde;

Dr Muhammad Usman – electronic engineer. He works in the field of 5G, radio frequency sensing and communication, cyber security;

Dr Sajid Nazir – Computing specialist. His current research interests include deep learning, embedded systems, blockchain and cloud computing. He worked on developing solar-powered remote monitoring systems supporting satellite and cellular communications. He has also worked in the industry as a Systems Engineer at Firstco Ltd., London;

Dr Caroline Gallagher – Environmental Impact Assessment and Geographical Information Systems (GIS). Her applied research informs policy and practice in urban greenspace planning;

Prof Bonnie Steves – astrophysicist, who studies celestial mechanics, solar system dynamics, and chaotic systems applied to planetary stellar systems;

Dr Roberto Ramirez-Iniguez –Building Integrated Photovoltaic (BIPV) Systems, optical front-ends for wireless infrared and visible light communications, optical antennas and optical collimators for illumination;

Dr Juanma Parrilla-Gutierrez – engineer, who studies the Origin of Life using Artificial Intelligence, Computer Vision and 3D-printing in building autonomous robots.

Connections:

Research into the Space Economy;

Built Environment Asset Management (BEAM) Centre;

ESA.

HERIOT WATT UNIVERSITY

The Heriot Watt University has several programmes directly related to the space sector: BEng (Hons) Aerospace Engineering and MEng Aerospace Engineering, MSc Imaging, Vision and High-Performance Computing.

There are Institutes of Photonics and Quantum Sciences, of Mechanical, Process and Energy Engineering, of Sensors, Signals, and Systems.

Several scholars were identified to be directly involved in manufacturing, data analysis for the space sector, analysis of the data acquired through space technologies or theoretical studies of space-related topics:

Prof Robert Thomson – photonics and its applications in astronomy, laser manufacturing, fundamental physics and medicine. Co-founder of the laser-manufacturing spin out, Optoscribe;

Prof Yvan Petillot – Robotics and Computer Vision. He works on robotics solutions to service the offshore renewable sector, but similar technologies of robots could be used in space;

Prof Duncan Hand – specialist in Applied Optics and Photonics, who works on the applications of high-power lasers for manufacturing, sensing and medical applications;

Prof Brian Gerardot – Quantum Photonics. His research may play a crucial role in the development of future hardware for the communications, metrology, etc;

Prof Gerald Buller, Prof Ajoy Kar – Photonics and Optics. They work on quantum cryptography and single-photon technologies for enhanced imaging approaches;

Prof George Goussetis – Wireless Communications, Antenna Components for Space; His interests include satellite communications and developing technologies to enhance spaceborne antennas;

Prof Ross Donaldson – quantum optical technologies for satellite communications: receivers for satellite, high-bandwidth and addressing background noise in free space;

Prof Mehul Malik – quantum photonics. His research is focused on fundamental aspects of quantum mechanics and practical aspects such as quantum communication;

Dr Dimitrios Anagnostou – antennas, microwaves and applied electromagnetics;

Prof Mathini Sellathurai – Signal Processing in a range of applications including Radar, Lidar, Sonar and RF networks, Network Coding, Cognitive Radio, MIMO signal processing, satellite communications and underwater communications. She has a significant industrial research experience;

Dr Natalia Herrera Valencia – Photonics and Quantum Communication;

Dr Feng Zhu – Quantum Information and Quantum Optics. He is working on super-resolution of quantum imaging;

Prof Abderrahim Halimi –statistical signal and image processing, with applications to remote sensing (hyperspectral imaging, satellite altimetry).

Connections:

UK Astronomy Technology Centre (UKATC);

The National Robotarium – a world-leading centre for Robotics and Artificial Intelligence. Its research groups are Robotics and Autonomous Systems, Human-Robot Interaction, Precision Laser Applications;

UK Space Agency.

UNIVERSITY OF ABERDEEN

University has the Department of Planetary Sciences (www.abdn.ac.uk/geosciences/departments/planetary-sciences/about-us-1448.php). Their main research topics: Mars Research (REMS/Curiosity, HABIT/Exomars Surface Platform, ACS/Trace Gas Orbiter, ISEM/ExoMars rover, …), Climate Change studies, Geomorphological studies, 3D mapping system and geological studies, Remote Sensing and Radiative Transfer of planetary atmospheres (Far-infrared- Outgoing-Radiation Understanding and Monitoring (FORUM) of the ESA Earth Explorer Mission 9), Hardware development for planetary exploration. In addition, the department has expertise in astrobiology, especially investigating biomarkers, and collaborates with Biological Sciences in studying the impact of microorganisms on climate.

The Team of the Department of Planetary Sciences are

Prof Javier Martín-Torres – a theoretical physicist with expertise in radiative transfer, remote sensing, atmospheric studies, Mars Research and Astrobiology. The Principal Investigator of the HABIT/ExoMars 2020 instrument, and co-I of NASA´s Curiosity rover, Exomars rover and the ESA´s Trace Gas Orbiter;

Dr Thasshwin Mathanlal – engineer focused on instrument development for space and planetary exploration. He works currently on the HABIT project.

Dr Miracle Israel Nazarious – development of hardware and software for Earth and planetary research and exploration: instrument prototyping, laboratory and field site campaigns: Sub-liquid and Atmospheric Measurement (SAM), Metabolt, Methanox, HABIT project.

Juan Antonio Ramirez Luque – an experienced specialist in data analysis and software development for space instruments (HABIT) and drone mapping.

Dr Anshuman Bhardwaj – a specialist in remote sensing, trained in glacio-hydrological and planetary sciences. He has experience in high-resolution terrain modelling, using drones for environmental and Mars research;

Dr Shaktiman Singh – field-based terrestrial glacio-hydrological research using satellite data. He has been involved in planning and carrying out Martian land-surface research;

Dr Lydia Sam – environmental research of planetary surfaces using drones, airborne and satellite remote sensing and GIS, terrain modelling and interpretation, including Martian landforms;

The Department of Planetary Sciences runs a programme: MSc Planetary Sciences

Several other scholars were identified to be directly involved in manufacturing, data analysis for the space sector, analysis of the data acquired through space technologies or theoretical studies of space-related topics:

Dr Iraklis Giannakis – geophysicist, who uses machine learning and signal processing for non-destructive testing and geophysical investigation. It was applied to analyse lunar radar data and see what lies beneath the lunar surface;

Dr Alexander Brasier – geochemist and astrobiologist, who studies the identification of ancient microbial fossils in addition to palaeoenvironmental reconstructions;

Prof Malcolm Hole – volcanologist, who is also interested in lunar research;

Prof. John Parnell – geologist involved in Mars research including life search and field campaigns support;

Dr Yingfang Zhou – advanced imaging techniques to study the minerals and mechanical properties of asteroid rocks;

Dr Maria Manoli – international space law with emphasis on sociopolitical aspects, including territoriality in outer space, and regulation of private companies operating in space;

Dr Amir Siddiq – multiscale modelling of materials and structures for a range of temperatures (cryogenic to high) and for a broad range of loading conditions including space crash/impact, and explosion-related damage simulations;

Dr Alfonso Martínez-Felipe – monitoring emissions and energy flow via visualisation tools and satellite technology. This research has implications for climate action;

Dr Maria Elena Giannaccini – expert in the fields of bioinspiration, mechatronics, soft robotics, robot sensing and safety in human-robot interaction;

Dr Raffaello Secchi – investigation of the impact of new video streaming technologies on satellite networking. He participates in the research supported by ESA: "Future Web Technologies and Protocols over Broadband GEO Satellite Networks";

Prof Vladimir Nikora, Dr Stuart Cameron and Dr Mark Stuart – the study of the turbulence flows related to the characterization of planet surfaces and their formation mechanisms;

Dr Fabio Verdicchio – researcher of signal processing and information theory, distributed communication systems and peer-to-peer networks, including satellite-based systems;

Prof Godred Fairhurst – researcher of Internet Engineering and Satellite Internet, especially IP transmission over DVB. Participant of the Satellite Network of Excellence;

Dr Marcus Campbell Bannerman – the development of engineering simulation software, which allows studying particle dynamics, such as cement. These simulations could also be applied to space rocks;

Dr William Harcourt – remote sensing & Earth observation, data science, artificial intelligence, Arctic science;

Dr David Green – environmental applications of geospatial technologies including: GIS, remote sensing, cartography, WebGIS and UAVs/drones to coastal & marine spatial planning, precision agriculture & viticulture.

Connections:

UK Space Agency;

ESA;

UNOOSA (The United Nations Office for Outer Space Affairs)

HABIT((HabitAbility, Brine Irradiation and Temperature)) (ExoMars Mission): HABIT will characterize the habitability of the ExoMars landing site Oxia Planum, in terms of Ultra-Violet (UV) radiation, air and ground temperature (T), as well as liquid water availability and in-situ atmospheric water extraction usage. This project involves international collaborations such as with ESA. HABIT will be the first demonstrator of a water-capturing system on the surface of Mars, and the first European In-Situ Resource Utilization on the surface of another planet. To be launched in 2028. (www.abdn.ac.uk/geosciences/departments/planetary-sciences/news/14262/);

Far-infrared-Outgoing-Radiation Understanding and Monitoring (FORUM) will measure from space the far-infrared part of the electromagnetic spectrum emitted from Earth. This has very important implications related to problems such as Climate Change. To be launched in 2026. (www.abdn.ac.uk/geosciences/departments/planetary-sciences/news/14263/);

Space North East: an outreach initiative to help teach students in schools more about space and planetary sciences.

UNIVERSITY OF DUNDEE

The University of Dundee is listed as a research organisation by the Science and Technology Facilities Council and UK Space Agency (www.ukspacefacilities.stfc.ac.uk/Pages/University-of-Dundee.aspx). There were several successful space projects developed at the Space Technology Centre at the University of Dundee: image processing chips for vision-based navigation for planetary landers, a software tool to simulate planetary landing, surface roving and in-orbit rendezvous operations (PANGU, currently used by ESA), data-handling network for on-board spacecraft (SpaceFibre). The latter two are currently supported by the spinout STAR-Dundee (www.dundee.ac.uk/stories/space-research).

I have not found open information about the Space Technology Centre at the University of Dundee. I have sent an e-mail enquiry to them to find out, whether it is possible to find out whether it still operates and what are the current projects there, but received no response. It is possible, that this Centre is not funded anymore, therefore Scotland's Space Strategy does not mention the University of Dundee as an important Research and Development centre.

Several scholars were identified to be directly involved in manufacturing, data analysis for the space sector, analysis of the data acquired through space technologies or theoretical studies of space-related topics:

Prof Mark Cutler – Earth Observation methods to extract information relating to terrestrial and freshwater ecosystems;

Dr Thomas Jones – the development of new manufacturing processes by implementing devices such as Laser, 3-D printing, inkjet and traditional metal casting;

Prof Gunnar Hornig – the magnetohydrodynamics, behaviour of electrically conducting fluids such as plasmas in the atmospheres of stars;

Dr Agis Athanassoulis and Dr Irene Kyza – numerical algorithms for the Schrodinger- Poisson system with applications in cosmology;

Dr Scott Gregory – analysis of the stellar magnetism data and multi-wavelength observations of young stars study stars and planetary systems development;

Dr Soko Matsumura – theoretical astrophysics, with a focus on the formation, evolution, and dynamics of planetary systems, especially the circumstellar disks and the debris disks;

Dr Karen Meyer – simulation and observations of the Sun's magnetic field;

Dr Aurora Sicilia Aguilar – theoretical astrophysics, with a focus on star formation and protoplanetary disks

Dr David Pontin – investigation of the dynamics of magnetic fields: from the corona to the solar wind;

Connections:

UK Space Agency;

STAR-Dundee (www.star-dundee.com/);

Dundee Satellite Station Ltd (www.dundeesat.co.uk/#0), which is the former University of Dundee Satellite Receiving Station.

UNIVERSITY OF EDINBURGH

The University of Edinburgh has several study programmes related to the Space sector: BSc and MPhys Astrophysics, BSc and MPhys Physics with Meteorology, BSc and MEarthPhys Geophysics and Meteorology. There are also numerous programmes teaching Physics and Astronomy as a part of the course.

The Bayes Centre (www.ed.ac.uk/bayes/access-expertise/space-satellites) brings together the University of Edinburgh's expertise in Space and Satellites and facilitates collaborations with the space industry, creating real-world impact. It works closely with the Edinburgh International Data Facility which hosts large volumes of satellite and other geospatial data to enable new research and large-scale analysis in areas such as environmental sustainability, agricultural technologies and geo-spatial planning.

There is **the Space Innovation Hub**, whose ambitious mission sounds like "establish the city of Edinburgh as the Space Data Capital of Europe by 2030". They host large volumes of satellite and other geospatial data, support the strategic expansion of Space and Satellite-related research across the University, create partnerships with companies, NGOs and governments, create an ecosystem for start-ups and spin-outs, and enhance sector-specific training.

Team (www.ed.ac.uk/bayes/access-to-expertise/specialist-areas/space-satellites/space-hub/space-and-satellites-team): Kristina Tamane – Space Sector Lead, Prof Iain Woodhouse – Space Research Theme Lead;

Academic colleagues working in Space: (list taken from the website above. Scholars, who do not have mentioning of space-related research in their profile are marked with asterisks)

Prof Tughrul Arslan – engineer addressing the challenges associated with current and future electronic system design. Algorithmic research and software and hardware platform developments addressing areas such as navigation and telecommunication. He works on fault tolerance, adaptive digital systems;

Prof Robert Bingham – investigating world's ice sheets and glaciers dynamics;

Prof Charles Cockell – astrobiology and microbiology. His research focus lies in the study of life in extreme environments, understanding the diversity, processes and biosignatures of life in extremes, the potential habitability of extraterrestrial environments and bio-mining;

*Dr Rachael Craufurd Smith – specialist in media law, the regulation of culture and European Union law;

Prof Colin Cunningham – precision engineering for astronomy, especially optical telescopes;

*Prof Andrew Curits – imaging and inverse theory, machine learning, seismology, mathematical and quantitative geology;

*Prof Godfrey Fitton – developing X-ray analytical techniques in petrology and geochemistry of basic volcanic rocks;

Prof Raja Ganeshram – marine biogeochemistry and oceanography with a focus on polar sea ice environments;

Dr Yanyan Gao – particle physicist working on topics including Dark Matter in space;

Prof Noel Gourmelen – investigation of the response of the Cryosphere to a changing climate. Using Earth observation techniques for measuring ice caps, glaciers;

*Prof Margaret Graham – carbon and biogeochemical cycles in sustaining life;

Dr Steven Hancock – developing methods to measure vegetation structure with remote sensing instruments and using these data to better understand climate, weather and ecological processes. Global Spaceborne LIDAR.

*Dr Lara Kalnins – geologist, whose expertise includes analysis of magmatism and paleogeology on Mars;

Dr Stuart King – mathematician, who studies fluid dynamics and applications of machine learning algorithms, particularly to image-like data. For example, he works on improving synthetic aperture radar satellite imagery;

*Prof Finn Lindgren – mathematician, working on spatio-temporal stochastic models, environmetrics, computational methods and software;

*Prof James Loxley – specialist in Renaissance and early modern literature. He used geolocation and visualisation technologies to map historic literary scape;

*Prof Ian Main – geologist studying fluid-rock interactions and earthquakes: predictability, dynamics, triggering.

Dr Fraser MacDonald – specialist in historical geography, geopolitics, visual culture, histories of social and scientific knowledge, the Cold War and the history of astronautics;

Prof Edward Mitchard – developing methods for mapping natural carbon stocks globally using satellite data. He is the Chief Scientist of Space Intelligence Ltd;

Prof Simon Mudd – specialist in arid region hydrology, geomorphology and landscape changes due to tectonic, climatic and bio factors, who uses satellite data;

*Dr Mark Naylor – statistical seismology and forecasting of earthquakes and other hazards

seismic monitoring of bedload transport in mountain rivers;

*Prof Bryne Tendelo Ngwenya – aqueous environmental and microbial geochemistry of metals, coupled fluid flow and rock deformation;

Dr Caroline Nichol – remote sensing of photosynthetic light use efficiency, including using space-borne LiDAR;

*Tom Ogilvie – Senior Consultant at Edinburgh Innovations;

Prof Paul Palmer – Atmospheric composition modelling. He is developing novel mathematical models for satellite data on CO2 and methane in Earth's atmosphere, is developing a 3D Mars Global Circulation Model with a focus on atmospheric chemistry, is studying the atmosphere of exoplanets;

*Caroline Parkinson – strategy lead for the engagement with the Creative Industries at the Edinburgh Futures Institute;

Dr Genevieve Patenaude – carbon management, forest loss risks, forest finance, Kyoto Protocol and Post-Kyoto international negotiations, Ecosystem services. She was involved in the development of a mission concept for a Spaceborne Multispectral Lidar (NERC NCEO).

Dr Symon Podilchak – engineer in antenna and radar systems, professional software design, including in small satellites and military applications;

Dr Hugh Pumphrey – geophysicist and meteorologist, who uses microwave limb sounding and develops techniques for the UARS (Upper Atmosphere Research Satellite) and the EOS AURA satellite;

*Prof Murray Roberts – a marine biologist who studies the biology and ecology of deep-sea or cold-water corals. He is a coordinator of iAtlantic project: integrated assessment of Atlantic marine ecosystems in space and time;

*Dr David Rush – Fire Safety Engineering, focusing on the structural performance in fire of both conventional and innovative structural materials and systems;

*Dr Nayha Sethi – bioethics and in particular, the interface between medicine, ethics and the law. She worked on the design of autonomous medical systems;

*Ksenia Siedlecka – Financial Services & Fintech Engagement Manager, Edinburgh Futures Institute;

*Prof Chris Seed – informatician, who studies the Network Society, Digital Art and Technology, and The Internet of Things;

*Prof Dan van der Horst – specialist in the sustainable use of natural resources, energy and ecosystem services. He also worked on the policy-related aspects of renewable energy projects;

Tom Wade – Chief Pilot and Facility Manager, Airborne Research and Innovation;

Dr Gary Watmough – specialist in developing approaches for geographical targeting of scarce resources across the planet. He uses multi-source data, such as satellite imagery to map and monitor aspects of human livelihoods. The majority of his projects have been co-designed with UN agencies;

*Prof Wyn Williams – Rock magnetism and Palaeomagnetism;

*Dr Marisa Wilson – human geography with the focus on uneven effects of plantation agriculture on environments and cultures.

The key Partners of the University of Edinburgh in Space Research are

SPRINT network (www.sprint.ac.uk/capabilities) – UK-wide of expertise and skills in space-related activities;

EDINA (edina.ac.uk/) – a world-class centre for data and digital expertise;

The Higgs Centre for Innovation (www.roe.ac.uk/higgscentre/) – an incubator for commercialising research in the space sector;

Ecometrica – a platform providing access to Earth Observation, geospatial intelligence and satellite mapping applications;

The National Robotarium – a world-leading centre for Robotics and Artificial Intelligence;

The Milo Space Science Institute (miloinstitute.org/) – a collaboration with Arizona State University and Lockheed Martin;

The Space Enterprise Lab by the Satellite Applications Catapult.

UK Astronomy Technology Centre – a national centre for the development of scientific instrumentation and facilities for ground- and space-based astronomy;

UK Centre for Astrobiology – a research centre studying life in extreme environments, and habitability on Earth and beyond;

Centre for Satellite Data in Environmental Science – the centre for doctoral training was launched in 2019 and aims to train 50-70 specialists in advanced data science and Earth Observation techniques. Funded by UK Space Agency and UKRI, it is a collaboration of the Universities of Edinburgh, Leeds, the National Oceanography Centre and the British Antarctic Survey.

Also, the University of Edinburgh is home to the Centre for Engineering Biology. One of its focus areas is Bio-Based Manufacturing in Space. It explores using microorganisms and other biological systems to secure the production of materials and resources needed to sustain life in space.

Several other scholars were identified to be directly involved in manufacturing, data analysis for the space sector, analysis of the data acquired through space technologies or theoretical studies of space-related topics:

Dr Matjaz Vidmar – researcher in innovation, entrepreneurship and future design, especially in the space industry, artificial intelligence and data-driven economy. He co-founded two new research networks, the Scottish Social Dimensions of Outer Space network and the international Social Studies of Outer Space network;

Prof Louise Horsfall – synthetic biology to improve the sustainability of biological processes and products. One of the themes is using microbes to accumulate rare metals from contaminated soils;

Dr Stephen Wallace – industrial biology using a combination of synthetic biology and chemistry to create novel metabolic pathways, which can be used in greener recycling;

Dr Alistair McCormick – biologist, who studies the optimisation of photosynthesis to engineer synthetic systems for the production of high-value biofuels and biochemicals;

Dr Rosa Santomartino – sustainable space exploration using microorganisms, space bioproduction, biomining;

Dr Samuel Patrick – astrophysicist interested in the formation of the universe using mathematical simulation models, high-performance computing;

Dr Pieter Blue – mathematician, who studies the geometry of black holes;

Dr Karen Donaldson – modular robots for enabling operations in extreme environments;

Dr Joan Simon Soler – mathematician studying particle physics and black holes;

Dr Adam Stevens – astrobiologist with a focus on the habitability of Mars;

Prof Simon Lewis – geologist, who uses Airborne SAR and LIDAR measurements to characterise biomass structure and water resources;

Dr Fergus Cullen, Dr Adam Carnall, Dr Derek McLeod – astrophysicists studying the evolution of galaxies using a combination of imaging and spectroscopic surveys and cosmological simulations;

Prof Ian Underwood – engineer in the field of in the field of liquid crystal microdisplays. He is a co-founder of MicroEmissive Displays (MED). He was involved in developing a water activity sensor system for planetary exploration;

Dr James Lucietti – a mathematical physicist working on black holes, general relativity and gravitational theories inspired by string theory and holography;

Prof Wasiu Popoola – electrical engineer in optical communications;

Dr Michael Davidson – Survey Astronomy Software Developer. For example, he worked on Gaia mission data;

Stelios Voutsinas – software engineer in Royal Observatory, who worked with Gaia mission data;

Dr Dominique Laniel – a physicist working on chemical interactions within organic substances under high pressure and on using Nitrogen for novel rocket propellant;

Prof Ram Ramamoorthy – a computer scientist with specialization in robotics and machine learning, focusing on learning, adaptation and control mechanisms to enable autonomous robots to cope with the unknown, and effective work in human-AI teams;

Dr Chris Evans – astrophysicist with an interest in stellar evolution. He works with VLT-FLAMES Tarantula survey and the European Extremely Large Telescope;

Prof Majid Safari – engineer studying the modelling, design, and analysis of optical communication systems. MIMO and techniques for energy-efficient and high-speed atmospheric optical links suitable for terrestrial (e.g., mobile backhaul) or satellite applications;

Prof Austin Tate – specialist in Artificial Intelligence. His work has been applied to search and rescue and emergency response tasks, space technology applications;

Prof David Laurenson – engineer working on mobile radio channel modelling, biomedical imaging, multihop routing and cognitive radio. He contributed to the paper discussing the use of LEO satellite constellation for active network management in power distribution networks;

Dr Simon Malpas – specialist in aesthetics, Romanticism, continental philosophy, literary theory, postmodernism, and the literature, culture and politics of the Restoration period. He co-authored “Creative Visions and Critical Reflections on Scotland's Space Futures”. He leads Social Dimensions of Outer Space Research Network;

Prof Conchur O'Bradaigh – specialist in fibre-reinforced composite materials with interests in manufacturing, testing and modelling of composite materials for renewable energy applications, cryogenic properties and space applications;

Dr David Garcia Cava – engineer with interests in structural vibrations. One of his lab projects is the dynamic characterisation of 3D printed components for space applications;

Dr Agata Rozek – astrophysicist working on modelling of near-Earth asteroid environment with ground-based optical and radar observations;

Dr Ross Collins – survey astronomy software developer;

Dr Encarni Medina-Lopez – civil and environmental engineering, remote sensing to study water, energy and environmental problems;

Dr Liang Feng – methane and carbon observations using satellite data;

Dr Alessandro Novellino – geoscientist, analysing natural hazards and landslides using remote sensing, Synthetic Aperture Radar;

Dr Murray Collins – specialist in environmental economics and forest carbon ecosystem, who uses satellite data;

Dr Mark Lunt – understanding of greenhouse gas emissions, using data from satellites and ground-based platforms;

Dr Douglas Finch – geoscientist, who worked on the detection of atmospheric NO2 plumes from satellite data;

Dr Chris Old – engineer, working measurement and characterisation for Offshore Renewable Energy development using satellite data observations;

Dr David Milodowski – landscape dynamics and forest structure impact analysis using satellite observations, for example, Light Detection and Ranging (LiDAR) surveys;

Prof Simon Tett –quantitative analysis of models and observations of climate change in order to constrain the future using satellite records;

Prof Peter Nienow – glacier hydrology and ice dynamics, ice-ocean interactions using satellite investigations;

Prof Wenxuan Hou – specialist in corporate finance, financial development, law and finance. He used satellite data to study drivers of low-carbon economy;

Prof Brian McKinstry – Health Service research particularly in remote information exchange between clinicians and patients. He is interested in telemonitoring chronic diseases including using geolocation;

Prof Dylan Clements – clinical and laboratory projects investigating osteoarthritis in dogs and cats. Part of his research is quantifying the mobility of animals using GPS;

Dr Andrew Gray – glacial Biogeochemistry. He used satellite data to characterise algae in the Antarctic.

UNIVERSITY OF GLASGOW

The University of Glasgow runs many study programmes in the field of modern science and technology. Among them, there are directly space sector-related: Physics & Astronomy PhD/EngD/MPhil/MSc, Astrophysics MSc, Geospatial data science PhD, Autonomous systems and connectivity PhD/MPhil/MSc.

Space Glasgow (www.gla.ac.uk/research/az/spaceglasgow/) is an umbrella group for space activities at the University. The research themes of the group are

Solar and heliospheric physics, Space weather monitoring and solar-flare forecasting – to mitigate risk in sensitive technological systems, on the ground, but also aircraft and spacecraft. The research involves spatial-temporal modelling of sensor data, optimal sensor positioning, sampling and data selection in 3D sensor networks, including satellites. Scholars: Prof Lyndsay Fletcher, Prof Marian Scott, Dr Matteo Ceriotti, Dr Eduard Kontar;

Water and life in the solar system – to develop models for the early evolution of Earth and Mars and exoplanets, to understand the availability of water and hydrogen on the moon, asteroids and Mars, and how it could be used to support human exploration of the Solar System. Scholars: Prof Martin Lee;

Extraterrestrial hydrology – to identify suitable extraterrestrial habitats. Scholars: Prof Darren Mark, Prof Finlay Stuart

The Sun as astrophysical accelerator – to understand fundamental plasma and high energy processes throughout the universe: from black holes to fusion laboratories on Earth. Scholars: Dr Iain Hannah;

Ultrasonic drill tools for planetary exploration – to obtain access to these underground areas of extraterrestrial planets such as Mars to search for water and other resources. Scholars: Dr Patrick Harkness;

Autonomous guidance of planetary rovers – to provide rovers with the capability to make decisions about path planning in situ, improving their reliable operation distance and ultimately increasing the data gathering about extraterrestrial objects. Scholars: Dr Douglas Thomson, Dr Euan McGookin, Prof Darren Mark;

Numerical models of stellar and planetary dynamos – to characterise the geomagnetic field and its implications on our plant, to investigate influences of solar magnetism, to use these processes as a navigational aid; Scholars: Dr David MacTaggart, Dr Radostin Simitev;

UK Fireball network – to build a network of all sky cameras across the UK to detect falling meteorites, recover and study them. Scholars: Dr Luke Daly;

Orbital dynamics, control and formation flight – to investigate methods to control the motion of bodies in space. This research should lead to reducing space technology costs. Scholars: Dr Matteo Ceriotti, Prof Colin Mcinnes;

Solar Sailing – to study the orbital dynamics and the control of solar sails, ultimately to allow cheaper and longer space missions. Scholars: Dr Matteo Ceriotti, Dr Patrick Harkness, Prof Colin Mcinnes;

Orbital debris – to improve the precision of the prediction of the orbit of debris to achieve safer space missions. Scholars: Dr Matteo Ceriotti, Dr Gianmarco Radice;

Asteroid deflection and exploitation – to improve the detecting of Near Earth Objects and to investigate mitigation and threat removal possibilities. Scholars: Dr Ian Watson, Prof Colin Mcinnes;

Technologies of the future developed at the University of Glasgow:

CubeSat-based ionospheric sounders – to develop an antenna system for measurements of the ionospheric channel that are crucial for the space-based radars of the future. Also, this mission will train expertise in building complex antennae and beacons in small satellite carriers. Scholars: Dr Patrick Harkness;

High-precision laser interferometry – to probe gravitational effects. The group is involved in the LISA mission, a joint effort of ESA and NASA to measure gravitational waves in space. There might be future applications in the area of high-power lasers, in manufacturing, in defence and communications. Scholars: Dr David Robertson, Prof Henry Ward, Dr Alasdair Taylor, Mr Michael Perreur-Lloyd;

3D printing of chemical nanofactories – to develop a chemical platform to use raw materials on Mars and Moon for fuel/water/basic chemical transformations. Scholars: Prof Lee Cronin;

Aerobrakes for space debris mitigation – to remove old spacecrafts securely. Scholars: Dr Patrick Harkness;

Landing on other worlds – to tackle challenges of extraterrestrial landing such as extreme conditions during atmospheric entry and abrasive dust. Scholars: Prof Konstantinos Kontis, Dr Hossein Zare-Behtash, Dr Andrea Cammarano;

ANDING ON OTHER WORLDS

Diamond electronics for space-based operation and exploration – to research solid-state-based electronics solutions to address the requirements of electronic component operation within the harsh environmental conditions of space. Scholars: Prof David Moran;

Cognitive binocular vision of space robotics – to develop reliable cognitive vision systems to allow robots to undertake complex missions. Scholars: Dr Paul Siebert;

Emerging Space technologies, Micro-to-Macro – to investigate new concepts for space technologies, satellite platforms and mission design from micro-to-macro length scales. The

group envisage a direct printing of structures in space, adaptable space platforms and a new class of space system, which uses clouds of networked sensor nodes. Scholars: Prof Colin McInnes, Dr Kevin Worrall, Dr Matteo Ceriotti;

Autophage nanolaunchers – to develop launchers for individual nanosatellites. Scholars: Prof Patrick Harkness, Dr Kevin Worrall, Prof Konstantinos Kontis;

Electric propulsion for small satellites – to develop microfabrication of electrospray sources for satellite propulsion. Scholars: Dr Enric Grustan-Gutiérrez;

Connections:

ESA.

NASA.

The University of Glasgow is involved in public initiatives to popularise Space research such as ISSET (International Space School Educational Trust), REXUS-BEXUS, Space internship network.

James Watt Nanofabrication Centre (JNWC): the source of many micro- and nano-fabricated components in use throughout the UK quantum technology programme. The University of Glasgow is working on the construction of the Clyde Waterfront Innovation Campus, which will be the expansion of the university's facilities in Medicine and Engineering, including the JWNC.

The University of Glasgow has notable expertise in Materials Research, Quantum and Nano Technologies, Robotics and Autonomous Systems.

There is a Centre for Quantum Technology translating quantum technologies into real-world applications.

Partners: Dnipro National University, Orbital Access Ltd (Prestwick), Royal Academy of Engineering, Alba Orbital Ltd, Craft Prospect Ltd, The Royal Society, EU Horizon 2020 Framework Programme, Clyde Space Ltd, OHB SE, Astronika, British Antarctic Survey.

UNIVERSITY OF ST ANDREWS

The University of St Andrews has several study programmes related to the Space sector: Environmental Earth Sciences BSc, Earth Sciences MGeol, Astrophysics BSc and Astrophysics MPhys.

Below is a list of scholars identified to be directly involved in manufacturing, data analysis for the space sector, analysis of the data acquired through space technologies or theoretical studies of space-related topics. Some of them are combined in clusters according to their research institutes and groups:

Dr Mark Claire – a planetary scientist focused on the study of the early Earth, especially biogeochemical cycles of oxygen, carbon, hydrogen, and iron. He was part NASA funded research of Mars geochemistry and atmosphere;

Dr Aubrey Zerkle – isotope geochemist and geobiologist with research interests in the early Earth and extraterrestrial environments: isotope biosignatures for microbial activity, examining biogeochemical cycling in extreme environments such as Martian systems;

Dr Peter Woitke – a specialist in the field of star and planet formation. The PI of a SPACE project DIANA (DIsc ANAlysis) to learn about the physical and chemical properties of the planet formation;

Dr Paolo Pagano – investigation of magnetohydrodynamics, especially in the solar corona;

Dr John Elliott – specialist in developing capabilities for signal content analytics, decipherment of unknown phenomena and message construction, which is important for security systems, but also for extra-terrestrial life search. He is a Chair of the UK SETI Research Network and a Coordinator for the SETI Post Detection Hub;

Dr Katy Louise Chubb – characterising the atmospheres of exoplanets, with a focus on theoretical molecular spectroscopy.

Prof R Alan Cairns – theoretical physicist studying plasma physics relevant to nuclear fusion and magnetohydrodynamics in astrophysics;

Dr Friedrich Ernst Wilhelm König – quantum optics and quantum information, in particular, quantum optics in curved spacetime;

Astronomy Group (astronomy.wp.st-andrews.ac.uk/):

Exoplanets, star formation, galaxies and their evolution, cosmology and theories of gravity.

Prof Ian Bonnell – numerical simulations to probe the gravitationally driven gas dynamics in which star formation occurs;

Dr Ian Czekala – planet formation, radio interferometry, high resolution spectroscopy, hierarchical Bayesian inference and machine learning;

Dr Juan Venancio Hernandez Santisteban – the multi-wavelength study of accreting compact objects;

Prof Moira Mary Jardine – primarily a theorist collaborating with international observing teams, such as MagIcS and Bcool, to study the magnetic activity of a range of stars, their effect on the exoplanets detection and astrobiology of exoplanets.

Dr Rita Tojeiro – astrophysicist researching spectra of galaxies to understand the content, geometry and expansion history of the Universe;

Dr Anne-Marie Weijmans – investigation of the structure and evolution of galaxies using integral-field spectroscopy. Participant of MaNGA (Mapping Nearby Galaxies at APO) survey;

Prof Vivienne Wild – observational data and large simulations to study both the spectral and morphological evolution of galaxies following a starburst phase;

Dr Kenny Wood – research of the star formation and the interstellar medium. He works closely with observers in modelling data from observatories: the VLA, Hubble and Spitzer;

Dr Hongsheng Zhao – research of the dark matter with modelling and gravitational lensing;

Solar And Magnetospheric Theory Group (solar-mcs.wp.st-andrews.ac.uk/):

Applied mathematicians who study the Sun and the Earth's magnetosphere using mathematical modelling techniques. They use observational data from satellites and from ground based observatories. Industrial relevance: space weather forecasts;

Prof Thomas Neukirch – magnetohydrodynamics (MHD) equilibria, reconnection, particle acceleration, rotating magnetospheres;

Prof Ineke De Moortel – phase mixing, MHD waves, coronal oscillations, observations with NASA's Transition Region And Coronal Explorer (TRACE) spacecraft;

Dr Tom Elsden – magnetospheres, low frequency waves;

Prof Alan Hood – MHD instabilities, magnetostatic equilibria, tearing modes, prominences;

Prof Duncan Mackay – prominence theory, flux transport simulations, coronal heating;

Prof Clare Parnell – magnetic reconnection, coronal heating, magnetic carpet, solar and heliospheric observations;

Dr Alex Russell – magnetic reconnection, MHD waves, magnetic topology, solar flares, space weather;

Dr Andy Wright – magnetic helicity, alfvén waves, magnetosphere, resonant absorption, particle acceleration;

Dr Vasileios Archontis – investigation of magnetic fields and coronal mass ejection;

Prof Peter Cargill – studying coronal heating, plasma physics, magnetospheric physics;

Dr Klaus Galsgaard – 3D numerical computations, magnetic reconnection, flux emergence;

Dr Tom Howson – investigation of energy dissipation and wave propagation in the solar corona;

Dr Jim Lang – a specialist in spectroscopy, atomic physics, SOHO, STEREO observatory

Prof Eric Priest – researcher of, the solar wind, the Earth's Magnetosphere and the magnetic field interactions, especially in the solar atmosphere.

Prof Bernard Roberts – developing coronal seismology, a new field about the solar coronal magnetic field;

St Andrews Centre for Exoplanet Science (exoplanets.wp.st-andrews.ac.uk/)

Using a combination of geochemistry, field geology, spacecraft data, and numerical modelling the scholars study how the evolution of life has changed our planet with aims to uncover general principles that could affect the evolution and detectability of planets elsewhere in the Galaxy. They also work with philosophers and social scientists at the University of St Andrews to explore topics of ethics, responsible communication and public dialogue around exoplanet science.

Dr Adam Bower – international law and governance, space security, disarmament and arms control.

Prof Andrew Cameron – investigation of stellar magnetic fields and the discovery and characterisation of exoplanets. He leads the data analysis group for the Science Team for the ESA S-class CHaracterising ExOPlanets Satellite (CHEOPS; launch expected 2019);

Dr Claire Cousins – planetary scientist (geothermal systems, volcanism, biosignatures), who works on the technologies related to robotic space missions She is a part of the Panoramc Camera instrument team for the ESA ExoMars Rover;

Dr Martin Dominik – exoplanet search by microlensing, robotic telescopes;

Dr Emily Finer – literature scientist with a focus on topics in the intersections between global science fiction, exoplanet science, and space policy.

Prof Andy Gardner – investigation of Darwinian adaptation to social evolution, cosmological natural selection, anthropic bias;

Prof Keith Horne – specialist in the interpretation of astrophysical observations, developing novel data analysis and astro-tomography methods for exoplanet search. He worked on developing concepts and proposals for two space missions - NASA/Kronos and ESA/Eddington, neither of which was selected for flight;

Dr Sami Mikhail – geochemistry, petrology, atmosphere-formation with a focus on the influence of the accretion, differentiation, and plate-tectonic cycling;

Dr Paul Savage – geochemist who studies the formation and evolution of rocky planets;

Dr Aleks Scholz – an observational astronomer working on problems in star and planet formation. He works with space-/telescopes like the ESO/VLT, Subaru, Spitzer, Kepler, James Webb, Gaia and facilities ALMA and SMA;

Dr Eva Stüeken – geologist and geochemist interested in the early evolution of life and habitability of other planets.

Also, there is a Photonics Group (photonics.wp.st-andrews.ac.uk/) and a Condensed Matter Physics Group (www.st-andrews.ac.uk/physics-astronomy/research/research-areas/condensed-matter/), The Centre for Designer Quantum Materials (www.quantummatter.co.uk/), The Organic Semiconductor Centre (www.st-andrews.ac.uk/~osc/home.shtml) .

Several scholars were identified to be directly involved in manufacturing, data analysis for the space sector, analysis of the data acquired through space technologies or theoretical studies of space-related topics:

Dr Manuel Fernando Benitez Paez – geoinformatician using GIScience and data science tools to develop new methods for spatiotemporal problems, focusing on data fusion methods and urban analytics;

Prof Mike Fedak – ecology, physiology and life history of marine mammals using satellite and mobile data systems;

Dr Tun Jan Young – geophysicist and radioglaciologist, interested in the dynamics of glaciers and ice sheets and their response to climate change. He uses geospatial data.

Connections:

NASA, ESA;

University's Access Teams runs a Space School for pupils from schools across Fife;

There is the James Gregory Telescope. Almost all components of the telescopes have been manufactured in Scotland. The optical telescope has now been in operation for more than fifty years. (observatory.wp.st-andrews.ac.uk/jgt/);

The School of Physics and Astronomy communicates with the following companies: Photonics Scotland, M Squared Lasers Ltd, Sodi-Tech EDM Ltd (Sodick Technology Hub), KP Technology Ltd, Thomas Keating Ltd, PhotoSynergy Ltd, Razorbill Instruments Ltd, Ambicare Health Ltd.

UNIVERSITY OF STIRLING

The University of Stirling has 1 space sector-related course: MSc Environmental Remote Sensing and Geospatial Sciences.

Several scholars were identified to be directly involved in manufacturing, data analysis for the space sector, analysis of the data acquired through space technologies or theoretical studies of space-related topics:

Dr Evangelos Spyrakos – Earth observation studies with a focus on water ecosystems. He was funded by the ESA and Scottish government to use satellite data to monitor rives and carbon fluxes in the Arctic;

Dr Armando Marino – monitoring the environmental conditions that are predictors of outbursts of malaria epidemics, monitoring ocean pollution. His research was funded by the UK Space Agency and ESA;

Dr Thiago Silva – earth observation, creating software and hardware for ecological sensing. He collaborated with NASA and the Japanese Aerospace Exploration Agency on the topics of biogeochemical models of tropical aquatic systems;

Dr Verity Flower – researcher in remote sensing and natural hazards. She works with NASA , ESA, JAXA satellites to investigate patterns of activity in natural hazards, volcanic eruptions;

Dr Peter Morland – environmental scientist, who studies forestry using satellite data;

Mr Matthew Blake – tech specialist in Earth observation monitoring inland and coastal waters;

Dr Mortimer Werther – optical water colour remote sensing, oceanography, computer science;

Dr Dalin Jiang – using remote sensing for assessing water quality;

Dr Peter Hunter – ecosystem assessment and monitoring, environmental management, regulation and evidence-based policy-formation by development, validation and application of methodologies for processing, analysing and visualising data from drones, aircraft and satellites;

Dr Cristian Jose Perez – monitoring of surface water extent (flood/drought) from SAR imagery, extracting information from satellite imagery supported by statistical and machine learning algorithms;

Prof Andrew Tyler – Scotland Hydro Nation Chair. He leads the NERC consortium Global Observatory of Lake Responses to Environmental Change and forges the collaborative relationships across the Scottish water sector to deliver solutions for sustainable water management in Scotland, including going beyond net zero, using Earth Observation methods;

Prof Alistair Jump – a global change ecologist with a strong focus on understanding and predicting the impacts of climate change on plant populations. Used satellite data in his research.

Connections:

UK Space Agency;

ESA;

NASA.

UNIVERSITY OF STRATHCLYDE

At the University of Strathclyde, there is 1 study programme directly related to the Space Sector: MSc Satellite Data for Sustainable Development. There are also other programmes, which may contribute to the Space economy of the future: MEng Electronic & Digital Systems, MSc Photonics, MSc Quantum Technologies, etc.

The University of Strathclyde has a Space cluster, which is a single entry point to space-related activity. They claim to have expertise in Small satellite technology & engineering, Space safety & sustainability, Space mechatronics, robotics & autonomy and Earth observation & data analysis.

The university takes part in many space-related activities, for example, Virgin Orbit's Inaugural Spaceflight from Spaceport Cornwall in Newquay. It leads international collaborations such as quantum technology networks.

I have identified several centres at the University of Strathclyde, which work on projects related to the Space sector:

Aerospace Centre of Excellence

(www.strath.ac.uk/engineering/mechanicalaerospaceengineering/aerospacecentreofexcellence/research/) : Research in Computational Intelligence, Research in Computational & Theoretical Aerodynamics, GNC & Autonomy, Flight & Spaceflight Mechanics and Space Systems.

Projects: UTOPIAE European Research Training Network – European research and training network looking at cutting-edge methods bridging optimisation and uncertainty quantification applied to aerospace systems;

GOCE Re-Entry Prediction Uncertainty Analysis – theoretical and computational methods helping to predict the orbit evolution of the object in space expected to impact on the ground due to loss of altitude due to orbit perturbations;

Future UK Small Payload Launcher – to develop short and long-term technical roadmaps for building national capabilities for reusable launch systems for small payloads, and to perform technical feasibility studies on different partially re-usable launch systems concepts;

Physics-based Modelling and Simulation of Spaceplanes Nonequilibrium Aerodynamics – formulating innovative computational approaches that use an explicit description of the dynamics of the air molecules to perform accurate studies of strongly accelerating, decelerating and distorting flows around vehicles moving at supersonic and hypersonic speeds and at high altitudes;

Debris Evolution Uncertainty Quantification – to model the dynamics of objects, drag sails and fragments during de-orbiting and re-entry. To analyse the dynamics of debris in LEO subject to ionospheric effects. To quantify the uncertainties related to those processes.

Advanced Space Concepts Lab

Prof Massimiliano Vasile – Computer Intelligence specialist and Aerospace engineer. He has worked on non-deterministic planning for robots, fault-tolerant navigation systems for spacecraft and nonlinear uncertainty quantification in space flight mechanics, with particular application to space debris and asteroid manipulation;

Dr Christie Maddock – an expert in mathematical modelling and system design optimisation for trans atmospheric flight vehicles, including spaceplane-based launch systems;

Dr Jinglang Feng – orbital dynamics and uncertainty analysis around small solar system bodies. She works in the field of space debris removal and asteroid deflection;

Prof Matthew Cartmell – modelling of nonlinear dynamical systems, application of the principles of nonlinear dynamics to problems in structural vibration, energy harvesting, flexible rotors, and momentum exchange space tethers. He is involved in new experimental work for making fundamental measurements of gravitation;

Future Air-Space Transportation Technologies Laboratory

Dr Edmondo Minisci – engineer working in model-based analysis and design optimisation of complex mechanical/aerospace systems/devices;

Prof Marcello Lappa – fluid motion and stability behaviour, computational fluid dynamics, organic and inorganic materials sciences, particle dynamics and microgravity science. He has conducted scientific experiments in materials science on board the International Space Station;

Dr Marco Fossati – multiphysics computational aerodynamics. His expertise is in the field of high-speed and non-equilibrium flows, modal-based Modeling for aerodynamics, mesh optimization and generation;

Dr Mohammed Afsar –multiphysics computational aerodynamics, aircraft and rotorcraft aerodynamics, high-speed and non-equilibrium flows, modal-based Modeling for fluid dynamics and aeroicing, mesh optimisation and generation;

Dr Christie Maddock;

The Intelligent Computational Engineering Laboratory

Dr Edmondo Minisci

Dr Annalisa Riccardi – computational scientist working on optimisation, blockchain applications in aerospace, socio-economic applications of EO data, AI for industrial decision support;

Dr Christie Maddock;

Prof Massimiliano Vasile;

Dr Jie Yuan – the development of tools to optimise nonlinear aerospace systems in conditions of uncertainty, stability stress and contact friction;

Centre for Space Science and Applications

(www.strath.ac.uk/science/physics/research/centreforspacescienceandapplications/)

Projects: Satellite test of the Equivalence Principle – testing a fundamental principle in Physics (the equivalence of gravitational and inertial mass) in an ultra-quiet environment of space;

The Gravity Group (www.strath.ac.uk/science/physics/research/gravity/);

Ocean colour remote sensing – observation of the blooms of, plumes of sediments from rivers and areas of coastal erosion and simulating and validating physical-ecosystem models. Developing radiative transfer simulations that predict water leaving reflectance signals. Processing remote sensing data from NASA and ESA in order to assess algorithm performance;

The Marine Optics and Remote Sensing Group (pols.phys.strath.ac.uk/research/marine/)

Silicon hydride-based chemical rocket and scramjet propulsion – developing more efficient silicon-based fuel;

Strathclyde Intense Laser Interaction Studies Group (silis.phys.strath.ac.uk/index.htm);

Space radiation reproduction and radiation hardness testing at SCAPA – using high-power lasers to irradiate a target to mimic certain types of radiation in space. This helps to facilitate testing procedures and to improve radiation durability for the space technology;

Strathclyde Intense Laser Interaction Studies Group (silis.phys.strath.ac.uk/index.htm);

Space-based quantum experiments

Computational Nonlinear & Quantum Optics Group – developing quantum experiments that can be launched on nanosatellite platforms, CubeSats,

(cnqo.phys.strath.ac.uk/research/quantum-information/space-based-quantum-experiments/)

Dr Daniel Oi – quantum theory, quantum engineering, the theory of quantum computation, and quantum space science and technologies;

Dr Thomas Brougham, Dr Roberto Gonzalez Pousa – quantum communication for satellites;

Centre for Signal & Image Processing

(www.strath.ac.uk/research/subjects/electronicelectricalengineering/instituteforsensorssignalscommunications/centreforsignalimageprocessing/): Research in Sensor Signal Processing and Security, Broadband Multi-Sensor Processing, Video and Hyperspectral Imaging, Applied Space Technology, Neuromorphic Sensor Signal Processing

Projects: Growth of the Scottish small-satellite sector with global impact (Impact case study: https://www.strath.ac.uk/media/1newwebsite/ref/ref2021/impactcasestudies/engineering/Growth_of_the_Scottish_small-satellite_sector.pdf)

Prof Malcolm Macdonald – Director of the Applied Space Technology Laboratory (democratisation, exploration, and exploitation of space). He is a Visiting Professor at the Centre for Space Research at the University College Dublin and vice-chair of the Space Technology Advisory Committee of the UK Space Agency. He was the Founding Director of the Scottish Centre of Excellence in Satellite Applications, SoXSA, and a Non-Executive Board Member of UK Space Agency;

Dr Ruaridh Clark – developing design tools for the next generation of satellite constellations with AAC Clyde Space, mapping tidal channels. He participated in horizon-scanning for the UK Space Agency and carried out rocket experiments for ESA's REXUS programme;

Concurrent and Collaborative Design Studio (no direct public link about it found) – developing assessments and virtual prototyping of new space missions and concepts. It uses a large toolbox collection as the Strathclyde Mechanical and Aerospace Engineering Toolbox to perform design optimisation in complex systems. This design approach is currently used at ESA and at Harwell;

xSPANCION Pioneer Partnership Project to develop an innovative satellite constellation service;

Dr Carmine Clemente – radiofrequency sensor signal processing for defence and civilian applications: Automatic Target Recognition, Electronic Surveillance, Earth Observation, emerging radar techniques;

Strathclyde Space Mechatronic Systems Technology Laboratory (no direct public link about it found) – system design, modelling, simulation and prototyping for use on high-reliability microcontroller systems in robotic space hardware and mechanical fabrication tools for prototype and proof-of-concept development.

Several other scholars were identified to be directly involved in manufacturing, data analysis for the space sector, analysis of the data acquired through space technologies or theoretical studies of space-related topics:

Dr Susan Spesyvtseva – expert in photonics and optical trapping. She works closely with industry and the public sector to facilitate collaboration and knowledge transfer of the department's applied research with key academic strengths in photonics, quantum technologies, space, plasma, etc;

Dr Johannes Herrnsdorf – semiconductor-based photonics, digital illumination, micro-LED in communications and imaging;

Dr Paul Griffin – experimental methods precision measurements in atomic physics based on quantum technologies;

Prof Harald Haas –Strathclyde's LiFi Research and Development Centre. Enhancing the communications infrastructure by switching to optical wireless communications instead of infrared;

Dr Christos Ilioudis –MIMO (Multiple-input multiple-output) Radar systems design and signal processing;

Prof John Soraghan – neural networks for multimedia signal processing, signal processing, radar signal analysis, parallel processing architectures and algorithms;

Prof Martin Dawson – Director of Research at the University of Strathclyde's Institute of Photonics. He has been involved in the formation and technical development of spin-out businesses, such as mLED and Neuro-VLC;

Mr Shahroz Khan – artificial intelligence (AI) assisted design system. He is working on the GRAPES (learninG, pRocessing, And oPtimising shapES) Project, developing intelligent computational design tools for the maritime and mechanical industry;

Prof Xiu Yan – mechatronic system design methodology with applications in autonomous space robotics and modular spacecraft assembly;

Dr Gianluca Filippi – network model for the design process of space systems;

Dr Jonathan McKendry – LED-based Visible Light Communications;

Mr Gwenole Henry, Mr Youhua Li – developing a mechatronic platform for Space Robotics;

Dr Robert Atkinson – industrial application of machine learning, cybersecurity, and the Internet of Things. He worked on the framework for Sentinel-1,2 analysis;

Dr Sebastian Diaz Riofrio, Dr Julie Graham, Dr Cheyenne Powell – radar technologies for satellite manoeuvre, space debris detection, satellite scheduling;

Dr Bryn Jones, Dr Peter Nagy – geometric sensitivity study for the aerodynamics;

Dr Maria Anna Laino – assembly and disassembly dynamics of modular solar power satellite;

Dr Christos Tachtatzis – Artificial Intelligence in Advanced Manufacturing and Cybersecurity. He participated in projects for asset tracking within aerospace manufacturing and using radar for coastal mapping;

Dr Scott Brady – mechatronics for space-based robotics applications;

Prof Michael Strain – high-sensitivity inter-satellite optical communications using chip-scale LED and single photon detector hardware;

Dr Duncan McArthur – viable satellite free space optical quantum communication;

Dr Olga Ganilova – application of smart materials in Aerospace Engineering;

Dr David McMillan – engineering and model analysis for energy security. He participated in the Satellite Climate Observation for Offshore Renewable Energy Cost Reduction project;

Ms Astrid Werkmeister – satellite data for condition monitoring, archaeological assessment, disaster management;

Prof Stephen Marshall – image analysis of data from Compact Multi-Spectral sensor from nanosatellites;

Dr Seonaid Rapach – earth observation data for sustainable finance;

Dr Edward John Hart – using satellite data for the offshore renewable energy sector;

Dr Robert Cowlishaw – decentralised data processing in Earth observation;

Dr Lewis Walker – mitigation of debris using space-based lasers;

Prof Federico Coffele, Kinan Ghanem – data usage of BGAN satellite communications for remote outstations;

Dr James Bowden – enhancing sustainable finance with satellite data and advanced analytics

Dr Joshua Gribben – Matryoshka Orbital Networks, satellite pickup and delivery scheduling;

Dr Iosto Fodde – satellite orbiting around asteroids;

MSc Mohammed Eshaq – flight software, electrical power, communication system design for CubeSat;

Dr Waqquas Bukhsh – optimisation, networks, algorithm design for electricity networks. He worked on developing new technologies for satellite communication antennas;

Connections:

(www.strath.ac.uk/science/physics/internationalnationalpartnerships/)

UK Space Agency;

The Space Enterprise Lab by the Satellite Applications Catapult;

ESA;

National Manufacturing Institute Scotland (NMIS);

Virgin Orbit;

Fraunhofer Centre for Applied Photonics;

Lockheed Martin;

There is an outreach programme engaging school pupils in Space research – Scottish Space School.

UNIVERSITY OF HIGHLANDS AND ISLANDS

University of the Highlands and Islands
Oilthigh na Gàidhealtachd agus nan Eilean

University of the Highlands and Islands has no specifically space sector-related course, but there are programmes with closely related topics, such as Aircraft Engineering BEng.

Several scholars were identified to be directly involved in manufacturing, data analysis for the space sector, analysis of the data acquired through space technologies or theoretical studies of space-related topics:

Prof Andrew Rae – aircraft and vehicle aerodynamics, aircraft design;

Dr Qusai Al-Hamdan – gas turbine engines design, modelling, simulation. He participated in testing rocket engines, for example of the HAWK missile rocket engine;

Dr Christopher MacLeod – investigator of spacecraft propulsion and artificial intelligence;

Dr Philip Anderson – using robotic aircrafts and remote sensing technologies in atmospheric analysis and studying sea-ice dynamics in the Arctic. He is a member of the British Antarctic Survey;

Dr Eddy (Eddie) Graham – meteorology, climate change, astronomy (site selection, site testing). He participates in NASA Global Precipitation Measurement Mission, Skyteam: Astronomical Site Characterisation and Site Testing, KOTI / SASKA: Kenyan Optical Telescope Initiative;

Dr Lonneke Goddijn-Murphy – marine optics and physics. Projects involve remote sensing of various aspects of the sea surface such as marine plastic pollution, air-sea gas exchange and wave energy;

Dr Kristin Burmeister – investigating the variability of temperature, salinity and biogeochemical components in ocean circulation and climate using different kinds of observational data, including satellite;

Dr Matthew Davey – algal ecologist, who is interested in space applications of algae biotechnology;

Dr David Constable – a planetary scientist with a background in physics and radio frequency engineering. Current research: auroral acceleration at Jupiter;

Dr Alison Cook – mapping and research on Antarctica, focusing on glaciology and ice/ocean interactions, using remote sensing techniques.

There are environmental scientists in UHI, who do not work on space-related projects, but who could contribute to understand the ecological, economic and societal impacts of such building developments as the Space Hub Sutherland.

Connections:

UKSA and ESA, for example The Connecting Health Care (CHC) Project to deliver satellite connectivity to care homes and GP practices;

The Space Hub Sutherland.

SPACE SECTOR SUPPORTING INSTITUTIONS

Fraunhofer Centre for Applied Photonics

(www.cap.fraunhofer.co.uk/)

A world-leading centre in the field of applied laser research and development. A wide range of space missions rely on critical optical technologies. Fraunhofer CAP has experience in a wide range of applications applicable to space, including single-frequency lasers for quantum technology (atom trapping, interferometry and clocks), lidar systems for Earth observation or navigation, remote laser spectroscopy systems for Earth observation, quantum-key-distribution systems and secure communication.

Space-related projects:

REMOTE (RuggEd Mirco-ECDL technology for cOld aTom applications in spacE) –quantum technologies research to reduce the size and cost of the critical industrial components in order to place the UK at the vanguard of QT development and commercialisation;

Next Generation Satellite QKD – developing the capability to manufacture the next generation of space Quantum Key Distribution payloads. A similar project is "3QN: Towards A New UK Industry for Novel Quantum Receivers in Nascent Satellite QKD Global Markets";

QUEST - Quantum Entangled Source – developing optical components for space applications satellite quantum communication.

Fraunhofer CAP has a key partnership with Fraunhofer IAF, the Institute for Solid-state Physics (Freiburg, Germany).

National Manufacturing Institute for Scotland

(www.nmis.scot/)

Collaborating with industry, academia and the public sector, NMIS aims to increase productivity, support the development of a modern workforce, strengthen supply chains and boost the transition to net-zero in Scotland.

There are the following centres: University of Strathclyde's Advanced Forming Research Centre, Lightweight Manufacturing Centre, Digital Factory, Digital Process Manufacturing Centre and Manufacturing Skills Academy.

The Institute is involved in the xSPANCION Pioneer project that will inform the design and operation of complex satellite networks and constellations of spacecraft;

Also, there is expertise in the field of orbital assembly and manufacturing. Also, the Institute collaborates with industries and agencies in the aerospace field. For example, they have engineered new spacecraft and satellite propellant aluminium tanks for ESA and Airbus.

CENSIS

(censis.org.uk/)

CENSIS is Scotland's not-for-profit Innovation Centre established to support private businesses and public sector organisations to accelerate the pace of innovation by exploiting sensing, imaging and Internet of Things (IoT) technologies.

This centre could become a link between business to expand applications of remote sensing, Earth observation and satellite-based communication.

The Data Lab

(thedatalab.com/)

The Data Lab is Scotland’s innovation centre helping companies, organisations and individuals benefit from the commercial opportunities that exist within data and AI field.

One of the projects Data Lab contributed to is Trade in Space: Monitoring supply chains with satellite data. The Data Lab funded research experts at the University of Edinburgh to create a report on modelling satellite and climate data with an aim to demonstrate the value of predicting coffee yield.

Royal Observatory Edinburgh

The Royal Observatory Edinburgh comprises the UK Astronomy Technology Centre of the STFC, the Institute for Astronomy of the University of Edinburgh, the Higgs Centre for Innovation and the ROE Visitor Centre.

UK ATC (www.ukatc.stfc.ac.uk/Pages/home.aspx) is a centre for excellence in the development of scientific instrumentation for ground and space-based astronomical observatories. Current projects include software for the SKAO, the world's largest radio telescope based in South Africa and Australia, instrumentation for both the Very Large Telescope and the Extremely Large Telescope in Chile. In the recent path, they contributed to constructing MIRI, one of four scientific instruments on the James Webb Space Telescope.

The ROE Visitor Centre (visit.roe.ac.uk/) organises public events to popularise space science.

The Higgs Centre for Innovation (www.higgscentre.org/) is a business-focused facility in collaboration with the University of Edinburgh, that supports startups and enterprises working in the space and data-intensive sectors and encourages collaboration between researchers, engineers and postgraduate students.

The Institute for Astronomy of the UoE (ifa.roe.ac.uk/) – one of the parts of the School of Physics and Astronomy at the UoE.

Its Research Areas are:

Active Galactic Nuclei (Dr James Aird, Prof Philip Best, Prof Andy Lawrence) – studying cores of distant galaxies with supermassive black holes using deep and wide radio surveys, studying relativistic jets, particle acceleration and quasars;

Cosmology (Dr Florian Beutler, Dr Yanchuan Cai, Prof Romeel Dave, Prof James S Dunlop, Prof Catherine Heymans, Prof Sadegh Khochfar, Prof Avery Meiksin, Prof John A Peacock, Dr Alkistis Pourtsidou, Dr Britton Smith, Prof Andy N Taylor, Dr Joe Zuntz) – investigating the contents, laws and history of the Universe on its largest scales. There is a particular specialism in the field of weak gravitational lensing, numerical simulations of the evolution of the Universe, the distribution of Dark Matter and galaxies.

Exoplanets (Dr Beth Biller, Dr Trent Dupuy, Prof Ken Rice) – direct imaging detection and characterization of extrasolar planets, their atmospheres and planet formation;

Galaxy Formation & Evolution (Dr James Aird, Prof Philip Best, Prof Romeel Dave, Prof James Dunlop, Prof Annette Ferguson, Prof Sadegh Khochfar, Prof Bob Mann, Prof Ross McLure, Dr Britton Smith) – studying the physical processes responsible for the formation and evolution of galaxies using large-scale multi-wavelength and spectroscopic surveys of the Universe;

Milky Way & Local Group (Dr Nick Cross, Prof Annette Ferguson, Dr Nigel Hambly, Dr Sergey Koposov, Prof Jorge Peñarrubia, Dr Nick Rowell, Dr Anna Lisa Varri) – searching for signatures of hierarchical assembly in galaxy peripheries, mapping the distribution of dark matter in galaxies, studying the internal stellar dynamics, measuring the star formation history of the Milky Way exploiting data from Gaia, the Hubble Space Telescope and various wide-field surveys conducted with large telescopes and running simulations on supercomputers;

Simulations (Prof Romeel Dave, Prof Sadegh Khochfar, Prof Avery Meiksin, Prof Jorge Peñarrubia, Prof Ken Rice, Dr Britton Smith, Dr Eric Tittley, Dr Anna Lisa Varri) – simulations of astrophysical systems, from the formation of planetary systems in the Galaxy to the evolution of cosmic structures and the large-scale structure of the Universe;

Solar System (Dr Cyrielle Opitom, Dr Colin Snodgrass) – tracing the conditions and processes at the formation of our Solar System to better understand how planets form. using a wide range of telescopes to observe and explore minor bodies using robotic spacecraft. Group members are involved with the ESA Rosetta comet mission, the NASA Dart and ESA Hera steroid deflection experiments, and a Chinese asteroid and main belt comet mission.

Wide-Field Astronomy Unit (www.roe.ac.uk/ifa/wfau/) (Prof Andy Lawrence, Prof Bob Mann) – survey astronomy projects, such as the GAIA Data Flow System to characterise radiation damage effects on the detectors;

The IfA also hosts or manages a number of resources for astronomers in different fields (ifa.roe.ac.uk/data-sets-resources).

The Satellite Applications Catapult

(sa.catapult.org.uk/)

It is one of nine Catapults established to transform the UK's capability for innovation in specific areas and to help drive future economic growth. It helps organisations make use of, and benefit from satellite technologies and bring together multi-disciplinary teams to generate ideas and solutions in an open innovation environment. The Catapult's missions are to drive a thriving, equitable and sustainable in-space economy, helping to solve grand challenges on Earth by 2030, to bring the benefits of advanced, resilient, satellite services to a new generation of autonomous services, to see safe, secure and performant connectivity available everywhere and affordable by every person by 2030, to use space capabilities to enable safe and just outcomes for climate displaced people and their communities by 2030. Their missions are strongly aligned with the UK Government Space Strategy themes.

They have created the Space Enterprise Labs (SELs), a UK-wide network of local places for space innovation that are free-to-use and digitally inclusive. They include free access to resources and expertise to facilitate connecting and collaborating, prototyping and development, manufacturing, testing and validation. 2 out of 14 are located in Glasgow (hosted by the University of Strathclyde) and Edinburgh (hosted by the University of Edinburgh).

Asteria

(www.asteria-space.com/)

Asteria is a group from Edinburgh and the world to engage the students in the space industry, equip, and inspire the next generation of engineers, scientists, and artists, and set a precedence for student space engineering in the UK. Asteria is supported by Chancellor's Fellow for Space and Satellite Analysis at the University of Edinburgh, members of the European Space Agency and private sponsors.

There are three departments: Engineering – building small satellites, high-altitude balloons for remote-sensing with multiple applications, Research – exploring methods to achieve sustainable space exploration. Creative – promoting the just governance of outer Space.

ANNEX G

SSAC REPORT – Scotland's Space Sector: Exploring potential future opportunities

Comparison of International Markets in Commercial Space Applications

15 March 2024

Table of Contents

1. Executive Summary 2
2. Future Opportunities and Vision within the Global Space Sector 3
3. Scotland's Position in Space Sector and Countries Similar to Scotland 5
4. Strategic Position of Selected Space-Active Countries 8
5. Scotland's Relative Position in Comparison with similar Countries 12
6. Potentially Overlooked Opportunities and Gap Areas 13
7. Suggested actions to close these gaps 15
Brief Notes on the Space Strategies of Various Countries 17
Country Strategy Summary - Sweden 17
Country Strategy Summary – Luxembourg 19
Country Strategy Summary – Lithuania 21
Country Strategy Summary – Belgium 23
Country Strategy Summary – Israel 25
Country Strategy Summary – Norway 27
Country Strategy Summary – Denmark 29
Country Strategy Summary – Finland 31
References 33

1. Executive Summary

This report aims to present a comparative study of international space markets reflecting status of the national space strategies and activities across some of the countries similar to Scotland. These countries include some of the EU nations including Sweden, Luxembourg, Israel, Lithuania, and Belgium, along with Norway, Denmark, Finland. Starting with a general outlook of the global commercial space sector opportunities, a brief on the status of Scotland is presented. This is followed by reflecting strategic position of specific space-active nations and key highlight of their space programs and achievements. Scotland's relative position compared to other countries is summarised highlighting potential competitors and collaborators. Finally gap areas in current space strategy of Scotland are noted in comparison to similar countries and actions to fill those gaps are suggested. Summary of the space strategy of included nations are provided in the end notes, for each country. By its nature, this report is not intended to be comprehensive but aims rather to provide an impression of space-related activity in several countries based on freely available public domain information. It will not cover all aspects of space activity in the selected countries, and there will be a degree of subjectivity in the review.

The space industry is on the brink of significant expansion in the next two decades due to increased private sector involvement, technological advancements, and improved regulations. Long term opportunities are abundant in satellite manufacturing and operation, launch, data communication, and space tourism. Scotland's space sector is also experiencing rapid growth in recent years, driven by its ambition to lead Europe's space endeavours by 2030. With a focus on small satellite innovation and production, and leveraging expertise in data analytics, Scotland aims to gain a significant share in the global space market. Despite potential competition from countries like Sweden and Belgium, Scotland's strengths in small satellite manufacturing and its environmentally conscious approach position it well for future growth.

Scotland could work with countries like Norway, Denmark, and Finland, who are trying to do similar activities in space and could also learn from Luxembourg and Israel in their approaches to exploiting space resources. Scotland faces gaps in strategic activities and resources for space resource utilisation and in comparison, to Luxembourg, and Israel. Also, Sweden, and Belgium would appear to be a future competitor in the small satellite manufacturing segment. In satellite launch activities, it will be competing with countries like Sweden and Luxembourg. In areas such as space tourism and satellite data processing based value added services, Scotland also faces competition from Sweden, Denmark, France, and Italy. However, applications in sectors like forestry and agriculture could provide rich application areas to exploit Scotland's position. While Scotland enjoys government support similar to countries like Sweden and Finland, it may be able to learn from Luxembourg's proactive regulatory approach, while acknowledging the UK government's role in this area.

Some of the actions to close the gaps with other nations may also include the following: initiatives for space resource utilisation and asteroid mining, fostering collaborative partnerships and incentivising innovation. Although, the UK national space strategy reflects intentions to develop activities in the emerging areas such as in-orbit servicing, in-space manufacturing and in-situ resource utilisation, other prospects for Scotland include developing long-term satellite manufacturing infrastructure and expertise, promoting international collaboration, exploring opportunities in space tourism and energy generation, encouraging entrepreneurship, and increased focus on data processing capabilities. Further, participating in regulatory framework development in the rapidly evolving space industry and exploring new business opportunities that may derive from that activity.

2. Future Opportunities and Vision within the Global Space Sector

The global space sector appears set for significant growth over the next 20 years, with numerous opportunities emerging. Space agencies such as NASA, ESA, ISRO, and private companies like SpaceX and Blue Origin are driving exploration, satellite deployment, and interplanetary missions, creating a favourable outlook for the industry.

The space sector is expected to witness substantial growth with opportunities in areas such as space tourism, commercial recovery of space resources, satellite manufacturing, and satellite launch. The global space economy is projected to expand, offering opportunities for private sector participation and technological advancements.

Growth Factors

The driving factors behind the growth of the global space sector include increased private sector participation, technological advancements, growing demand for space-related services, favourable policy changes, and the development of a robust regulatory framework. These factors are expected to contribute to the expansion of the global space economy and the emergence of new commercial opportunities.

Other factors affecting the growth of the space sector include collaborations between government agencies and private parties, the development of space parks as manufacturing hubs for space-related technology, and the potential for international collaborations. The talent and low-cost engineering mindset in certain countries are also identified as prime drivers of their emergence in the global space industry.

Upstream Commercial Opportunities

In the short term, upstream commercial opportunities include setting up ground stations for space craft, applications of space technology for upstream applications including materials manufacturing, processing, design of novel propulsion systems, reusable rockets for low-cost access to orbit, in-orbit servicing, and component manufacturing. The surge in demand for supplementary services is poised to increase the space economy, leading to more innovative startups and businesses entering the sector.

Long-term upstream commercial opportunities include satellite manufacturing, satellite launch, and the development of new technologies and services for satellite or space missions. In addition, other opportunities will arise from deep space explorations, advanced launch vehicle development, and space resource utilisation. The global space economy is projected to accelerate, offering substantial potential for private sector participation and collaboration with space agencies in other countries.

Downstream Commercial Opportunities

Short-term downstream commercial opportunities include areas such as data communication and cloud services, media and entertainment provision, and space-related tourism. The ease of doing business in the space sector is expected to increase, allowing for more SMEs and startups to enter the market and contribute to its growth.

In the long term, downstream commercial opportunities are expected to expand in areas such as, health and social care, climate change assessment and mitigation, disaster management, navigation, maritime, broadband and cloud services. In addition, a wide variety of public services can be improved, and even new public services may be enabled utilising the space-based data from satellites. Some of the examples include the traditional public services such as environmental monitoring, agriculture and food security, urban planning and smart city, natural resources management, transportation and logistics, crisis response and resilience. The development of a robust regulatory framework and schemes to promote ease of doing business for space technology are likely to further enhance these opportunities.

3. Scotland's Position in Space Sector and countries similar to Scotland

Scotland's space industry is rapidly growing, and it aims to become Europe's leading space nation by 2030, with a £4 billion share of the space market. The country has a long and successful history of manufacturing, particularly in electronics, aerospace, and oil and gas engineering, which are now contributing to its dynamic and fast-growing space sector. Scotland is already recognised as the largest producer of small satellites in Europe, and with five spaceports under construction, and two near completion, and is making significant headway in realising its ambition. Scotland's space strategy reflects focus on developing and strengthening world-class space infrastructure for manufacturing small satellites and launch facilities across coastal region, growing domestic and international customer base and utilising existing expertise in data analytics, and enhancing collaboration within UK, ESA and worldwide

The space sector in Scotland is expected to be a significant contributor of the country's economy, with the potential to become a huge economic driver. The sector's revenue currently accounts for 14% of the total UK space economy, and nearly a fifth of all jobs in the UK space sector are based in Scotland. The country's space sector is built on broad expertise and experience in various fields, including defence, electronics, photonics, aerospace, manufacturing, and engineering. Scotland's environmentally conscious approach to space aims to generate green and impactful jobs.

Countries Similar to Scotland with Comparable Space Programs

There are countries which share some similarities with Scotland in terms of their size, economic focus, as well as involvement and ambitions in the space sector, making them potential candidates for collaboration or competition in the global space industry. These include, Sweden, Luxembourg, Israel, Lithuania, and Belgium, along with Norway, Denmark, Finland, and others having similar ambitions and potential. Most of these countries have shown increased level of activities in similar periods between 2018 and 2022, with a national space strategy drafted or updates and ambitions declared. Some countries have even proposed and passed space-oriented laws recently.

A short review of the space strategy and activities of the above-mentioned nations is summarised in the '*endnote titled - Brief Notes on the Space Strategies of Various Countries'*. Information from these notes as well as from additional sources is used in the sections ahead to find the similarities, gaps and potential for a collaboration or competition for Scotland in the forward journey in commercial space sector. In comparison to the other mentioned countries, Scotland's focus on small satellite manufacturing, data analysis, and its ambitious growth plans, positions it as a significant player in the European space sector. Highlights of the specific features noted in the space programmes and national strategies of Scotland and similar countries are presented in Table-1 below.

Table-1: Program Highlights of Space Active Countries Similar to Scotland

Country	Population	GDP/capita (£)	Space Program Highlights
Scotland	5,436,600	34,457	Glasgow is small satellites manufacturing hub (more than anywhere in EU), space strategy launched 2021, space hub in Sutherland, SaxaVord spaceport in Shetland, plus three more. Small launch vehicle development. Earth Observation community. Environmental strategy for space industry, instruments for missions such as James Webb space telescope. International space advisory group. UK partner participation includes ESA, LISA and ExoMarse.
Sweden	10,327,589	43,656	Small satellite platforms, PRISMA satellites, and the contribution to various ESA missions, RIT project (Space for innovation and growth) for 8 years completed.
Luxembourg	650,000	104,299	Partner in first European spaceport, Arctic space centre and James Webb Space Telescope participation; 50+ companies and two public research organisations.
Lithuania	2,692,798	19,550	ESA business incubation centre established in 2022, LT space hub, several space startups established; NanoAvionics (small and micro spacecraft, including nanosatellites and CubeSats), Vilnius University Institute of Space and Earth Sciences.

Belgium	11,700,817	39,295	High-performance scientific and industrial fabric in the space sector, focusing on “small” missions and applications for public authorities and citizens.
Israel	9,760,640	32,131	Beresheet mission, Israel’s first lunar lander, expertise in Earth observation with satellites like Venus and TecSAR, Amal mission to Mars
Norway	5,367,580	72,996	Focus on the Arctic region and small satellite technology. Building the first launch base for satellites on the European continent at Andøya Spaceport. Establishing Arctic Space Center – innovation hub. Several companies and institutions in global space supply chain - Kongsberg Satellite Services. Partner in James Webb Space Telescope, the Copernicus Earth observation program, and the Galileo navigation system.
Denmark	5,932,654	53,411	Similar to Norway, partner in international space missions and projects; several institutions active in space supply chain.
New Zealand	5,133,820	38,501	Electron rocket (Rocket Lab), enhancing regulatory frameworks, swiftly gained prominence

4. Strategic position of selected Space-active countries

National space strategies of the Scotland, and other similar nations e.g. Sweden, Luxembourg, Israel, Lithuania, and Belgium, along with Norway, Denmark, Finland, was reviewed using published official strategies where available, plus other reports and articles reflecting the space policy as available in the public domain.

In the endnotes, cumulative information from various sources on the space strategies of individual countries is summarised for each country researched. Here, in the Table-2, a selection of some of the specific features of the space program is presented to help illustrate the comparative position of the countries.

Table-2: Position Comparison of Space Active Countries Similar to Scotland

Country	Upstream Commercial Elements	Downstream Commercial Elements	Global Supply Chain Relevance	Space Funding, and Organisations	Academic Strength, Excellence Areas
Scotland	Managed launch & orbital services, Potentially largest launch capability in Europe, Environmental sustainability strategy, satellite manufacturing & development	Emphasis on green technologies, Data analysis and research	multiple satellite and delivery vehicle manufacturing facilities and launch sites.	UK Space Agency and the Scottish government	Satellite technology, space engineering and astrophysics.
Sweden	Satellite manufacturing, launch services and systems, propulsion systems, space exploration technologies	Satellite data analysis, Earth observation applications and telecoms.	Saab and OHB Sweden are renowned for expertise in satellite manufacturing Esrange Space Center (launch service)	Swedish National Space Agency, European Space Agency funds; both public and private.	Esrange Space Center, KTH Royal Institute of Technology and Lund University, specialised programs in aerospace engineering and space science.
Luxembourg	Space resource utilisation and mining, satellite manufacturing	Satellite data analytics, Earth observation services, Telecoms	Favourable regulatory environment for space mining companies and hosts satellite operators like SES.	Luxembourg Space Agency, and the Luxembourg Future Fund, supporting startups and companies	University of Luxembourg and the Luxembourg Institute of Science and Technology space law, satellite comms, and space resource utilisation.

Israel	Satellite manufacturing & development, launch services, Space exploration technologies	Earth observation applications, Satellite comms, Space-based technologies, Commercial space industry collaboration	Israel Aerospace Industries and SpaceIL expertise	Israel Space Agency, and the Ministry of Science & Technology, supporting R&D and commercialisation.	Technion – Israel Institute of Technology and the Weizmann Institute of Science. Aerospace engineering, astrophysics, and satellite comms.
Lithuania	Satellite manufacturing & development launch services	Earth observation applications, Satellite data analytics	International collaborator for satellite projects and applications	Lithuanian Space Association, and the European Space Agency	Vilnius University and Kaunas University, aerospace engineering, satellite technology, and space science.
Belgium	Satellite manufacturing & development Space exploration technologies, Launch services	Satellite data analysis, Earth observation applications	Thales Alenia Space Belgium, supporting satellite manufacturing, space research & exploration	Belgian Science Policy Office, and the European Space Agency	Université libre de Bruxelles, and the University of Liège. Aerospace engineering, astrophysics, and satellite comms.
Norway	Satellite manufacturing & development, Space research & development	Earth observation applications, Satellite data analysis	Hosts ground stations and satellite research facilities, supporting international space missions.	Norwegian Space Agency and the Research Council of Norway fundings for research, development, & commercialisation efforts	University of Oslo and the Norwegian University of Science and Technology

Denmark	Satellite manufacturing & development, launch services and systems	Earth observation applications, Satellite comms	Companies GomSpace and Terma, contributing to satellite development and space exploration	Danish Space Research Institute, and the European Space Agency fundings	Technical University of Denmark, University of Copenhagen, aerospace engineering, astrophysics, and satellite comms.
Finland	Satellite manufacturing & development, Space research & development	Earth observation applications, Satellite data analysis	Collaborates with international partners for satellite projects and applications.	Finnish Meteorological Institute and ESA grants, research, development, educational initiatives	Aalto University and the University of Helsinki, satellite technology space physics, and climate monitoring.

5. Scotland's relative position in comparison with similar countries

Scotland aims to become a leading European space nation by offering end-to-end satellite manufacture, launch and operational data analysis, with a focus on earth observation and environmental data. Almost one-fifth of all UK jobs in the space sector are based in Scotland. Further, Scotland has well known expertise for small satellite manufacturing and hosts the largest centre for informatics in Europe (Edinburgh Informatics Forum). Having noted that, EU nations and other countries also have strong relative positioning in space programmes and are evolving their ambitions. The current state of these countries in commercial space development is broadly comparable although not necessarily superior to Scotland. These countries were a few years ahead in designing and announcing their national space strategy in second half of the past decade, still the fact remains that Scotland appears to be ahead of those countries in certain segments, particularly in small satellite manufacturing. However, with the growing ambition of these European countries, and because many are already working collaboratively under ESA platform, it is likely that there could be significant competition among those countries and Scotland in future. Nonetheless, the strength of those countries suggests that there are opportunities for collaboration as well as prospects for exploring into those strategic areas not yet covered by Scotland. The brief below attempts to highlight such areas of potential.

Potential Competition

Sweden and Belgium may emerge as competitors for Scotland in the space sector. These countries have well-established aerospace and defence industries, with expertise in *satellite manufacturing, launch services, and space research*. Competition may arise in areas such as satellite deployment, commercial space missions, and attracting investment for space-related ventures.

Potential Collaboration

Norway, Denmark, and Finland could be potential collaborators for Scotland in the space sector. These countries share similarities in terms of technological advancements, research capabilities, and a *strategic focus on satellite technology and space exploration*. *Collaborative efforts could lead to joint satellite missions, research projects, and technology development initiatives.*

Luxembourg and Israel have some unique strengths and focus in the space sector compared to Scotland. Luxembourg is positioning itself as a leader in *space resource utilisation* and commercial space activities, whereas Israel is renowned for its innovation in satellite technology and space exploration missions. However, their priorities and approaches may differ from Scotland's objectives. *In this case, collaborative efforts could lead to exchange in those areas.*

Norway, Denmark, and Finland share commonalities with Scotland in terms of their *strategic emphasis on satellite technology, and collaboration with international partners*. These countries prioritise innovation, research, and investment in the space sector, aligning with Scotland's objectives in space-related activities. *Here, collaborative efforts could potentially be in promoting research exchange and innovative joint ventures in complementing supply chain.*

6. Potentially overlooked opportunities and gap areas

6.1 Upstream Activities

Major Gap Area

Scotland does not seem to have known strategic activities or dedicated resources in space resource utilisation and asteroid mining, where Luxembourg and Israel have made significant strides.

Minor Gap Area

Scotland currently holds a leading position and is further focussing at making small satellites, such as Spire and AAC Clyde Space with a reputation for agility and innovation. However, in Sweden, companies like Saab and OHB Sweden have been long established (1930s, and 2004) with diverse portfolio of products and services, including military aircraft, submarines, radars, and electronic warfare systems, satellite manufacturing, space systems, and related services with a strong reputation and collective experience and know how. Luxembourg, Israel, and Belgium are also good at making small satellites. For example, Luxembourg has SES, Israel has Israel Aerospace Industries, and Belgium has Thales Alenia Space Belgium

In satellite launch activities - Scotland might have to compete with countries like Sweden, which has the Esrange Space Centre and has been launching satellites since 1966. Since its creation, the space centre has expanded its capabilities to include satellite tracking, telemetry, and command services, as well as hosting ground stations for satellite communication and Earth observation Luxembourg, although not directly offering launch services, is positioning itself as a centre for space activities, including potential partnerships for satellite launches.

6.2 Downstream/Midstream Activities

Major Gap Area

In other activities, Scotland has not yet targeted opportunities in areas such as space tourism and space-based energy generation utilising space resources, while countries like Sweden and Denmark are actively pursuing such prospects and initiatives along with EU countries.

Minor Gap Area

Scotland is likely under-utilising its well-known capability and strength in data processing and analysis currently compared to countries in possible competition in this area in the EU (ESA countries: France, Sweden) and globally. The use of space data is a potential area of the space industry with one of the greatest levels of growth opportunity for Scotland. For example, ESA's Copernicus Land Monitoring Service program uses space data for land monitoring insights and other companies provide value added services based on Copernicus data. Some EU countries (France and Italy) have developed strong capabilities in providing value-added services based on satellite data. These countries offer specialized analytics, software platforms, and solutions tailored to specific industries or applications such as environmental monitoring, urban planning, policymaking, agriculture, and climate monitoring for example, The European Image Mosaic (EIM) product, a part of the Copernicus Land Monitoring Service, provides a comprehensive, seamless, and cloud-free mosaic of satellite images from across Europe. This visual representation serves as a powerful tool for developing a deeper

understanding of Europe's geography and landscape; and such data can be processed and used for value added services.

Scotland could further enhance collaborations with sectors such as agriculture, fishing, forestry, environmental monitoring, and developing other satellite-based application solutions. That being said, some recent startups, such as Trade in Space, have started exploring or developing activities in this area.

Learning from countries in the EU, as well as elsewhere (Israel, Australia), Scotland may look to exploit opportunities to foster more entrepreneurship and innovation in downstream space activities supporting startups and small businesses establishing a widening space supply chain within Scotland.

6.3 Other Areas

Regulatory Environment and Government Support

Scotland benefits from a supportive regulatory environment and government support for the space sector, similar to countries like Sweden, Norway, Denmark, and Finland. However, there may be learnings from Luxembourg – which has been particularly proactive in creating a favourable regulatory framework for commercial space activities and offering attractive incentives for companies to operate in the country.

Defence-enabled Space activity

While Scotland is rapidly growing its space industry, it does not appear to have leveraged the same advantages from aerospace and defence industries that countries like Sweden, Norway and Israel have, where technology transfer from these industries into the commercial sector is starting to be seen.

7. Suggested actions to close these gaps

Gap Area	Action
	Upstream Activities
Major Gap Area	Explore the potential for initiatives for space resource utilisation and asteroid mining.
	Establish strategic objective and activities to foster partnerships and provide incentives for innovation and investment
Minor Gap Area	Enable infrastructure for advanced manufacturing and test of satellite equipment producers in view of long-term competition developing across the EU and worldwide.
	Explore actual potential for international collaboration and promote it
	Midstream/Downstream Activities
Major Gap Area	Explore Scottish potential and long-term opportunities in space resource and data uses for space tourism and space-based energy generation.
	Promote entrepreneurship and innovation activities and industry-academia collaborations
Minor Gap Area	Support data processing and analysis capabilities for applications, including the use of cyber security and artificial intelligence as differentiators.
	Study business models emerging worldwide and explore Scotland relevant prospective business models and opportunities for value added space data uses
	Other Areas
Regulatory Environment	Work with the UK and EU governments to initiate and accelerate regulatory framework for the emerging space industry in sync with the space industry growth.
	Introduce improvements in the licencing process to allow the sector to react and respond to the commercial opportunities created by the launch sector in Scotland. Review the number of launches allowed and potential for on-demand services.

Space Industry Growth	Explore space industry supported business and growth opportunities and establish programs to exploit the potential, possibly including a “space innovation hub” and impact acceleration activities. Make better use of existing facilities (Robotarium, NMIS, Universities
Parallel Technology Exploitation	Harness Scotland’s strengths in photonics, laser communications, quantum communication and sensing, science missions, space robotics, cybersecurity, and life sciences for space industry with better coordination and communication.
Defence and civilian balance	Review the current defence and civilian exploitation of space sector in UK. Aim for the right balance of space funding and private investment. Identify opportunities to promote the mutual growth prospects including development of the supply chain.

Brief notes on the space strategies of various countries

This end note includes a brief on space strategies of countries similar to Scotland, including space ambitions, upstream and downstream activities, defence interest in space and space clusters engagement presented for each country separately.

Country strategy summary - Sweden

Sweden's space activities began in the early 1970s with the establishment of the Swedish National Space Agency (SNSA), marking the inception of its formal space programme. Over the decades, Sweden has evolved into a significant player in the global space arena. The Swedish Space Corporation (SSC) has been instrumental in advancing the nation's capabilities, contributing to both civilian and defence-related initiatives.

Space Activities and Ambitions

Sweden's space activities span a wide spectrum, from satellite ground station services and launch services to data analytics. The SSC, a key player, is actively engaged in providing advanced space services and has joined the “Exponential Roadmap Initiative” to align its activities with sustainability goals. There is a commitment to leveraging space data for applications such as climate change monitoring.

Upstream Commercial Activities

The SSC is at the forefront of upstream commercial activities, providing spacecraft operations and engineering services for the international space market. With a focus on sustainability and climate integration, Sweden aims to expand its capabilities in the upstream sector, ensuring a robust presence in the evolving global space industry. Following are the major activities:

- Satellite Manufacturing: producing advanced satellite systems for various purposes, including communication, Earth observation, and scientific research.
- Launch Services and Systems: robust presence in the field of launch services, providing reliable and efficient launch systems for satellites. Companies like SSC (Swedish Space Corporation) offer launch services, including sounding rockets and satellite deployment.
- Propulsion Systems: engaged in the development and manufacturing of propulsion systems for satellites and launch vehicles.
- Space Exploration Technologies: investing in and developing technologies related to space exploration. This includes advancements in space propulsion, robotics, and other exploration-related capabilities.

Downstream Commercial Activities

In addition to upstream activities, the SSC is actively involved in downstream commercial services, particularly in data analytics. Future strategies involve further development and expansion of downstream services. Following are the major activities:

- Satellite Data Analysis: leverage satellite data for various analytical purposes, including environmental monitoring, climate studies, and resource management.
- Earth Observation Applications: monitoring and analysing changes in the Earth's surface, weather patterns, and natural phenomena for applications in agriculture, forestry, and environmental protection.
- Telecommunications: utilising satellite technology for communication services. This includes satellite-based internet services, broadcasting, and telecommunication infrastructure.
- Space-Based Technologies: include technologies derived from satellite data, such as navigation systems, remote sensing technologies, and global positioning systems.

Defence Interests in Space

Recognising the strategic importance of space in national defence, Sweden is actively pursuing a dedicated defence strategy for space. This involves enhancing military capabilities and strengthening national defence through space-related activities.

Space Clusters

Sweden has strategically positioned itself with the Esrange Space Center, situated above the Arctic Circle, owned, and operated by the SSC. This centre serves as a crucial hub for space activities, enabling regular contact with passing satellites. The Esrange Space Center, along with other space clusters like the Kiruna Space Campus and Stockholm Space Alliance, fosters collaboration, innovation, and research within the Sweden’s space industry.

Country strategy summary – Luxembourg

Luxembourg has been actively involved in space activities since the 1980s, establishing a solid foundation for its space program. The nation's space sector has made significant contributions to its GDP, ranking among the highest in Europe. In 2018, Luxembourg intensified its commitment to space endeavours with the creation of the Luxembourg Space Agency (LSA), further solidifying its position as a key player in the global space community.

Space Activities and Ambitions

Luxembourg's space activities encompass a wide spectrum, ranging from satellite-telecom infrastructure to global communications and data traffic. The nation has pioneered advancements in TV and radio broadcasts and developed high-tech components for satellites, positioning itself as a hub for commercial space innovation. The SpaceResources.lu Initiative, launched in 2016, has reinforced Luxembourg's status as a leading commercial space innovator in Europe.

Upstream Commercial Activities

Luxembourg aims to create new space industries by nurturing entrepreneurial space research and business. It has recently implemented a legal framework and provides diverse financial tools, including tax incentives and direct aids, to support companies throughout their business lifecycle. Following are the major activities:

- Space Resource Utilisation and Mining: there is significant interest in space resource utilisation and mining. The country aims to be a leader in the exploration and extraction of valuable resources from asteroids and other celestial bodies.
- Satellite Communications: a strong presence in the satellite communications sector. The country supports companies engaged in satellite communications services, fostering advancements in satellite technology for global connectivity.
- Satellite Manufacturing: supports and invests in companies involved in the design and development of advanced satellite systems.

Downstream Commercial Activities

There is a concentration of dynamic space companies involved in manufacturing satellite and instrument structures, system integration of micro-satellites, electric propulsion, robotic payloads, in-space manufacturing, composites, RF payloads, and FPGA. The country has implemented a range of measures to support these highly innovative companies, ensuring a thriving ecosystem and addressing the diverse needs of the downstream space sector. Major activities include:

- Satellite Data Analytics: utilising satellite data for analytics, focusing on applications such as Earth observation, climate monitoring, and environmental assessments.
- Earth Observation Services includes applications in agriculture, forestry, urban planning, and environmental protection.
- Telecommunications: satellite-based telecommunications, supporting services such as satellite broadcasting, broadband, and other communication applications.

- Space-Based Technologies: promotes the development and application of space-based technologies, including navigation systems and remote sensing technologies for various industries.

Defence Interests in Space

Luxembourg positions itself as a European hub for commercial space activities, with the space and satellite sector accounting for almost 2% of the country's GDP. The government's efforts to establish Luxembourg as an attractive and vibrant ecosystem for space business are reflected in its growing economic importance. While not traditionally focused on defence-related activities, Luxembourg contributes to the European space landscape through its commitment to fostering a robust and sustainable space economy.

Space Clusters

Luxembourg is home to a thriving space industry, hosting over 50 companies and two public research organizations. The European Space Resources Innovation Centre (ESRIC) further cements Luxembourg's position as a hub for commercial space activities.

Country strategy summary – Lithuania

Lithuania's Space Journey

Lithuania has a remarkable potential in the space industry, with a history of involvement in space research and technology. The country has been participating in European and global space exploration for decades, and in 2014, Lithuania launched its first satellites, marking a significant milestone in its space endeavours.

Space Activities and Ambitions

Lithuania positions itself to play a pivotal role in the space technology revolution and is an Associate Member state of the European Space Agency. It has plans for a Business Incubation Centre showing the commitment to supporting space-related business ideas and commercial start-ups, highlighting the country's dedication to technological advancement and entrepreneurship in space.

Upstream Commercial Activities

Upstream commercial activities of the Lithuania space industry include the development of systems and elements for space shuttles, as well as participation in joint international projects. The country's future strategy involves furthering its involvement in international space programmes and expanding its role in the development of consumer applications for the space industry. Following are the major activities known:

- Satellite Manufacturing and Development: plans to contribute to satellite manufacturing through collaborative efforts with other European nations or private entities involved in satellite projects.
- Launch Services: does not have its own launch services but may collaborate with other countries or private entities that offer launch services for satellites.

Downstream Commercial Activities

Downstream commercial activities of the Lithuanian space industry encompass the launch of satellites, spaceflight experiments, and the establishment of a space business incubator to expand the range of space-related companies. Lithuania aims to more than double the number of companies participating in space supply chains within the next five years, indicating a strong focus on downstream commercial activities and future growth in this sector. Major activities are:

- Earth Observation Applications: for various applications, including environmental monitoring, agriculture, and land-use planning.
- Satellite Data Analytics: satellite data analytics, extracting valuable insights for applications such as climate studies and disaster management.

Defence Interests in Space

While specific details about Lithuania's defence interests in space are not readily available, the country's membership in the ESA indicates a commitment to contributing to peaceful applications of space technology. Lithuania is expected to play a role in various areas such as environmental

monitoring, climate change research, and telecommunications, aligning its space activities with broader European initiatives for the peaceful use of outer space.

Space Clusters

Lithuania is actively shaping its space ecosystem, fostering synergies with businesses and organizations outside the traditional space sector. Efforts are focused on encouraging the development of new space industries and expertise.

Country strategy summary – Belgium

Belgium's involvement in space activities spans over 40 years, highlighting a rich history in innovative space exploration. The establishment of the Belgian Space Office (BELSPO) in 1986 formalised the nation's commitment to space, bringing together a diverse cluster of space expertise, including notable entities like the satellite manufacturer Aerospacelab.

Space Activities and Ambitions

Belgium's space policy operates within an international framework, emphasising bilateral and multilateral cooperation. As the 5th largest contributor to the European Space Agency, Belgium actively participates in co-financed projects and strategic initiatives. The country's space policy is strategically aligned to stimulate projects close to commercial markets. The European Investment Bank has entered a deal with Belgium's southern region, Wallonia, to explore funding and advisory support for the space industry. This partnership aims to support the growth of the space economy and develop the region's aerospace cluster, including co-financing opportunities.

Upstream Commercial Activities

Belgium aims to mobilise investment to maintain a central position in space exploration. The nation's future strategy focuses on encouraging the development of key skills and expertise, creating new space industries, and nurturing entrepreneurial space research and business. This forward-looking approach is aimed at ensuring that all stakeholders, including industrial, scientific players, and users, can fully benefit from the advantages of space, reinforcing Belgium's position as a key player in the global space arena. Major upstream activities are:

- Satellite Manufacturing and Development: contribute to satellite manufacturing through its involvement in collaborative projects within the European context.
- Space Exploration Technologies: space exploration technologies, contributing expertise and resources to collaborative space exploration missions.

Downstream Commercial Activities

Investments in space research programs have not only led to scientific advancements but also provided significant fiscal returns and job creation in the broader economy. Major activities include:

- Satellite Data Analysis: utilises satellite data for various downstream applications, including Earth observation and data analysis for environmental monitoring, climate studies, and urban planning.
- Earth Observation Applications: provide valuable data for agriculture, forestry, disaster management, and other purposes.
- Telecommunications: supporting services such as satellite broadcasting, broadband, and communication technologies.

Defence Interests in Space

While specific details about Belgium's defence interests in space are not explicitly outlined, the strategic considerations and priority areas in its space policy indicate a broader focus on security and

defence in space. Belgium's alignment with ESA's objectives and its active participation in multilateral space initiatives contribute to the broader European efforts to ensure the security and resilience of space assets.

Space Clusters

Belgium's thriving space industry is supported by a robust cluster of space expertise that has evolved over the years. These space clusters have served as catalysts for collaboration, innovation, and knowledge exchange, reinforcing Belgium's role as a central hub in the European space community.

Country strategy summary – Israel

Israel's ventured into space in 1983 with the establishment of the Israel Space Agency (ISA). Over four decades, Israel has built a robust space infrastructure, with a focus on satellite development, communication services, and remote sensing.

Space Activities and Ambitions

Israel's space strategy is aimed at capturing 1% of the global market share, emphasising economic growth, scientific advancement, and enhanced international status. The ISA leads the charge, promoting innovation, supporting new space-related projects, and strengthening the civilian space industry as a sustainable growth engine. Israel's ambitions in space extend beyond national borders, aiming to position the country as a global leader in the space industry.

Upstream Commercial Activities

Israel's future strategy is geared towards cultivating a vibrant space ecosystem that nurtures entrepreneurial space research and business. The private space sector in Israel is actively developing diverse technologies with global applications. The country aims to scale its capabilities, becoming a significant player in the international space market. Activities include:

- Satellite Manufacturing and Development: there is a robust satellite manufacturing and development sector. Companies like Israel Aerospace Industries (IAI) and Rafael Advanced Defence Systems are actively involved in producing satellites for various purposes, including communication, Earth observation, and military applications.
- Launch Services: Israel has developed its launch capabilities through entities like the Israel Space Agency (ISA) and private companies like SpaceIL. The Shavit launch vehicle has been used for satellite launches.
- Space Exploration Technologies: active in developing space exploration technologies, including unmanned lunar exploration missions. Notably, SpaceIL's Beresheet mission aimed to land an Israeli spacecraft on the Moon.
- Research and Development invests in research and development in space-related technologies, contributing to upstream elements that drive innovation in satellite systems, propulsion, and other space technologies.

Downstream Commercial Activities

Israel's private space sector is actively engaged in satellite development and operation, communication services, remote sensing, and other space-based applications. The emphasis is on developing technologies with diverse applications across industries to attract international customers and investors. Following are the major activities known:

- Earth Observation Applications: including monitoring environmental changes, agriculture, water resources, and disaster management.
- Satellite Data Analytics: satellite data analytics for various purposes, such as extracting insights for agriculture, urban planning, and environmental monitoring.

- Satellite Communications: actively engaged in satellite communications, providing satellite-based communication services, broadband, and telecommunication infrastructure.
- Space-Based Technologies: application of space-based technologies to various downstream areas, including navigation systems, remote sensing technologies, and global positioning systems.
- Commercial Space Industry Collaboration: Israel collaborates with private companies involved in downstream activities in telecommunications, Earth observation, and other applications.

Defence Interests in Space

While specific details about Israel's defence interests in space are not explicitly outlined, the strategic investments in the civilian space industry are anticipated to have broader implications for national defence and security capabilities.

Space Clusters

Israel's space industry is characterized by a robust private sector actively involved in all aspects of space planning, development, and operation. The country has established cooperation agreements with international space agencies.

Country strategy summary – Norway

Norway commenced its venture into space during the 1960s. The Norwegian Space Agency (NOSA) was formally established in 1987. Over decades, Norway has evolved into a key player in the global space community. In 2020, the country adopted a new national space strategy, emphasising its dedication to the space industry and its potential contributions to economic growth and scientific research.

Space Activities and Ambitions

Norway's space activities are inspired by the ambition of becoming a leading player in the global space industry. The country aims to leverage its space capabilities for economic growth, scientific advancement, and enhancing its international status. Norway's space efforts also focus on addressing communication, navigation, surveillance, and preparedness needs in the “High North.”

Upstream Commercial Activities

Norway's future strategy involves cultivating a vibrant space ecosystem that supports entrepreneurial space research and business. The country's space industry, characterized by a robust private sector actively involved in all stages of planning, development, and operation, is integral to this strategy. The Norwegian government expresses its ambition to develop Norway into a space nation capable of supporting national defence, aligning space activities with broader strategic interests. Activities include:

- Satellite Manufacturing and Development: contribute to collaborative satellite projects within the ESA or other international frameworks. Norway does not have an extensive independent satellite manufacturing sector so far.
- Space Research and Development: Norway invests in research and development in space-related technologies, contributing to upstream elements that drive innovation in satellite systems, space exploration technologies, and scientific instruments.

Downstream Commercial Activities

Downstream, Norway's commercial activities revolve around satellite-based systems addressing communication, navigation, surveillance, and preparedness needs in the High North. The country's space industry is poised to significantly contribute to economic growth and job creation. Following are the major activities known:

- Earth Observation Applications: Norway utilises satellite data for Earth observation applications, including monitoring environmental changes, climate studies, and contributions to international Earth observation programs.
- Satellite Data Analytics: Norwegian companies and research institutions engage in downstream activities related to satellite data analytics. This involves extracting insights for environmental monitoring, maritime surveillance, and resource management.
- Space-Based Technologies: application of space-based technologies to various downstream applications, including navigation systems, remote sensing technologies, and global positioning systems.

Defence Interests in Space

Norway's strategic investments in the civilian space industry extend to broader implications for defence and security capabilities. The integration of space technologies into Norway's defence framework aligns with the broader national strategy.

Space Clusters

Norway's space industry works along with key organizations like Space Norway, responsible for managing and developing strategic space infrastructure to address crucial societal needs.

Country strategy summary – Denmark

Denmark's space interest and activities have evolved significantly in recent years, marked by a strategic focus on the commercial utilisation of space. The European Space Agency Business Incubation Centre (ESA BIC Denmark) was hosted in Denmark to bolster commercial space endeavours. Denmark has commitment to leveraging space for multiple societal benefits.

Space Activities and Ambitions

Denmark's space activities are driven by an ambition to exploit the commercial utilisation of space. The country aims to accelerate innovation and entrepreneurial space endeavours, positioning itself as a formidable player in the global space industry. The national space strategy emphasises the dual goal of economic growth and scientific advancement through strategic international collaborations.

Upstream Commercial Activities

Denmark's future strategy revolves around actively supporting new and established Danish companies in their commercial space pursuits. The nation is dedicated to cultivating a vibrant space ecosystem that encourages the development of crucial skills and expertise. Denmark's aspirations include solidifying its position as a hub for commercial space innovation, fostering a dynamic environment for space-related businesses to thrive. Activities include:

- Satellite Manufacturing and Development: Denmark does not have an extensive independent satellite manufacturing sector, although Danish institutions and companies participate in the development of satellite technologies in collaboration with European space agency and partners.
- Space Research and Development: Denmark invests in research and development in space-related technologies, contributing to upstream elements that support innovation in satellite systems, scientific instruments, and space exploration technologies.

Downstream Commercial Activities

Denmark's focus is on supporting the development of novel space industries and expertise. The nation is committed to nurturing entrepreneurial space research and business. Denmark's dedication to downstream activities aligns with its comprehensive strategy to capitalize on the full spectrum of opportunities in the evolving space sector. Activities include:

- Earth Observation Applications: Denmark utilises satellite data for Earth observation applications, contributing to environmental monitoring, agricultural assessments, and climate studies.
- Satellite Data Analytics: Danish companies and research institutions engage in downstream activities related to satellite data analytics such as extracting insights for environmental monitoring, urban planning, and resource management.
- Space-Based Technologies: application to various downstream areas, including navigation systems, remote sensing technologies, and global positioning systems.

Defence Interests in Space

Specific details about Denmark's defence interests in space are not readily available, the country's strategic investments in commercial space exploitation are anticipated to have wider implications for defence and security capabilities.

Space Clusters

Denmark's space industry thrives with the support of the European Space Agency Business Incubation Centre (ESA BIC Denmark), a key player in fostering innovation and supporting the growth of new space industries.

Country strategy summary – Finland

Finland initiated its space program in the 1980s, and the national space strategy underwent a transformative update in 2018, aligning with the New Space Economy's principles. This strategic overhaul focused on the emergence of small satellites and globally scalable business models. The Finnish Space Agency (FINSA), established in 2018, encapsulates Finland's commitment to staying internationally competitive in the evolving space industry.

Space Activities and Ambitions

Finland has ambition to become the world's most attractive and agile space business environment by 2025. The national space strategy, overseen by the Space Committee, guides Finland's direction, emphasising market access requirements, international influence, and research. The country aspires to leverage its competence to benefit companies, fostering efficiency, innovation, and economic growth on a global scale.

Upstream Commercial Activities

Finland's future strategy revolves around setting ambitious targets, aiming to secure a prominent position in the global space industry. The country envisions achieving these goals by actively supporting the development of new space industries and expertise. Following are the major space activities:

- Satellite Manufacturing and Development: Finland contribute to collaborative satellite projects within the ESA or other international partnerships. Finnish companies and institutions may participate in the development of satellite technologies.
- Space Research and Development: Finland invests in research and development in space-related technologies, supporting innovation in satellite systems, scientific instruments, and space exploration technologies.

Downstream Commercial Activities

There is commitment to nurturing entrepreneurial space research and business, with ambition to establish Finland as a leading player in the global space market. The strategic approach involves leveraging space-based applications for societal and economic benefits, positioning Finland as a pivotal player in the evolving space landscape. Major activities include:

- Earth Observation Applications: Finland uses satellite data for Earth observation applications, contributing to environmental monitoring, forestry, agriculture, and climate studies.
- Satellite Data Analytics: Finnish companies and research institutions may engage in downstream activities related to satellite data analytics.
- Space-Based Technologies: Finland applies space-based technologies to various downstream applications, including navigation systems, remote sensing technologies, and global positioning systems.

Defence Interests in Space

Specific details about Finland's defence interests in space are not available.

Space Clusters

Finland's space industry thrives within collaborative clusters, supported by the national space strategy. The strategy aims to create a vibrant and innovative space sector.

References

Scotland's space industry opportunities and space capabilities (sdi.co.uk)

European Image Mosaic — Copernicus Land Monitoring Service

Why VC investors are looking to Scotland and what the space sector offers (investmentmonitor.ai)

Economy, Trade and Investment - Scotland's International Strategy

Under the surface of Scotland's space industry - Royal Society of Edinburgh (rse.org.uk)

Committees.parliament.uk/writtenevidence/125216

Explore opportunities in Indian Space Sector (investindia.gov.in)

Exploring the Opportunities in Indian Space Sector (aippi.org)

The Commercial Space Age Is Here (hbr.org)

Space for all: here are some of the huge commercial opportunities away from Earth – Physics World

Space Opportunities for India In Space Sector What Experts Say Space Internet Satellite Services (abplive.com)

Sweden Needs a Defence- and Security-related Space Strategy

Swedish Space Corporation - Wikipedia

Swedish Space Corporation joins the Exponential Roadmap Initiative - Exponential Roadmap Initiative

Swedish Space Corporation: An arctic gateway to space - Nordic Investment Bank (nib.int)

Sweden's latest astronaut in space - Government.se

Space Policy and Strategy - The agency - Luxembourg Space Agency (public.lu)

Luxembourg space industry, a rising star for companies | Deloitte Luxembourg | Technology

How Luxembourg becomes Europe's commercial space exploration hub | Cairn.info

How Luxembourg is positioning itself to be the centre of space business (theconversation.com)

» Space (tradeandinvest.lu)

Space Policy - Ministry of the Economy and Innovation of the Republic of Lithuania (lrv.lt)

Lithuania is ready to strengthen its role in the space technology revolution | Ministry of the Economy and Innovation of the Republic of Lithuania (lrv.lt)

ESA - Lithuania becomes ESA Associate Member state

Space Policy and Strategy - The agency - Luxembourg Space Agency (public.lu)

Belgian space strategy | Space in Belgium | Space Research & Applications | Belspo

Aerospace | FPS Foreign Affairs - Foreign Trade and Development Cooperation (belgium.be)

Belgium: 40 years of innovative space exploration | Embracing Belgium (embracingopenness.be)

Space Policy and Strategy - The agency - Luxembourg Space Agency (public.lu)

New Strategic Plan for Advancing the Israeli Civilian Space Industry

Israel Space Industry Opportunities (trade.gov)

Israeli Space Program - The Challenges Ahead - Indian Council of World Affairs

The Startup Nation in Space – Israel's Equation for the Space Ecosystem - Space News

Israel Space Agency - Wikipedia

Exploring the space industry's impacts on security and the environment in the High North | NMBU

A leading environment in Norwegian space industry | Space Norway

Norwegian Airspace Strategy - regjeringen.no

Norway Launched Into the Commercial Space Age - Arctic Today

Home - ESA BIC Denmark

Microsoft Word - policytownplanning31.commercialstrategy.completedocument (denmark.wa.gov.au)

The National Strategy for Finlands Space Activities - Ministry of Economic Affairs and Employment (tem.fi)

Becoming a Spacefaring Nation. Finland's Success Story | LinkedIn

Scottish Space Strategy launched - gov.scot (www.gov.scot)

Scotland's space sector set to become greenest on Earth (geospatialworld.net)

committees.parliament.uk/writtenevidence/124634

Home - Space Scotland

SSAC group internal communications