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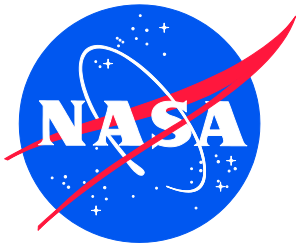

Aerospace Valve Industrial Base and Acquisition Practices Assessment

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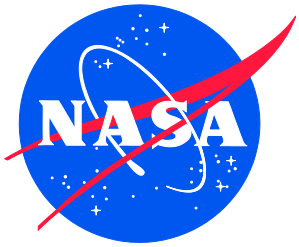

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Preface

The Human Exploration and Operations Mission Directorate (HEOMD) and the Science Mission Directorate (SMD) Chief Engineers (CEs) requested that the NASA Engineering and Safety Center (NESC) assess the aerospace valve industrial base and NASA's application of design and construction (D&C) standards to identify risks and potential mitigation steps to avoid future problems. This request was in response to the significant number of valve-component-related issues experienced by NASA across multiple programs/projects and mission directorates. Numerous valve-related anomalies within the HEOMD and SMD have led to this being tracked by the Office of the Chief Engineer (OCE) as a crosscutting issue for NASA.

The key stakeholders for this assessment are Mr. John McManamen, HEOMD CE; Mr. Joseph Pellicciotti, NASA Deputy CE (formerly SMD CE); and multiple other programs/projects across HEOMD and SMD.

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Nomenclature

AIAA	American Institute of Aeronautics and Astronautics
ANSI	American National Standards Institute
CCP	Commercial Crew Program
CE	Chief Engineer
CM	Crew Module
COTS	Commercial Off-the-Shelf
CST	Crew Space Transportation
D&C	Design and Construction
EUS	Exploration Upper Stage
FAA	Federal Aviation Administration
GMIP	Government Mandatory Inspection Point
GOES	Geostationary Operational Environmental Satellite
GRC	Glenn Research Center
GSFC	Goddard Space Flight Center
HEOMD	Human Exploration and Operations Mission Directorate
ISS	International Space Station
JANNAF	Joint Army-Navy-NASA-Air Force
JPSS	Joint Polar Satellite System
JSC	Johnson Space Center
JWST	James Webb Space Telescope
KSC	Kennedy Space Center
LaRC	Langley Research Center
M&P	Materials and Processes
MIL	Military
MPCV	Multi-Purpose Crew Vehicle
MSFC	Marshall Space Flight Center
NESC	NASA Engineering and Safety Center
NRB	NESC Review Board
OCE	Office of the Chief Engineer
OMS	Orbital Maneuvering System
R&D	Research and Development
SBIR	Small Business Innovation Research
SLS	Space Launch System
SM	Service Module
SMD	Science Mission Directorate
SME	Subject Matter Expert
SSC	Stennis Space Center
TRL	Technology Readiness Level
U.S.	United States
USG	United States Government

Abstract

Based on some recent valve issues, it was requested that the NASA Engineering and Safety Center (NESC) assess the aerospace valve industrial base and NASA's current acquisition practices to identify risks and potential mitigation steps to avoid future problems. A three-pronged approach was used for this assessment. First, questionnaires were sent to NASA programs/projects across multiple NASA Centers. Next, valve vendor data received as part of an independent 2017 Department of Commerce study of the propulsion industry base were mined for issues with the participating valve companies. Lastly, several valve vendors were sent questionnaires to obtain feedback on supply issues they were experiencing with NASA's acquisition practices or valve design requirements. Based on the survey data and subject matter expert evaluations, although real problems were noted with a few aerospace valve suppliers, the industry as a whole does not appear to be eroding or in decline.

1.0 Executive Summary

NASA has recently experienced a significant number of valve-component-related issues (discussed in Section 3.0) across multiple programs/projects and mission directorates. Numerous valve-related[1] anomalies within the *Human Exploration and Operations Mission Directorate* (HEOMD) and *Science Mission Directorate* (SMD) have led to this issue being tracked by the Office of the Chief Engineer (OCE) as a crosscutting issue for NASA. The HEOMD and SMD Chief Engineers (CEs) requested that the NASA Engineering and Safety Center (NESC) assess the aerospace valve industrial base and NASA's current acquisition practices to identify risks and potential mitigation steps to avoid future problems.

The valve failures (e.g., leakage, maximum operating pressure, lifecycle) and the resulting inability to meet performance requirements has led to the perception that there might be systemic or chronic design/quality and handling issues from an eroding valve supply chain and/or system integrators. Examples of fundamental design and quality issues exist with valves from multiple suppliers used in flight hardware development across HEOMD and SMD programs/projects (e.g., the Multi-Purpose Crew Vehicle (MPCV) Orion crew module (CM)/European service module (ESM) and the Commercial Crew Program (CCP) launch vehicle and spacecraft). Although most of the problems were identified during qualification and/or acceptance testing, the sources of these issues must be determined and are currently being worked by individual programs/projects. The problem is potentially compounded by NASA schedule pressures, which often necessitate the use of commercial off-the-shelf (COTS) components and may discourage the development and testing that was done for previous programs. The objective of this assessment, however, was not to determine the root causes of the reported failures but rather to determine the overall state of the valve industry and evaluate NASA's application of design and construction (D&C) requirements.

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[1] For the purposes of this report, *valve* is defined as any related valve component (e.g., valve, regulator, propulsion component, etc.).

A three-pronged approach was used for this assessment. First, questionnaires were sent to NASA programs/projects across multiple NASA Centers. The questionnaire was developed by valve subject matter experts (SMEs) to preclude biased results from respondents. The intent was to identify the valve companies used by NASA programs, the issues the programs have with their vendor base, and how the programs feel about NASA's design, construction, and test requirements. Next, valve vendor data received as part of an independent 2017 Department of Commerce study of the propulsion industry base were mined for issues with the participating valve companies. Lastly, several valve vendors were sent questionnaires to obtain feedback on supply issues they were experiencing with NASA's acquisition practices or valve design requirements.

Based on the survey data and the SME evaluations, although real problems were noted with a few aerospace valve suppliers, the industry as a whole does not appear to be eroding or in decline. Companies or suppliers new to the aerospace industry appear to be prospering. Financial data reviewed for the valve suppliers that participated in the Department of Commerce survey showed growth, and there was no indication of decline across the industry. The valve-related issues experienced by NASA programs may be attributed to multiple factors and should be investigated beyond this assessment. For example, NASA is currently working multiple programs in parallel through stages of program life requiring concurrent development, qualification, and manufacturing of a large number of challenging and unique valve designs on a compressed schedule. Coupled with other aerospace industry demands, this may have potentially overwhelmed valve suppliers. Further, several newer aerospace companies are supplying valves to NASA. Therefore, the issues may be the result of design and/or production difficulties for these companies as they gain experience. Based on this assessment, the aerospace valve supplier base appears to be growing.

2.0 Assessment Plan

The purpose of this assessment was to gain an understanding of the connection between valve failures, the health of the valve industry, the current industry workload effects, and NASA's acquisition strategy or requirements. Although specific valve failures were assessed as part of this exercise, direction to any supplier relating to ongoing issues being worked by a program/project was not in scope, and assessment team members did not perform work toward a resolution of any specific valve issue. The scope of this effort was limited to aerospace flight valve components.

This assessment included the following activities:

1. Conduct program/project survey.
    - Survey programs/projects to identify recent applicable valve component issues, resolution efforts, and outcomes.
    - Request list of vendors supporting each program/project element.
    - Compile and analyze issues for common and systemic causes and potential solutions.
2. Conduct vendor/integrator survey.
    - In parallel with program/project survey, conduct a survey of valve suppliers and project integrators for feedback on NASA's flow-down of performance and D&C requirements, procurement strategy, workload, and schedule constraints.

- Discuss the survey feedback, issues, and findings with vendor and program/project representatives.

3. Conduct vendor deep dives.
   - Based on the feedback from vendors and programs/projects, identify up to two vendors (or sub-vendors) with which to conduct face-to-face meetings. The purpose of the meetings was to determine if/how NASA's procurement strategy played a role in the specific failures observed.
4. Based on data gathered from steps 1 through 3, identify risks associated with different valve/component requirements, technical issues, other issues, as well as potential mitigations.
5. Mine the results of an independent Department of Commerce study of the propulsion industry base for issues with the participating valve companies. (This step was added to the original assessment scope based on the timely availability of the Department of Commerce survey data following the initial assessment plan acceptance by the NESC Review Board (NRB).)
6. Document findings, observations, and NESC recommendations in an NESC final report and a stakeholder briefing to the OCE.

3.0 Problem Description

NASA has experienced valve-component-related issues across multiple programs/projects and mission directorates. Design/quality and handling issues within the valve supply chain and system integrators are resulting in the inability to meet performance requirements (e.g., leakage, maximum operating pressure, lifecycle). Numerous examples of fundamental design and quality issues exist with valves from multiple suppliers used in flight hardware development across HEOMD and SMD programs/projects. NASA has always had and will have component problems related to design/process/quality at any given manufacturer. This is often driven by the fact that NASA builds one-of-a-kind missions where we are always changing or tweaking the requirements. All hardware manufacturers can experience issues if there are changes to heritage designs without proper development testing, or if the design entity no longer has the original designer or detailed knowledge of the design, leading to unexpected effects due to small changes in the design. However, the number of high visibility or critical path valve issues are what initiated the effort behind this report.

Issues have been and are currently being worked by individual programs/projects. The numbers and types of fundamental design issues may indicate a more systemic issue of an eroding supplier base for these component types. The problem is compounded by NASA schedule pressures that result in the use of both COTS and unique components and may discourage development and acceptance testing.

- Examples of recent valve component issues relevant to this study include:
  - Geostationary Operational Environmental Satellite (GOES) check valves experienced leakage likely caused by a process escape resulting in damage and particulate in the valve.
  - James Webb Space Telescope (JWST) leak rates were traced to degraded elastomeric seals transferring material onto valve seats.

4.0 Survey Methodology

Three survey sources were used to obtain the input for this assessment:

- Initially, questionnaires were sent to NASA programs/projects located across multiple NASA Centers to identify the valve companies used by the programs, issues these programs have with their vendor base, and how they feel about NASA's design, construction, and test requirements.
- Secondly, valve vendor data received as part of an independent Department of Commerce study of the propulsion industry base were mined for any issues with those valve companies participated.
- Finally, specific valve vendors were asked to provide feedback on issues they have in general or with NASA's valve design requirements.

4.1 Program/Project Survey

Project/programs questionnaires were prepared and disseminated by the assessment team across multiple NASA Centers. The intent of this questionnaire was to obtain feedback from program or project offices regarding which vendors support program/project activities, issues they have observed with those vendors, vendor pushback on NASA requirements, and how they communicate with their vendors. Feedback was received from 26 programs/projects, and the notable comments are discussed here.

Key or notable observations from the questionnaire feedback are:

- Twenty-four suppliers were identified as providing valves for NASA programs. In the majority of instances reported, suppliers provided two or fewer unique designs for the responding program. However, there were suppliers providing more than ten unique designs for specific programs.
- The most commonly reported issue types observed by programs were "Manufacturing quality issues" and "Process escapes leading to component/system operational issues." Four other issue types, "Inadequate acceptance test program," "Inadequate design due to extremely difficult to meet performance requirements," "Inadequate resources," and "Failure to meet schedule," were reported by a smaller but significant number of programs.
- The issues reported by the programs were not surprising and are systemic to all components. This reinforces the need for a robust quality system with component-level checks (e.g., acceptance vibration testing).
- All other issue types proposed in the questionnaire were reported by at least one program. There were issue types reported by programs in the "Other issues that you feel may indicate a vendor is strained" category. Most notably, one program stated that issues were attributable to a small and young engineering group that lacked knowledge transfer and technical skill to oversee the quality of products.
- Nearly all projects stated they interact with their valve suppliers through an integrator. Integrators do not manufacture individual components but instead put various component manufacturers on contract to build that hardware. Some projects reported, for cases in which the valve supplier is multiple sub-tiers (e.g., four levels in some cases) deep, that communication is difficult, not timely, and sometimes resisted by the integrator.

- In some cases, the integrator and valve supplier were the same entity. Instances of difficulty resolving hardware issues were noted when working with a valve supplier through an integrator or manufacturing prime.
    - Program/project respondents indicated they felt they had little or no authority over or input into technical decisions made by the valve supplier. Instead, the authority belonged to the integrator.
    - Others reported that they were made aware of significant valve supplier issues but felt they may not be aware of minor or systemic issues.
    - One notable response indicated that an integrator might choose to accept hardware prior to NASA resolving hardware non-conformances. Understanding the risk or making changes after that initial hardware acceptance by the integrator can result in cost or schedule impacts. The integrator may also try to answer NASA's questions regarding issues without engaging the valve supplier, which can lead to schedule delays.
- There were a significant number of positive responses stating that the program has regular status meetings or technical interchange meetings with the valve supplier. In addition, two programs noted that they were able to gain knowledge of their hardware from other government customers who procured the same design.
- Almost all programs levied D&C requirements on their contract. Roughly half reported pushback from vendors on those requirements.
    - Four programs reported pushback on fracture control requirements in NASA-STD-5019 [ref. 1].
    - Two programs reported pushback on NASA-STD-5017 (Mechanism Design) [ref. 2].
    - Several programs reported pushback on a single requirement (e.g., government mandatory inspection points (GMIPs), number of seals of hazardous propellants, bellows fracture control, bellows best practices guidelines, and materials and processes (M&P) requirements).
- All programs reported flowing qualification and acceptance test requirements on their contract.
    - Several programs indicated tailoring of standards, which enabled elimination of non-value-added testing. In some cases, test elimination was based on a risk-based assessment driven by cost or schedule impacts.
    - The most commonly noted test valve suppliers objected to was acceptance vibration testing.
- There were a significant number of respondents that stated design, construction, and test requirements are needed to minimize or eliminate risk and that these should be flowed to designs regardless of vendor pushback.
- A significant number of respondents indicated they felt their valve suppliers had issues related to limited personnel resources (e.g., skilled technicians, key personnel, engineering support, workload, etc.). This may be a result of the loss of expertise due to competition, retirement, or lack of bandwidth for difficult and intricate designs.
- One respondent stated, "The Orion, Space Launch System, and Commercial Crew Programs are utilizing the same vendors. The design and manufacturing demands on the valve vendors

to meet programs' schedules may be reaching such a pace that leads to more manufacturing mistakes." It can be inferred from this statement that one reason the number of observed valve issues seems higher than normal is that NASA is doing more concurrent design, development, and qualification across multiple parallel programs. Issues are more likely to occur during these design phases than in an operational mode (e.g., Space Shuttle and Expendable Launch Vehicle Programs).

- A significant number of programs reported utilizing "heritage" hardware or hardware with design aspects that could be considered "heritage." Multiple programs reported the use of heritage designs, but only after requalification for new environments. Note: NASA builds one-of-a-kind missions but does not often want to develop new hardware. NASA/vendors often take a heritage design and makes small changes without assessing the impact.

4.2 Department of Commerce Survey

The Department of Commerce completed a thorough survey of the propulsion community in 2017. This was a mandatory government survey for data covering the previous 5 years and was very thorough. The survey topics covered were organizational information, facilities, mergers, acquisitions, joint ventures, propulsion-related products or services, United States (U.S.) government customers, supply chain and sub-tier suppliers, employment, sales, propulsion customer base, research and development spending, financial information, standards/ certifications, additive manufacturing capabilities, capital expenditures, U.S. government contract information, competitiveness/long-term viability, and cyber security. Initially, the survey was sent to approximately 150 companies known to supply propulsion-related products to the U.S. government. A second wave of surveys was then sent to the companies that were identified as sub-tier or major suppliers to the original list of companies. The data are stored on a government computer in the possession of The Aerospace Corporation. Only The Aerospace Corporation has access to the data; thus, retrieving information on the valve vendors required their time and cooperation. The Department of Commerce survey can be viewed in Appendix A. Note that the restrictive notice included in the Survey is used for protection of data entered in a completed form and is not a restriction for the uncompleted form.

The Aerospace Corporation was given the list of approximately 25 vendors that were noted as part of the NASA program/project questionnaire as valve suppliers. This list was broken into two groups: "integrators" and "valve suppliers." A cross-reference exercise was completed, and 11 companies listed as "valve suppliers" participated in the Department of Commerce survey. Almost all companies noted as "integrators" participated in the Department of Commerce survey. Approximately 30 companies stated as part of the Department of Commerce survey that they supplied valves to the U.S. government. The assessment team reviewed the list and noted that several companies were effectively sub-tier suppliers to valve suppliers (e.g., machine shops, plating housings, forging houses, etc.). The team did not review the data from these companies in detail.

The assessment team prioritized specific questions on the Department of Commerce survey, and The Aerospace Corporation extracted the data. In many cases, the data for the valve suppliers or integrators were compared with the overall propulsion supply base that participated in the survey. This aggregate comparison consisted of approximately 350 companies. Key takeaways from the data reviews were:

- Of the approximately 350 respondents to the Department of Commerce survey, more than 200 reported providing direct or indirect support to NASA.

- In terms of support to the U.S. government, valve suppliers noted indirect and direct contracts with NASA.
- In general, for valve vendors, propulsion-related customers make up less than 25% of their total U.S. customer base and generally less than 25% of their total U.S. sales.
- The valve suppliers showed a similar increase in employment numbers compared with the aggregate of all propulsion-related suppliers from 2013 to 2015, but showed a larger increase than the aggregate in 2016.
- The valve vendor employment distribution was similar to the aggregate in terms of age and education level.
- In terms of hiring, the valve vendors noted difficulty with finding engineers with the required skill set.
- In terms of overall sales for the time period from 2013 to 2016:
  - Integrators reported ~25% increase in propulsion-related sales.
  - Integrators reported ~3% increase in NASA sales.
  - On average, NASA as a customer represented ~8 to 12% for the integrators.
  - Valve vendors' propulsion-related sales were generally flat for this time period.
  - On average, NASA as a customer represented ~2% of total sales for the valve suppliers. Note that, for all the numbers, "NASA sales" may not necessarily mean valve-related sales.
- Regarding the top-rated issues reported by the valve suppliers, the nine most negatively reported impacts were:
  - "Government acquisition practices"
  - "Access to USG [U.S. government] R&D [research and development] funding"
  - "Aging equipment, facilities or infrastructure"
  - "Competition - domestic"
  - "Labor skills"
  - "Government regulatory burden"
  - "Labor availability"
  - "Government purchasing volatility"
  - "Skills retention and availability of capital"
- The list of explanations supplied by the valve vendors for their issue rankings was varied. Roughly 100 were reviewed by the assessment team. Notable comments were:
  - "Can't plan more than a year out."
  - "Funding profiles, starts, stops, changes, slips, make predicting and managing expenses difficult."
  - "Startup Space companies are willing to lose significant money while taking market share is difficult to combat while being an established public company."
  - "Extremely difficult to find qualified personnel."
  - "Testing costs can be very expensive, and if there are changes, there are added costs."

- "The U.S. Government needs to bridge propulsion-related products designed within SBIR [Small Business Innovation Research] through development of TRL9 [technology readiness level 9] producible products."
- "Incumbents hold majority of funding; no on-ramps for new, maturing competition; government demands high TRL with flight history, but few chances to mature into flight demonstration."
- "The Government favors legacy cost-plus engine companies over commercial entrants."
- "Gov't acquisition process is complex, and correspondingly slow."

4.3 Vendor Questionnaire

A list of questions specifically for valve suppliers was generated by the assessment team and compiled in a questionnaire. The questionnaire was disseminated to nine suppliers noted in the program surveys as supplying the most valves to NASA. Questionnaire participation by the vendors was low, with only two vendors providing feedback at the writing of this report. Most promised feedback verbally but never followed through, even though there was significant follow-up communication. One vendor stated they wanted to help, but were concerned there would be retaliation for any negative feedback. Despite this, there was notable feedback in the two responses received. A copy of the questionnaire is provided in Appendix B. Notable feedback included:

- Competition for skilled engineers and technicians make finding and hiring talent difficult.
- Top issues/barriers to providing aerospace hardware on schedule and budget were:
  - Requirement iterations (e.g., changing, interpretation, clarification, etc.).
  - Changing performance requirements and timeliness of this adjudication process when there are disagreements between the supplier, the integrator, and NASA SMEs.
  - Technician skill level, coupled with increased engineering oversight from NASA.
  - Contractual requirements. One example noted by vendors was flowing an entire standard as a requirement for earned value management accounting.
  - Timely contractual documentation approval. For example, integrators may require NASA approval for all test procedure and drawing changes, which can stall the design or build process.
- NASA is emphasizing schedule, which can lead to cost, quality, and performance issues.
- When asked whether NASA or integrators are providing inexperienced personnel for program insight or oversight and whether that leads to reduced quality or performance, multiple respondents stated they deal with inexperienced NASA personnel. In general, the larger the project, the more prevalent this response. The impact is not in the quality or performance of the hardware, but rather in the cost and schedule for the product. This is due to having to provide additional data for understanding, feedback on the implications of requirements, or explanations of design aspects prior to receiving approval to proceed.
- The vendors supplied recommendations on how NASA could improve the way it does business. Those recommendations were:
  - Ease contractual requirements and flow downs for small programs. Typically, NASA flows the same standards and requirements to vendors, regardless of program size.

- Improve requirements definition at the project inception. In many cases, NASA flows entire documents as requirements, and it is up to the vendor to create compliance matrices for third-, fourth-, or fifth-tier requirements that all may require tailoring specifically for a valve. The military does a better job of defining requirements for new hardware. There does not appear to be much difference in defining requirements from Center to Center. NASA does a better job of defining requirements for heritage hardware than for new designs.

- Multiple respondents noted concern with NASA's handling of Intellectual Property. One company stated they require personal nondisclosure agreements (civil servant or support contractor) or they will not share detailed design data with NASA. Another stated that detailed design information often ends up in *American Institute of Aeronautics and Astronautics* (AIAA) or Joint Army-Navy-NASA-Air Force (JANNAF) papers without the consent of the valve supplier. Consent may not have been pursued to any level, or the integrator may have granted consent without requesting permission from the valve vendor.
- Multiple respondents noted that research and development (R&D) is driven primarily by sales.

5.0 Conclusions

Although strain was noted by several aerospace valve suppliers, the industry as a whole does not appear to be in decline. Newer companies and suppliers new to aerospace applications appear to be prospering. Financial data reviewed for the valve suppliers that participated in the Department of Commerce survey indicated growth. The recent valve-component-related issues experienced on NASA programs may be attributed to multiple factors. First, NASA is developing multiple programs in parallel through stages of program life requiring concurrent development, qualification, manufacturing, and proper application of a large number of unique valve designs. This industry was primarily dormant with respect to NASA's needs during the last years of the Space Shuttle Program. However, since 2011, NASA and the aerospace propulsion industry have inundated the market with work in support of new programs. Valve issues at these stages of the development cycle are more likely and may seem excessive in number, especially when compared with the rates observed near the end of the Space Shuttle Program while NASA was in a sustaining engineering mode for similar hardware. Further, new aerospace companies are supplying valves to NASA, and these emerging companies may be experiencing issues as they establish their design base and manufacturing processes to meet NASA valve requirements. From the assessment team's perspective, the aerospace valve supplier base appears to be growing.

The Department of Commerce survey collected data on a significant number of propulsion hardware suppliers. Valves are the first category of specific hardware for which a deep dive was performed using this data. Prior to this activity, the data were only viewed as the aggregate of all propulsion hardware suppliers. The data are extremely thorough, covering 2013 to 2016. However, this date has a finite shelf life.

A common issue noted in the program survey was the number of sub-tiers between NASA program management and valve suppliers. Typically, integrators are used for NASA programs, and valve suppliers may be several contractual layers removed from NASA. This may be unavoidable, but it was evident that this structure is a major source of frustration, cost and

schedule effects, and, in some cases, added or unknown program risks. Several respondents indicated this structure, if not controlled by the program, can result in the integrator having sole knowledge and control over valve-component-related issues.

All programs flow test requirements for valves to their suppliers. In most cases, tailoring of the requirements was required. The program/project survey indicated that the most pushback for any single type of test was in regard to acceptance vibration testing. Vendors and NASA disagree on the validity of acceptance vibration testing as a workmanship screen. The program survey indicated in most cases that engineering support felt the test was value-added for a majority of valve types or designs. This pushback may be due to the cost and lead time of vibration testing.

Programs reported pushback from valve vendors on D&C requirements. NASA-STD-5019, NASA-STD-5017, and SMC-S-016 [refs. 1-3] were the only standards specifically identified. However, other specifications and standards are suspected by NASA to be of vender concern. Vendor feedback indicated that NASA could do a better job specifying requirements in performance standards so that the intent is clarified at program inception.

6.0 Findings, Observations, and NESC Recommendations

6.1 Findings

The following findings were identified:

F-1. Although problems were noted with a few aerospace valve suppliers, the industry as a whole does not appear to be in decline. In fact, newer companies, or suppliers new to aerospace applications, appear to be prospering.

F-2. Some of the recent NASA valve-component-related issues can be attributed to NASA and other organizations fielding a large number of new flight systems requiring the simultaneous development, qualification, manufacture, and proper application of many unique valve designs on a compressed schedule.

F-3. Sub-tier separation between NASA and valve-component suppliers can result in increased cost, delayed schedule, delivery, and unrecognized risks.

F-4. System integrators, who often have sole knowledge and control over valve-component-related issues, may not be communicating these issues and resolutions to NASA programs/projects.

F-5. NASA and many vendors disagree on the validity of acceptance vibration testing as a workmanship screen.

F-6. Programs report pushback from valve-component vendors on D&C requirements.

F-7. Multiple vendor respondents noted concern with NASA's handling of intellectual property.

F-8. Component suppliers are having issues finding qualified personnel to design, build, and test the designs required for NASA's challenging missions.

F-9. The valve suppliers showed a similar increase in employment numbers compared with the aggregate of all propulsion-related suppliers from 2013 to 2015, but showed a larger increase than the aggregate in 2016.

6.2 Observations

The following observations were identified:

O-1. The Department of Commerce survey collected data on a significant number of propulsion hardware suppliers from 2013 to 2016.

O-2. One vendor stated they wanted to help, but did not reply to the NASA questionnaire because they were concerned there could be retaliation for negative feedback.

6.3 NESC Recommendations

The following NESC recommendations are directed to the OCE:

R-1. Determine the applicability of acceptance vibration testing for valve-component designs. ***(F-5)***

R-2. Assess the need for a valve-specific D&C standard. ***(F-5)***

R-3. Mine the Department of Commerce survey data for any other specific component types (e.g., bellows or COPVs) for which there is a concern that the supplier base is in decline or is limited to a small number of companies. ***(O-1)***

7.0 Lessons Learned

The following lessons learned during this assessment are more broadly applicable and will be entered into the NASA Lessons Learned Information System (LLIS).

- Conduct any future vendor surveys through an intermediary to address vendor concerns regarding retaliation for providing negative feedback.
- Review program/project contractual language to address the perceived lack of communication between NASA and sub-tier vendors.

8.0 Recommendations for NASA Standards and Specifications

Assess the need to develop a valve-specific NASA D&C standard.

9.0 Definition of Terms

Corrective Actions	Changes to design processes, work instructions, workmanship practices, training, inspections, tests, procedures, specifications, drawings, tools, equipment, facilities, resources, or material that result in preventing, minimizing, or limiting the potential for recurrence of a problem.
Finding	A relevant factual conclusion and/or issue that is within the assessment scope and that the team has rigorously based on data from their independent analyses, tests, inspections, and/or reviews of technical documentation.
Lessons Learned	Knowledge, understanding, or conclusive insight gained by experience that may benefit other current or future NASA programs and projects. The

	experience may be positive, as in a successful test or mission, or negative, as in a mishap or failure.
Observation	A noteworthy fact, issue, and/or risk, which may not be directly within the assessment scope, but could generate a separate issue or concern if not addressed. Alternatively, an observation can be a positive acknowledgement of a Center/Program/Project/Organization's operational structure, tools, and/or support provided.
Problem	The subject of the independent technical assessment.
Proximate Cause	The event(s) that occurred, including any condition(s) that existed immediately before the undesired outcome, directly resulted in its occurrence and, if eliminated or modified, would have prevented the undesired outcome.
Recommendation	A proposed measurable stakeholder action directly supported by specific Finding(s) and/or Observation(s) that will correct or mitigate an identified issue or risk.
Root Cause	One of multiple factors (events, conditions, or organizational factors) that contributed to or created the proximate cause and subsequent undesired outcome and, if eliminated or modified, would have prevented the undesired outcome. Typically, multiple root causes contribute to an undesired outcome.
Supporting Narrative	A paragraph, or section, in an NESC final report that provides the detailed explanation of a succinctly worded finding or observation. For example, the logical deduction that led to a finding or observation; descriptions of assumptions, exceptions, clarifications, and boundary conditions.

10.0 References

1. "Fracture Control Requirements for Spaceflight Hardware," NASA-STD-5019, Revision A with Change 2, March 29, 2018.
2. "Design and Development Requirements for Mechanisms," NASA-STD-5017, Revision A with Change 1, May 31, 2016.
3. Air Force Space Command, "Space and Missile Systems Center Standard: Test Requirements for Launch, Upper-Stage and Space Vehicles," SMC-S-016, September 5, 2014.

Appendix A. Department of Commerce Propulsion Industry Base Survey

NOTE: The restrictive notice included in the Survey is used for protection of data entered in a completed form and is not a restriction for the uncompleted form.

OMB Control Number: 0694-0119
Expiration Date: 12/31/2017

U.S. ROCKET PROPULSION INDUSTRIAL BASE ASSESSMENT:
Propulsion Survey

SCOPE OF ASSESSMENT

The U.S. Department of Commerce, Bureau of Industry and Security (BIS), Office of Technology Evaluation, in coordination with the National Aeronautics and Space Administration (NASA) and U.S. Department of Defense co-chaired Joint Army, Navy, NASA, Air Force Interagency Propulsion Committee (JANNAF) is conducting a survey and assessment of organizations responsible for researching, designing, engineering, developing, manufacturing, testing, and integrating of rocket propulsion-related products, and services. The principal goal of this assessment is to gain an understanding of the intricate supply chain network supporting the development, production, and sustainment of products and services across both the U.S. Government and commercial propulsion-related sectors. With the data collected in this survey, U.S. Government agencies will be better informed and able to develop targeted planning, acquisition, and investment strategies to ensure industry's ability to support critical defense and civil missions and programs.

RESPONSE TO THIS SURVEY IS REQUIRED BY LAW

A response to this survey is required by law (50 U.S.C. App. Sec. 2155). Failure to respond can result in a maximum fine of $10,000, imprisonment of up to one year, or both. Information furnished herewith is deemed confidential and will not be published or disclosed except in accordance with Section 705 of the Defense Production Act of 1950, as amended (50 U.S.C App. Sec. 2155). Section 705 prohibits the publication or disclosure of this information unless the President determines that its withholding is contrary to the national defense. Information will not be shared with any non-government entity, other than in aggregate form. The information will be protected pursuant to the appropriate exemptions from disclosure under the Freedom of Information Act (FOIA), should it be the subject of a FOIA request.

Notwithstanding any other provision of law, no person is required to respond to, nor shall a person be subject to a penalty for failure to comply with a collection of information subject to the requirements of the Paperwork Reduction Act unless that collection of information displays a currently valid OMB Control Number.

BURDEN ESTIMATE AND REQUEST FOR COMMENT

Public reporting burden for this collection of information is estimated to average 14 hours per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information to BIS Information Collection Officer, Room 6883, Bureau of Industry and Security, U.S. Department of Commerce, Washington, D.C. 20230, and to the Office of Management and Budget, Paperwork Reduction Project (OMB Control No. 0694-0119), Washington, D.C. 20503.

BUSINESS CONFIDENTIAL - Per Section 705(d) of the Defense Production Act

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Important Note:
The drop-down menus in several sections are based on your responses in earlier sections, or earlier parts of the same section.

In order for all menus to work properly, the survey should be completed in order. If a drop-down menu appears to be empty, confirm that you have filled out the relevant prior sections of the survey.

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Section I: General Instructions	
A.	Your organization is required to complete this survey using an Excel template, which can be downloaded from the U.S. Department of Commerce Census Bureau Survey Portal. For your convenience, a PDF version of the survey is available to aid your internal data collection. DO NOT submit the PDF version of your organization's response to the U.S. Department of Commerce, Bureau of Industry and Security (BIS). To access the Survey Portal, visit: https://www.bis.doc.gov/propulsion
B.	Each survey section should be completed consistently at the same reporting level (Corporate/Whole Organization or Business Unit/Division). If you have any questions regarding the level of your organization's response, call (202) 482-3808.
C.	Respond to every question. Surveys that are not fully completed will be returned for completion. Use the comment boxes, as necessary, to supplement any responses to the individual survey questions. Make sure to record a complete answer in the cell provided, even if the cell does not appear to expand to fit all the information. DO NOT CUT AND PASTE RESPONSES WITHIN THIS SURVEY. Survey inputs must be entered by typing in responses or by using a drop-down menu. The use of cut and paste can corrupt the survey template. If your survey response is corrupted as a result of cut and paste responses, a new survey can be downloaded from the Census Bureau Survey Portal for immediate completion.
D.	**DO NOT disclose any classified information in this survey form.**
E.	Estimates are often acceptable, but in sections that do not explicitly allow estimates you must contact BIS survey support staff before including estimates.
F.	Questions related to this Excel survey should be directed to: PropulsionSurvey@bis.doc.gov You may also speak with a member of BIS survey support staff by calling (202) 482-3808.
G.	After completing, reviewing, and certifying the Excel survey, submit the survey via our Census Bureau Survey Portal, available via the BIS survey website: https://www.bis.doc.gov/propulsion DO NOT submit the survey via email.
H.	For questions related to the overall scope of this Defense Industrial Base assessment, contact: Brad Botwin, Director, Industrial Studies Office of Technology Evaluation, Room 1093 U.S. Department of Commerce 1401 Constitution Avenue, NW Washington, DC 20230 PropulsionSurvey@bis.doc.gov DO NOT submit completed surveys to Mr. Botwin's postal or e-mail address. All surveys must be submitted electronically via the Census Bureau Survey Portal, available via the BIS website: https://www.bis.doc.gov/propulsion

Section II: Definitions

See definitions below. Extended definitions are available at: https://respond.census.gov/static/nasa/Propulsion-Extended-Glossary.pdf.

Term	Definition
Applied Research	A systematic study to gain knowledge or understanding necessary to determine the means by which a recognized and specific need may be met. This activity includes work leading to the production of useful materials, devices, and systems or methods, including design, development, and improvement of prototypes and new processes.
Authorizing Official	An executive officer of the organization or business unit or other individual who has the authority to execute this survey on behalf of the organization.
Basic Research	A systematic, scientific study directed toward greater knowledge or understanding of the fundamental aspects of phenomena and of observable facts.
Commercial and Government Entity (CAGE) Code	A numbering system that identifies companies doing or wishing to do business with the U.S. Federal Government. The code is used to support mechanized government systems and provides a standardized method of identifying a given facility at a specific location. Find CAGE codes at: https://cage.dla.mil/search/
Commercially Sensitive Information (CSI)	Privileged or proprietary information which, if compromised through alternation, corruption, loss, misuse, or unauthorized disclosure, could cause serious harm to the organization owning it. This includes customer/client information, financial information and records, human resources information, intellectual property information, internal communications, manufacturing and production line information, patent and trademark information, research and development information, regulatory/compliance information, and supplier/supply chain information.
Counterfeit	For the purpose of this survey, a counterfeit is a part, material, or other product that is not genuine because it 1) is an unauthorized copy; 2) does not conform to original design, model, and/or performance standards; 3) is not produced by the original manufacturer or is produced by unauthorized contractors; 4) is off-specification, defective, or used product sold as "new" or working; or 5) has incorrect or false markings and/or documentation.
Customer	An entity to which an organization directly delivers the product or service that the facility produces. A customer may be another company or another facility owned by the same parent organization. The customer may be the end user for the item but often will be an intermediate link in the supply chain, adding additional value before transferring the item to yet another customer.
Cyber Security	The body of technologies, processes, and practices designed to protect networks, computers, programs, and data from attack, damage, or unauthorized access.
Data Universal Numbering System (DUNS)	A nine-digit numbering system that uniquely identifies an individual business. Find DUNS numbers at: https://iupdate.dnb.com/iUpdate/viewiUpdateHome.htm
Electric Propulsion	Propulsion Industrial Base Segment including: electric propulsion systems with unique applications with low thrusts, low accelerations, and trajectories exclusively in space, high specific impulse, long operating times, and generally a relatively massive power supply system, organized into three basic types, electro thermal rocket propulsion (resembles the chemical rocket units), electrostatic or ion propulsion engine, and the electromagnetic or magneto plasma engine. Includes TRL 6 and above.
Facility	A building or the minimum complex of buildings or parts of buildings in which a company operates to serve a particular function, producing revenue, and incurring costs for the company. A facility may produce an item of tangible or intangible property or may perform a service. It may encompass a floor or group of floors within a building, a single building, or a group of buildings or structures. Often, a facility is a group of related locations at which company employees work, together constituting a profit-and-loss center for the company, and it may be identified by a unique DUNS number.
Full Time Equivalent (FTE) Employees	Employees who work for 40 hours in a normal work week. Convert part-time employees into "full time equivalents" by taking their work hours as a fraction of 40 hours.
Large Liquid Propulsion	Propulsion Industrial Base Segment including: larger chemical liquid propulsion systems and all engines with turbopumps (not including structural tanks, but including the features of the main propulsion system that reside in the tanks, as well as booster stages, upper stages, in-space transit stages, propellant, and pressurant). Includes TRL 6 and above.
Large Solid Rocket Motor	Propulsion Industrial Base Segment including: solid rocket motors that are typically characterized by large diameter (e.g. 40" and larger) requiring more than one mix to cast a single motor and relatively limited production rate. Includes TRL 6 and above.
North American Industry Classification System (NAICS) Code	Numbering system that identifies the category of product(s) or service(s) provided by an organization. Find NAICS codes at: http://www.census.gov/epcd/www/naics.html
Product/Process Development	Conceptualization and development of a product prior to the production of the product for customers.
Program Technology Transfer Activity	Agency and program initiatives to manage technology throughout the agency, program, and/or outside organizations. For example, the NSA Technology Transfer Program transfers NSA-developed technology to industry, academia, and other research organizations, benefitting the economy and the Agency mission. The program has an extensive portfolio of patented technologies across multiple technology areas. Another example includes the DHS Science & Technology - Technology Transfer Program Office, which serves as the centralized office to manage technology transfer throughout DHS and the DHS laboratory network. Technologies developed and evaluated within the department can have tremendous potential for commercial applications throughout the nation, enhance the competitiveness of individual small businesses, as well as expand areas of exploration and cooperation for all non-federal partners. Find more information about NSA's program at: https://www.nsa.gov/what-we-do/research/technology-transfer/ Find more information about DHS' program at: https://www.dhs.gov/science-and-technology/technology-transfer-program

Propulsion-related	Any activity/component/subsystem/test/product/service that contributes to U.S. Government or Commercial propulsion systems (including the propulsion of a launch vehicle, missile, and in-space spacecraft propulsion). The activity/component/subsystem/test/product/service does not have to be specifically intended to support propulsion applications.
Research & Development (R&D)	All efforts of scientific study and experimentation, theoretical work, and original investigation undertaken primarily to acquire new knowledge or understanding of the underlying foundations of phenomena and observable facts, including the creative and systematic application of knowledge with specific practical aim or objective or the production of useful materials, devices, and systems or methods. Comprises such efforts at all levels (basic, applied, design, etc.), including the design, development, and improvement of prototypes and new processes to meet specific requirements.
Science and Technology (S&T)	Propulsion Industrial Base Segment including: all propulsion-related S&T research & development activities at TRL 5 and below (including engineering services).
Service	An intangible product (contrasted to a good, which is a tangible product). Services typically cannot be stored or transported, are instantly perishable, and come into existence at the time they are bought and consumed.
Single Source	An organization that is designated as the only accepted source for the supply of parts, components, materials, or services, even though other sources with equivalent technical know-how and production capability may exist.
Small Business Innovation Research (SBIR) Contracts	A highly competitive program that encourages domestic small businesses to engage in Federal Research/Research and Development (R/R&D) that has the potential for commercialization. Through a competitive awards-based program, SBIR enables small businesses to explore their technological potential and provides the incentive to profit from its commercialization. By including qualified small businesses in the nation's R&D arena, high-tech innovation is stimulated and the United States gains entrepreneurial spirit as it meets its specific research and development needs. Find more information about SBIR at: https://www.sbir.gov/about/about-sbir
Small Business Technology Transfer (STTR) Contracts	A program that expands funding opportunities in the federal innovation research and development (R&D) arena. Central to the program is expansion of the public/private sector partnership to include the joint venture opportunities for small businesses and nonprofit research institutions. The unique feature of the STTR program is the requirement for the small business to formally collaborate with a research institution in Phase I and Phase II. STTR's most important role is to bridge the gap between performance of basic science and commercialization of resulting innovations. Find more information about STTR at: https://www.sbir.gov/about/about-sttr#three
Small Liquid Propulsion	Propulsion Industrial Base Segment including: small chemical liquid propulsion systems, pressure-fed engines, and spacecraft propulsion (including the entire propulsion system, to include pressurant and propellant tanks, flow-control components, dedicated sensors, and engines). Includes TRL 6 and above.
Small Solid Rocket Motor	Propulsion Industrial Base Segment including: solid rocket motors typically characterized by small diameter (e.g. 40" and smaller) allowing casting of multiple motors from a single mix and relatively limited production rate). Includes TRL 6 and above.
Sole Source	An organization that is the only source for the supply of parts, components, materials, or services. No alternative U.S. or non-U.S. based suppliers exist other than the current supplier.
STEM	STEM is the acronym for Science, Technology, Engineering and Mathematics.
Supplier	An entity from which your organization obtains inputs. A supplier may be another organization with which you have a contractual relationship, or it may be another facility owned by the same parent organization. The inputs may be goods or services.
Technology Readiness Level (TRL)	Each level estimates the maturity of technology of a program during the acquisition process. TRL 1, for example, indicates the transition from scientific research to applied research and TRL 9 indicates a fully integrated product with operational hardware/software systems. Full descriptions of each TRL are located here: https://esto.nasa.gov/files/trl_definitions.pdf
Test and Evaluation (T&E)	Propulsion Industrial Base Segment including: government and non-governmental test facilities and test capabilities applied to specific engine/motor components, engine/motor subsystems, and the entire stage (engines, propellant tanks, avionics, etc.). Covering test and evaluation of activities TRL 6 and above.
United States	The "United States" or "U.S." includes the 50 states, Puerto Rico, the District of Columbia, the island of Guam, the Trust Territories, and the U.S. Virgin Islands.
Utilization Rate	The percent of an organization's potential output that is actually being used in current production, where potential output is based on a 7 day-a-week, 3x8-hour shift production schedule. Note: 100% utilization rate equals no downtime with full employment.

Section 1a: Organization Information

This survey has been distributed on a Corporate/Whole Organization basis or a Business Unit/Division basis and should be completed at the requested level. The entire survey document should be completed consistently at the same level (Corporate/Whole Organization or Business Unit/Division). In the box to the right, confirm whether this survey represents a response for your Corporate/Whole Organization or an individual Business Unit/Division.

Corporate/Whole Organization
Business Unit/Division

A.	Provide the following information for your organization (at the level of reporting). If not applicable, write "N/A"	
	Organization Name	
	Business Unit/Division Name (if applicable)	
	Street Address	
	City	
	State	
	Zip Code	
	Website	
	Phone Number	
	Primary Data Universal Numbering System (DUNS) Code (associated with the response level) (https://iupdate.dnb.com/iUpdate/viewiUpdateHome.htm)	
	Primary CAGE Code (associated with the response level)	
	Is your organization publicly traded or privately held?	
	If your organization is publicly traded, identify its stock ticker symbol:	
	Percent of business equity owned by a non-U.S. entity:	
	Primary Non-U.S. Ownership Entity Name:	Country: / Percent:
	Secondary Non-U.S. Ownership Entity Name:	Country: / Percent:

Publicly Traded
Privately Held

B.	Does your organization have a parent company?		If yes, provide the following information for your parent organization(s):
		Parent Organization 1	Parent Organization 2
	Parent Organization Name		
	Street Address		
	City		
	State/Province		
	Zip/Postal Code		
	Country		
	Phone Number		
	Primary DUNS Code		
	Primary CAGE Code (If not applicable, write N/A)		
	Is your parent organization(s) publicly traded or privately held?		
	If parent is publicly traded, identify its stock ticker symbol.		
C.	Country in which your organization is headquartered:		
	U.S. subsidiary of a non-U.S. parent company:		
	Business unit or division of a U.S. parent company or organization:		

Yes / No

D.	Does your organization qualify as any of the following business types?	If yes, indicate which types:
	A small business enterprise (as defined by the Small Business Administration)	
	An 8(a) Firm (as defined by the Small Business Administration).	
	A historically underutilized business zone (HUBZone)	
	A minority-owned business	
	A woman-owned business	
	A veteran-owned or service-disabled veteran owned business	

Yes / No

E.	Point of Contact regarding this survey:				
	Name	Title	Phone Number	E-mail Address	State

Comments:	

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Section 1b: Organization Information (Cont.)

A. Provide the following propulsion-related identification codes for your organization, as applicable. If your organization has additional codes to report, ensure that the primary codes are entered in the boxes provided and include the additional codes in the Comments box at the bottom of this section.

Propulsion-related PSC Codes		Product and Service Code(s) (PSC) are federal supply codes used by the United States Government to describe the products, services, and research and development purchased by the government. NOTE: If your organization has government relationships that appear on Tabs 5a or 16, PSCs are required here. Find PSC Code(s) at: https://www.acquisition.gov/PSC_Manual
Propulsion-related HTS (10-digit) code(s)		The Harmonized Tariff Schedule (HTS) is the primary resource for determining tariff (customs duties) classifications for goods imported into the United States. NOTE: If your organization has foreign relationships that appear on Tabs 9 or 10, HTS codes are required here. If your organization has exports which are not propulsion-related, please explain in the comment box. The 10-digit HTS codes can be found in the "HTS Online Resource Tool" located under "Research Tools" at: https://hts.usitc.gov/
Propulsion-related NAICS (6-digit) Code(s)		North American Industry Classification System (NAICS) codes identify the category of product(s) or service(s) provided by your company. Find NAICS codes at: https://www.census.gov/eos/www/naics/

B. For all the categories that describe your organization's business type(s), indicate "Primary" for your primary business type or "Additional" for any other business types, based on current revenue contribution. Then indicate whether or not your participation in each selected business type is in a propulsion-related capacity and explain. This part must be completed before Section 1c, Part A.

Business Type	Participation	Propulsion-related?	Explain
Distributor			
Holding Company			
Laboratory			
Manufacturer			
Non-profit			
Prototype Manufacturer			
Research and Development			
Service Provider			
Testing Facility			
Other (specify)			

Participation: Primary, Additional

Propulsion-related?: Propulsion, Non-propulsion, Both, Not Applicable

Comments:

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Section 1c: Organization Information (Cont.)

For your organization's propulsion-related business lines, select your primary involvement for each propulsion industrial base business category. Drop-down menu options are based on the answers provided in Section 1b, Part B. Include all selected business types from Section 1b, Part B below. If "Other" propulsion industrial base business category is selected, explain in the comments box.

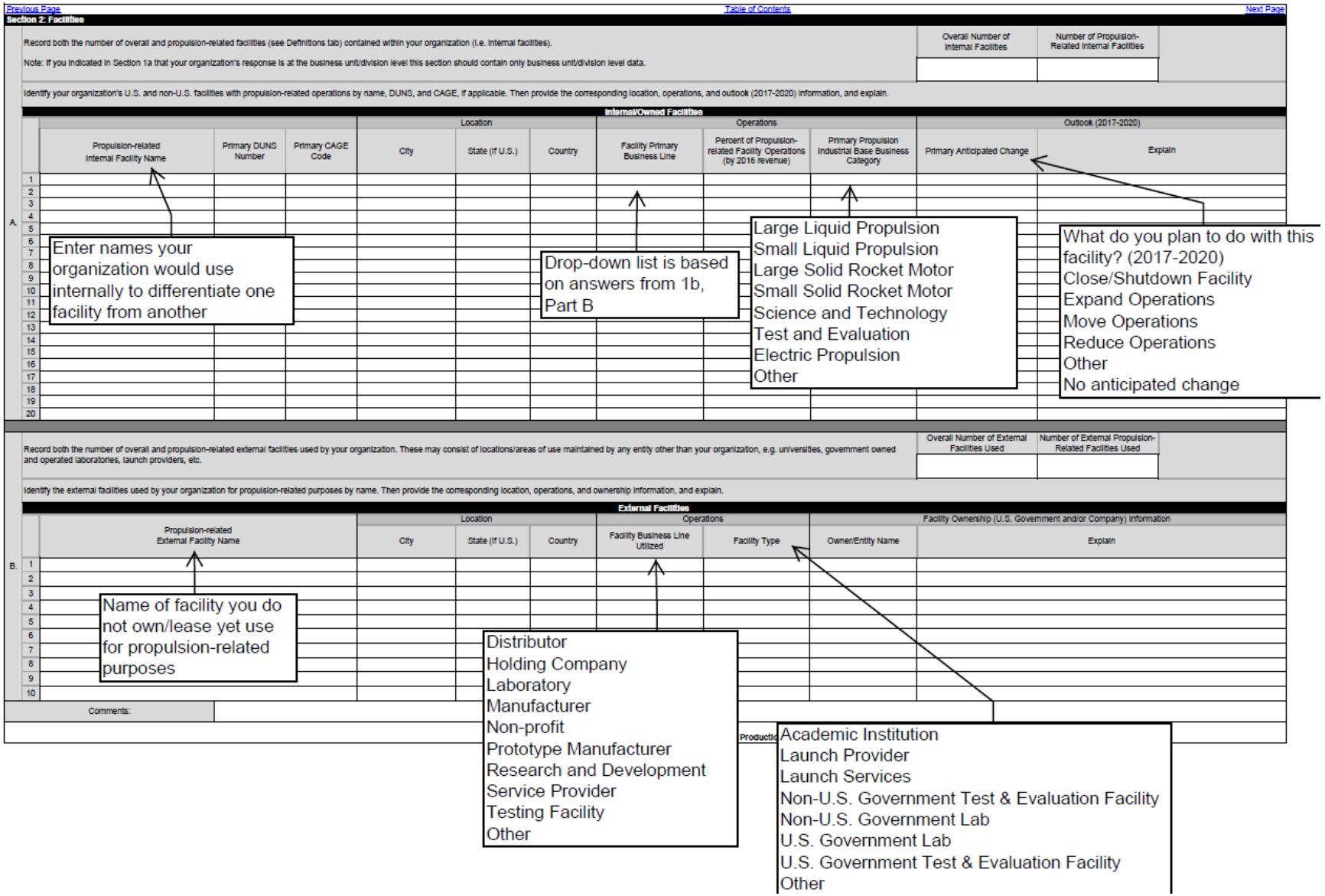
Note: A blank entry means no participation.

A.

Propulsion-Related Business Line	Propulsion Industrial Base Business Category							
	Large Liquid Propulsion	Small Liquid Propulsion	Large Solid Rocket Motor	Small Solid Rocket Motor	Science and Technology	Test and Evaluation	Electric Propulsion	Other
Composite materials								
Composite materials processing								
Electrical systems								
Engineering services								
Fabrication, (sub)system assembly								
Instrumentation, sensors, transducers								
Insulation								
Interconnects, fasteners, standards, seals								
Launch services								
Liquid propellant material								
Machining								
Maintenance/aftermarket/repair/refurbishing services								
Material preparation (casting, forming, molding, forging, additive manufacturing, etc.)								
Material processing/finishing (coating, plating, heat treating, etc.)								
Mechanical controls								
Ordnance/Ignition components or systems								
Prototyping								
Raw material provider								
Research and development								
Solid propellant material								
System integration								
Test equipment								
Testing services								
Other (specify)								
Other (specify)								
Other (specify)								

Drop-down list based on responses in 1b, Part B:
- Distributor
- Holding Company
- Laboratory
- Manufacturer
- Non-profit
- Prototype Manufacturer
- Research and Development
- Service Provider
- Testing Facility
- Other

Comments: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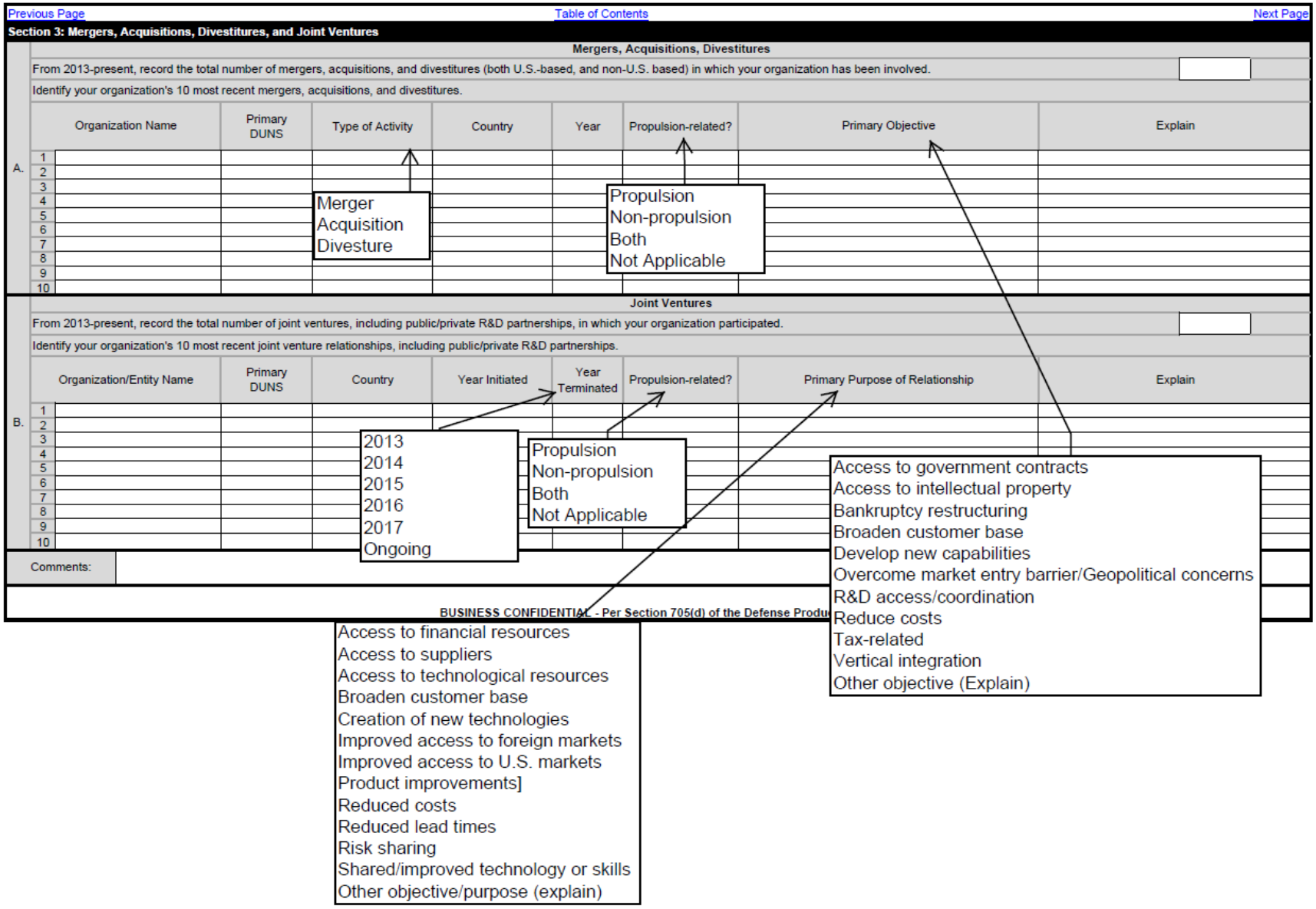
Section 2: Facilities
Record both the number of overall and propulsion-related facilities (see Definitions tab) contained within your organization (i.e. internal facilities).
Note: If you indicated in Section 1a that your organization's response is at the business unit/division level this section should contain only business unit/division level data.
Overall Number of Internal Facilities
Number of Propulsion-Related Internal Facilities
Identify your organization's U.S. and non-U.S. facilities with propulsion-related operations by name, DUNS, and CAGE, if applicable. Then provide the corresponding location, operations, and outlook (2017-2020) information, and explain.
Internal/Owned Facilities
Location
Operations
Outlook (2017-2020)
Propulsion-related Internal Facility Name
Primary DUNS Number
Primary CAGE Code
City
State (If U.S.)
Country
Facility Primary Business Line
Percent of Propulsion-related Facility Operations (by 2016 revenue)
Primary Propulsion Industrial Base Business Category
Primary Anticipated Change
Explain
A.
Enter names your organization would use internally to differentiate one facility from another
Drop-down list is based on answers from 1b, Part B
Large Liquid Propulsion
Small Liquid Propulsion
Large Solid Rocket Motor
Small Solid Rocket Motor
Science and Technology
Test and Evaluation
Electric Propulsion
Other
What do you plan to do with this facility? (2017-2020)
Close/Shutdown Facility
Expand Operations
Move Operations
Reduce Operations
Other
No anticipated change
Record both the number of overall and propulsion-related external facilities used by your organization. These may consist of locations/areas of use maintained by any entity other than your organization, e.g. universities, government owned and operated laboratories, launch providers, etc.
Overall Number of External Facilities Used
Number of External Propulsion-Related Facilities Used
Identify the external facilities used by your organization for propulsion-related purposes by name. Then provide the corresponding location, operations, and ownership information, and explain.
External Facilities
Location
Operations
Facility Ownership (U.S. Government and/or Company) Information
Propulsion-related External Facility Name
City
State (If U.S.)
Country
Facility Business Line Utilized
Facility Type
Owner/Entity Name
Explain
B.
Name of facility you do not own/lease yet use for propulsion-related purposes
Distributor
Holding Company
Laboratory
Manufacturer
Non-profit
Prototype Manufacturer
Research and Development
Service Provider
Testing Facility
Other
Academic Institution
Launch Provider
Launch Services
Non-U.S. Government Test & Evaluation Facility
Non-U.S. Government Lab
U.S. Government Lab
U.S. Government Test & Evaluation Facility
Other
Comments: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Section 3: Mergers, Acquisitions, Divestitures, and Joint Ventures
Mergers, Acquisitions, Divestitures
From 2013-present, record the total number of mergers, acquisitions, and divestitures (both U.S.-based, and non-U.S. based) in which your organization has been involved.
Identify your organization's 10 most recent mergers, acquisitions, and divestitures.
Organization Name
Primary DUNS
Type of Activity
Country
Year
Propulsion-related?
Primary Objective
Explain
A.
Merger
Acquisition
Divesture
Propulsion
Non-propulsion
Both
Not Applicable
Joint Ventures
From 2013-present, record the total number of joint ventures, including public/private R&D partnerships, in which your organization participated.
Identify your organization's 10 most recent joint venture relationships, including public/private R&D partnerships.
Organization/Entity Name
Primary DUNS
Country
Year Initiated
Year Terminated
Propulsion-related?
Primary Purpose of Relationship
Explain
B.
2013
2014
2015
2016
2017
Ongoing
Propulsion
Non-propulsion
Both
Not Applicable
Access to government contracts
Access to intellectual property
Bankruptcy restructuring
Broaden customer base
Develop new capabilities
Overcome market entry barrier/Geopolitical concerns
R&D access/coordination
Reduce costs
Tax-related
Vertical integration
Other objective (Explain)
Comments:
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Access to financial resources
Access to suppliers
Access to technological resources
Broaden customer base
Creation of new technologies
Improved access to foreign markets
Improved access to U.S. markets
Product improvements]
Reduced costs
Reduced lead times
Risk sharing
Shared/improved technology or skills
Other objective/purpose (explain)

Section 4a: Propulsion-related Products and Services

For each general propulsion-related product and service category, indicate whether or not your organization currently participates.

This broad category listing contains links to specific product and service types in Section 4b. Product and Service Category selections in Section 4a must reconcile with propulsion-related Product and Service Type declarations recorded in Section 4b.

Indicate all general categories associated with your organization's propulsion-related products and services.

Part	Product and Service Category	Participation
A	Electrical, Ignition, and Control	
B	Manufactured Components	
C	Production Techniques	Yes/No
D	Propellants and Other Materials	
E	Systems and Services	
F	Other	

Comments:	

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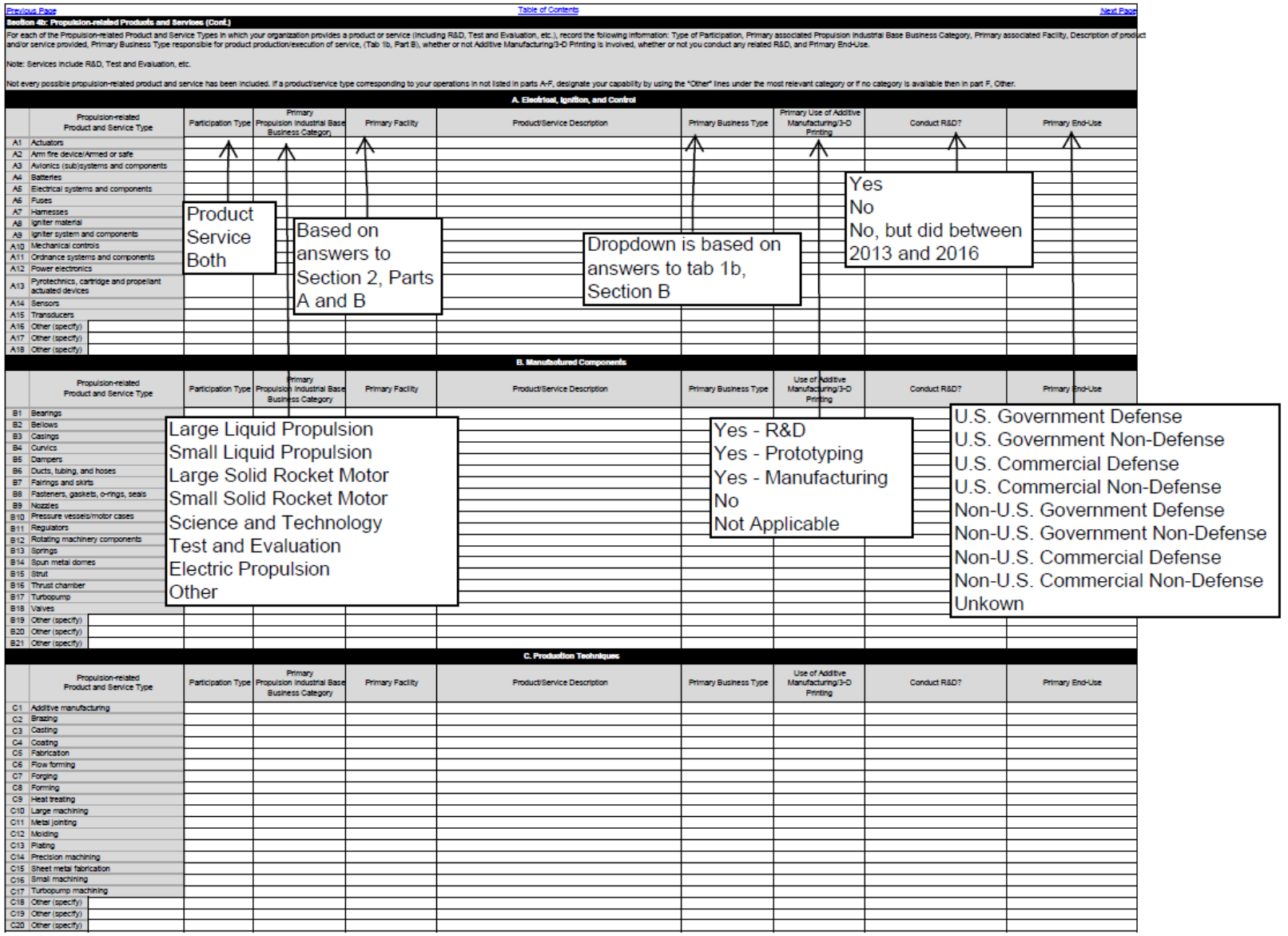
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Section 4b: Propulsion-related Products and Services (Cont.)
For each of the Propulsion-related Product and Service Types in which your organization provides a product or service (including R&D, Test and Evaluation, etc.), record the following information: Type of Participation, Primary associated Propulsion Industrial Base Business Category, Primary associated Facility, Description of product and/or service provided, Primary Business Type responsible for product production/execution of service, (Tab 1b, Part B), whether or not Additive Manufacturing/3-D Printing is involved, whether or not you conduct any related R&D, and Primary End-Use.
Note: Services include R&D, Test and Evaluation, etc.
Not every possible propulsion-related product and service has been included. If a product/service type corresponding to your operations in not listed in parts A-F, designate your capability by using the "Other" lines under the most relevant category or if no category is available then in part F, Other.
A. Electrical, Ignition, and Control
Propulsion-related Product and Service Type
Participation Type
Primary Propulsion Industrial Base Business Category
Primary Facility
Product/Service Description
Primary Business Type
Primary Use of Additive Manufacturing/3-D Printing
Conduct R&D?
Primary End-Use
A1 Actuators
A2 Arm fire device/Armed or safe
A3 Avionics (sub)systems and components
A4 Batteries
A5 Electrical systems and components
A6 Fuses
A7 Harnesses
A8 Igniter material
A9 Igniter system and components
A10 Mechanical controls
A11 Ordnance systems and components
A12 Power electronics
A13 Pyrotechnics, cartridge and propellant actuated devices
A14 Sensors
A15 Transducers
A16 Other (specify)
A17 Other (specify)
A18 Other (specify)
Product
Service
Both
Based on answers to Section 2, Parts A and B
Dropdown is based on answers to tab 1b, Section B
Yes
No
No, but did between 2013 and 2016
B. Manufactured Components
Propulsion-related Product and Service Type
Participation Type
Primary Propulsion Industrial Base Business Category
Primary Facility
Product/Service Description
Primary Business Type
Use of Additive Manufacturing/3-D Printing
Conduct R&D?
Primary End-Use
B1 Bearings
B2 Bellows
B3 Castings
B4 Curvics
B5 Dampers
B6 Ducts, tubing, and hoses
B7 Fairings and skirts
B8 Fasteners, gaskets, o-rings, seals
B9 Nozzles
B10 Pressure vessels/motor cases
B11 Regulators
B12 Rotating machinery components
B13 Springs
B14 Spun metal domes
B15 Strut
B16 Thrust chamber
B17 Turbopump
B18 Valves
B19 Other (specify)
B20 Other (specify)
B21 Other (specify)
Large Liquid Propulsion
Small Liquid Propulsion
Large Solid Rocket Motor
Small Solid Rocket Motor
Science and Technology
Test and Evaluation
Electric Propulsion
Other
Yes - R&D
Yes - Prototyping
Yes - Manufacturing
No
Not Applicable
U.S. Government Defense
U.S. Government Non-Defense
U.S. Commercial Defense
U.S. Commercial Non-Defense
Non-U.S. Government Defense
Non-U.S. Government Non-Defense
Non-U.S. Commercial Defense
Non-U.S. Commercial Non-Defense
Unkown
C. Production Techniques
Propulsion-related Product and Service Type
Participation Type
Primary Propulsion Industrial Base Business Category
Primary Facility
Product/Service Description
Primary Business Type
Use of Additive Manufacturing/3-D Printing
Conduct R&D?
Primary End-Use
C1 Additive manufacturing
C2 Brazing
C3 Casting
C4 Coating
C5 Fabrication
C6 Flow forming
C7 Forging
C8 Forming
C9 Heat treating
C10 Large machining
C11 Metal jointing
C12 Molding
C13 Plating
C14 Precision machining
C15 Sheet metal fabrication
C16 Small machining
C17 Turbopump machining
C18 Other (specify)
C19 Other (specify)
C20 Other (specify)

D. Propellants and Other Materials									
	Propulsion-related Product and Service Type	Participation Type	Primary Propulsion Industrial Base Business Category	Primary Facility	Product/Service Description	Primary Business Type	Use of Additive Manufacturing/3-D Printing	Conduct R&D?	Primary End-Use
D1	Adhesives and resins								
D2	Carbon Fibers								
D3	Coatings								
D4	Composite materials (including carbon)								
D5	Fuels (including RP-1 and RP-2)								
D6	HC polymer								
D7	Insulation								
D8	Liquid propellant and/or materials								
D9	PBI-NBR rubber								
D10	Oxidizer								
D11	Polymer								
D12	Pressurant								
D13	Raw materials (including Additive Manufacturing Stock)								
D14	Rayon								
D15	Solid rocket liner material								
D16	Solid rocket propellant material								
D17	Weld wire								
D18	Other (specify)								
D19	Other (specify)								
D20	Other (specify)								

E. Systems and Services									
	Propulsion-related Product and Service Type	Participation Type	Primary Propulsion Industrial Base Business Category	Primary Facility	Product/Service Description	Primary Business Type	Use of Additive Manufacturing/3-D Printing	Conduct R&D?	Primary End-Use
E1	Component testing								
E2	Composite materials testing								
E3	Engine/motor system testing								
E4	Engineering services								
E5	Fabricated assemblies								
E6	Launch services								
E7	Machine parts and tooling								
E8	Materials testing								
E9	System and/or subsystem assembly								
E10	System and or subsystem integration								
E11	Test equipment								
E12	Test services								
E13	Test stand design								
E14	Other (specify)								
E15	Other (specify)								
E16	Other (specify)								

F. Other									
	Propulsion-related Product and Service Type	Participation Type	Primary Propulsion Industrial Base Business Category	Primary Facility	Product/Service Description	Primary Business Type	Use of Additive Manufacturing/3-D Printing	Conduct R&D?	Primary End-Use
F1	Maintenance/aftermarket/repair/refurbishing								
F2	Cleaning agents								
F3	Propellant tanks								
F4	Other (specify)								
F5	Other (specify)								
F6	Other (specify)								
F7	Other (specify)								
F8	Other (specify)								
Comments:									

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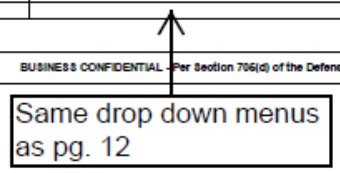

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Section 5a: Support of U.S. Government (USG) - Agencies

Indicate all U.S. Government departments and agencies your organization has supported, directly or indirectly, from 2013-2017 (including all affiliated laboratories). Then indicate if the support is propulsion-related, non-propulsion-related, or both, and the primary propulsion industrial base business category associated with your support.

	Agency Name		Support	Propulsion-related?	Primary Propulsion Industrial Base Business Category
A.	U.S. Air Force (USAF)				
	U.S. Army				
	U.S. Department of Energy (DOE)				
	U.S. Department of Homeland Security (DHS)				
	U.S. Department of State				
	U.S. DOD Defense Advanced Research Projects Agency (DARPA)				
	U.S. DOD Missile Defense Agency (MDA)				
	U.S. Intelligence Community (e.g. CIA, NGA, NRO, NSA, DNI, etc.)				
	U.S. Marine Corps (USMC)				
	National Aeronautics and Space Administration (NASA)				
	U.S. Navy				
	National Oceanic and Atmospheric Administration (NOAA, U.S. Department of Commerce)				
	Other Agency				
	Other Agency				
	Other Agency				
	Unlisted Agency (specify)				
	Unlisted Agency (specify)				
	Unlisted Agency (specify)				

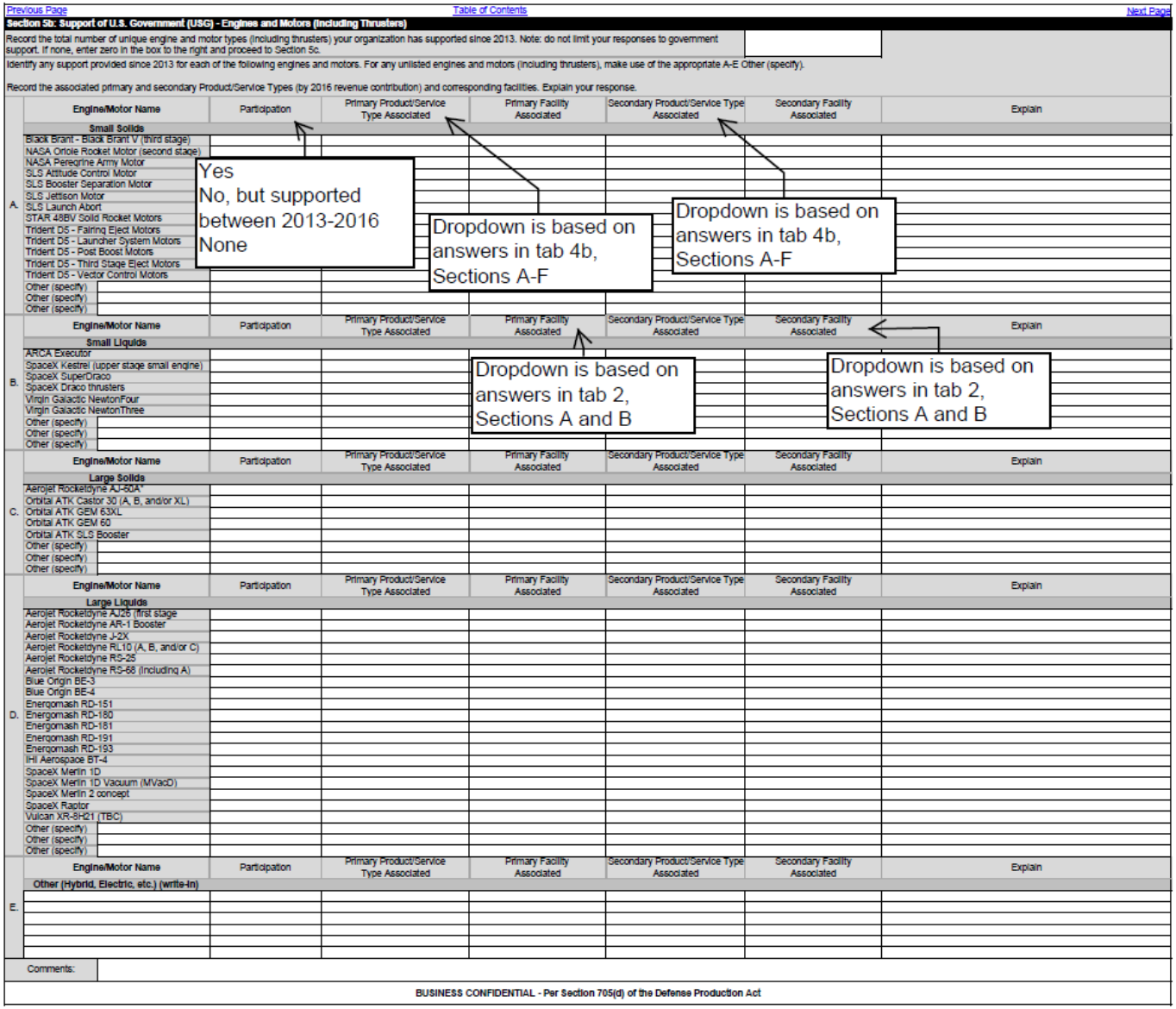
Direct
Indirect
Both
None
Unknown

Propulsion
Non-propulsion
Both
Not applicable

Large Liquid Propulsion
Small Liquid Propulsion
Large Solid Rocket Motor
Small Solid Rocket Motor
Science and Technology
Test and Evaluation
Electric Propulsion
Other

Comments:

BUSINESS CONFIDENTIAL - Per Section 705(d) of the Defense Production Act



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Section 5b: Support of U.S. Government (USG) - Engines and Motors (including Thrusters)

Record the total number of unique engine and motor types (including thrusters) your organization has supported since 2013. Note: do not limit your responses to government support. If none, enter zero in the box to the right and proceed to Section 5c.

Identify any support provided since 2013 for each of the following engines and motors. For any unlisted engines and motors (including thrusters), make use of the appropriate A-E Other (specify).

Record the associated primary and secondary Product/Service Types (by 2016 revenue contribution) and corresponding facilities. Explain your response.

	Engine/Motor Name	Participation	Primary Product/Service Type Associated	Primary Facility Associated	Secondary Product/Service Type Associated	Secondary Facility Associated	Explain
	Small Solids						
A.	Black Brant - Black Brant V (third stage)						
	NASA Oriole Rocket Motor (second stage)						
	NASA Peregrine Army Motor						
	SLS Attitude Control Motor						
	SLS Booster Separation Motor						
	SLS Jettison Motor						
	SLS Launch Abort						
	STAR 48BV Solid Rocket Motors						
	Trident D5 - Fairing Eject Motors						
	Trident D5 - Launcher System Motors						
	Trident D5 - Post Boost Motors						
	Trident D5 - Third Stage Eject Motors						
	Trident D5 - Vector Control Motors						
	Other (specify)						
	Other (specify)						
	Other (specify)						

Yes
No, but supported between 2013-2016
None

Dropdown is based on answers in tab 4b, Sections A-F

Dropdown is based on answers in tab 4b, Sections A-F

	Engine/Motor Name	Participation	Primary Product/Service Type Associated	Primary Facility Associated	Secondary Product/Service Type Associated	Secondary Facility Associated	Explain
	Small Liquids						
B.	ARCA Executor						
	SpaceX Kestrel (upper stage small engine)						
	SpaceX SuperDraco						
	SpaceX Draco thrusters						
	Virgin Galactic NewtonFour						
	Virgin Galactic NewtonThree						
	Other (specify)						
	Other (specify)						
	Other (specify)						

Dropdown is based on answers in tab 2, Sections A and B

Dropdown is based on answers in tab 2, Sections A and B

	Engine/Motor Name	Participation	Primary Product/Service Type Associated	Primary Facility Associated	Secondary Product/Service Type Associated	Secondary Facility Associated	Explain
	Large Solids						
C.	Aerojet Rocketdyne AJ-60A*						
	Orbital ATK Castor 30 (A, B, and/or XL)						
	Orbital ATK GEM 63XL						
	Orbital ATK GEM 60						
	Orbital ATK SLS Booster						
	Other (specify)						
	Other (specify)						
	Other (specify)						

	Engine/Motor Name	Participation	Primary Product/Service Type Associated	Primary Facility Associated	Secondary Product/Service Type Associated	Secondary Facility Associated	Explain
	Large Liquids						
D.	Aerojet Rocketdyne AJ26 (first stage						
	Aerojet Rocketdyne AR-1 Booster						
	Aerojet Rocketdyne J-2X						
	Aerojet Rocketdyne RL10 (A, B, and/or C)						
	Aerojet Rocketdyne RS-25						
	Aerojet Rocketdyne RS-68 (including A)						
	Blue Origin BE-3						
	Blue Origin BE-4						
	Energomash RD-151						
	Energomash RD-180						
	Energomash RD-181						
	Energomash RD-191						
	Energomash RD-193						
	IHI Aerospace BT-4						
	SpaceX Merlin 1D						
	SpaceX Merlin 1D Vacuum (MVacD)						
	SpaceX Merlin 2 concept						
	SpaceX Raptor						
	Vulcan XR-8H21 (TBC)						
	Other (specify)						
	Other (specify)						
	Other (specify)						

	Engine/Motor Name	Participation	Primary Product/Service Type Associated	Primary Facility Associated	Secondary Product/Service Type Associated	Secondary Facility Associated	Explain
	Other (Hybrid, Electric, etc.) (write-in)						
E.							

Comments:

BUSINESS CONFIDENTIAL - Per Section 705(d) of the Defense Production Act

Section 5c: Support of U.S. Government (USG) - USG Programs and Commercial Systems

A. Based on the product and service categories in which your organization has participated, indicate the total number of propulsion-related programs/systems your organization supported from 2013-2017. If none, enter zero in the box to the right and proceed to Section 6.

For each program/system supported by your organization from 2013-2017 (including rocket families and stages), identify the associated Product/Service Type and facility (both primary and secondary). Then record the primary Engine/Motor associated with your support (if applicable). Explain your response.

B.

Program/System	Primary Product/Service Associated	Primary Facility Associated	Secondary Product/Service Associated	Secondary Facility Associated	Primary Engine/Motor (if applicable)	Explain
Antares						
Antares Bi-Propellant Third Stage (BTS)						
Atlas V						
Atlas V - Centaur						
Atlas V - Common Core Booster						
Black Brant						
Blue Origin New Glenn						
Blue Origin New Shepard						
CST-100 Starliner						
Delta IV						
Delta IV - Heavy						
Delta IV - Common Booster Core						
Delta Cryogenic Second Stage (DCSS)						
Vulcan						
Space Launch System (SLS) - Booster System						
Space Launch System (SLS) - Exploration Upper Stage (EUS)						
Space Launch System (SLS) - Interim Cryogenic Propulsion Stage (ICPS)						
Space Launch System (SLS) - Orion MPCV						
Oriole						
Advanced Medium-Range Air-to-Air Missile (AMRAAM)						
AGM-114 Hellfire						
Evolved Expendable Launch Vehicle (EELV)						
Evolved Seasparrow Missile (ESSM) - Blk 1						
Evolved Seasparrow Missile (ESSM) - Blk 2						
SpaceX - Dragon						
SpaceX - Dragon V2/Dragon 2						
SpaceX - Falcon 9						
SpaceX - Falcon 9 Full Thrust						
SpaceX - Falcon 9 Heavy (Booster)						
SpaceX - ITS Launch Vehicle						
GMD/GBI - Orion						
GMD/GBI - RKV						
GRIFFIN						
JAVELIN						
M270 Multiple Launch Rocket System (M270 MLRS)						
MGM-140 Army Tactical Missile System (ATacMS)						
Minuteman III						
Patriot Advanced Capability (PAC-3)						
Patriot Advanced Capability (PAC-3) - MSE						
RAM						
RAM - Blk 2						
RIM-174 Standard Extended Range Active Missile (ERAM)/Standard Missile 6 (SM-6)						
Sidewinder/AIM 9X						
Standard Missile 3 (SM-3)						
Standard Missile 3 (SM-3) - Block IIA						
Standard Missile-2 (SM-2)						
Star 48BV						
Star 48 Upper Stage						
Tactical Tomahawk						
Terminal High Altitude Area Defense (THAAD)						
TOW						
Trident D5						
Other (specify here)						
Other (specify here)						
Other (specify here)						
Other (specify here)						
Other (specify here)						

Dropdown is based on answers in tab 4b, Sections A-F

Dropdown is based on answers in tab 2, Sections A and B

Dropdown is based on answers in tab 4b, Sections A-F

Dropdown is based on answers in tab 2, Sections A and B

Dropdown is based on answers in tab 5b, Sections A-E

Comments:

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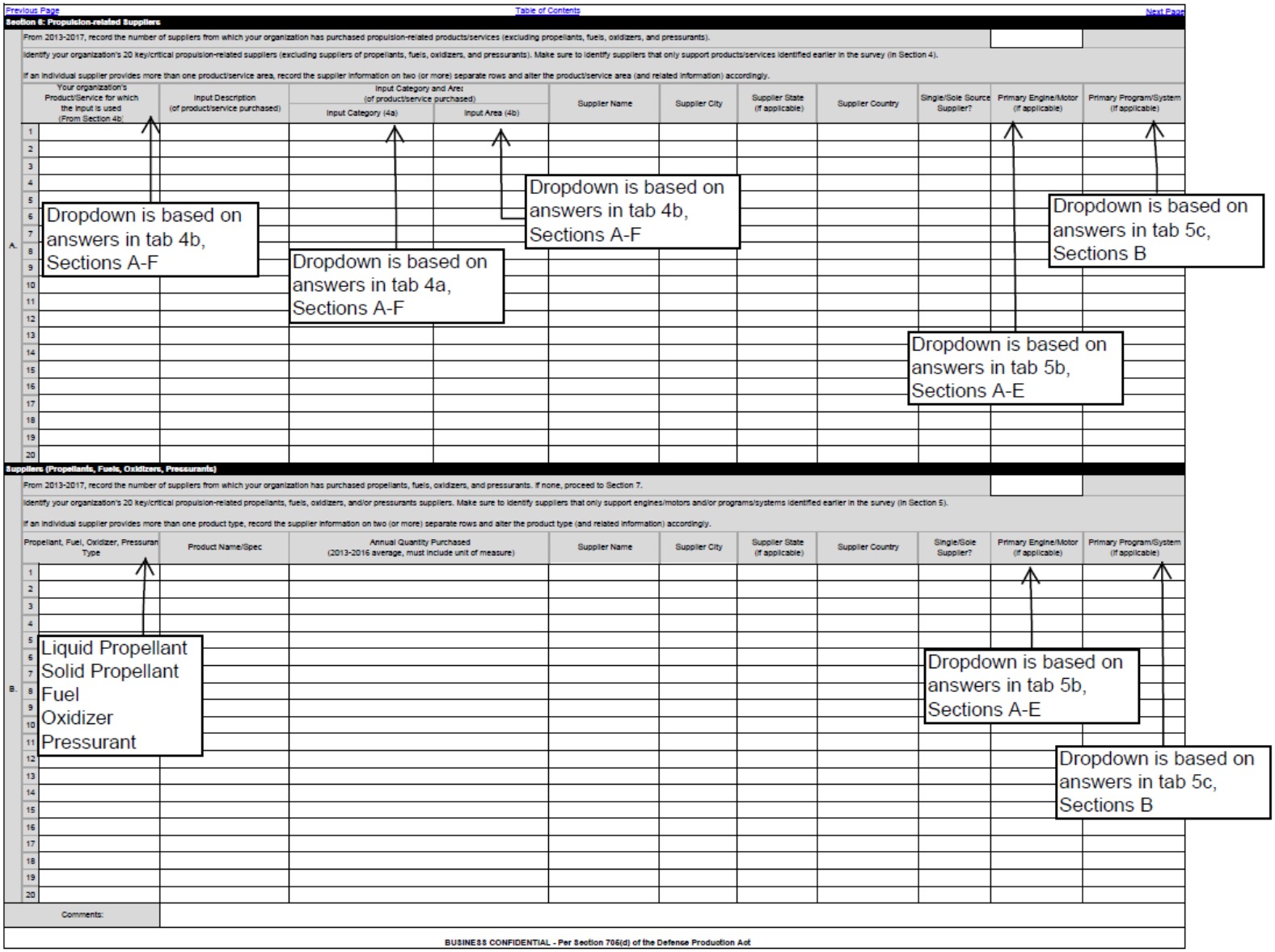
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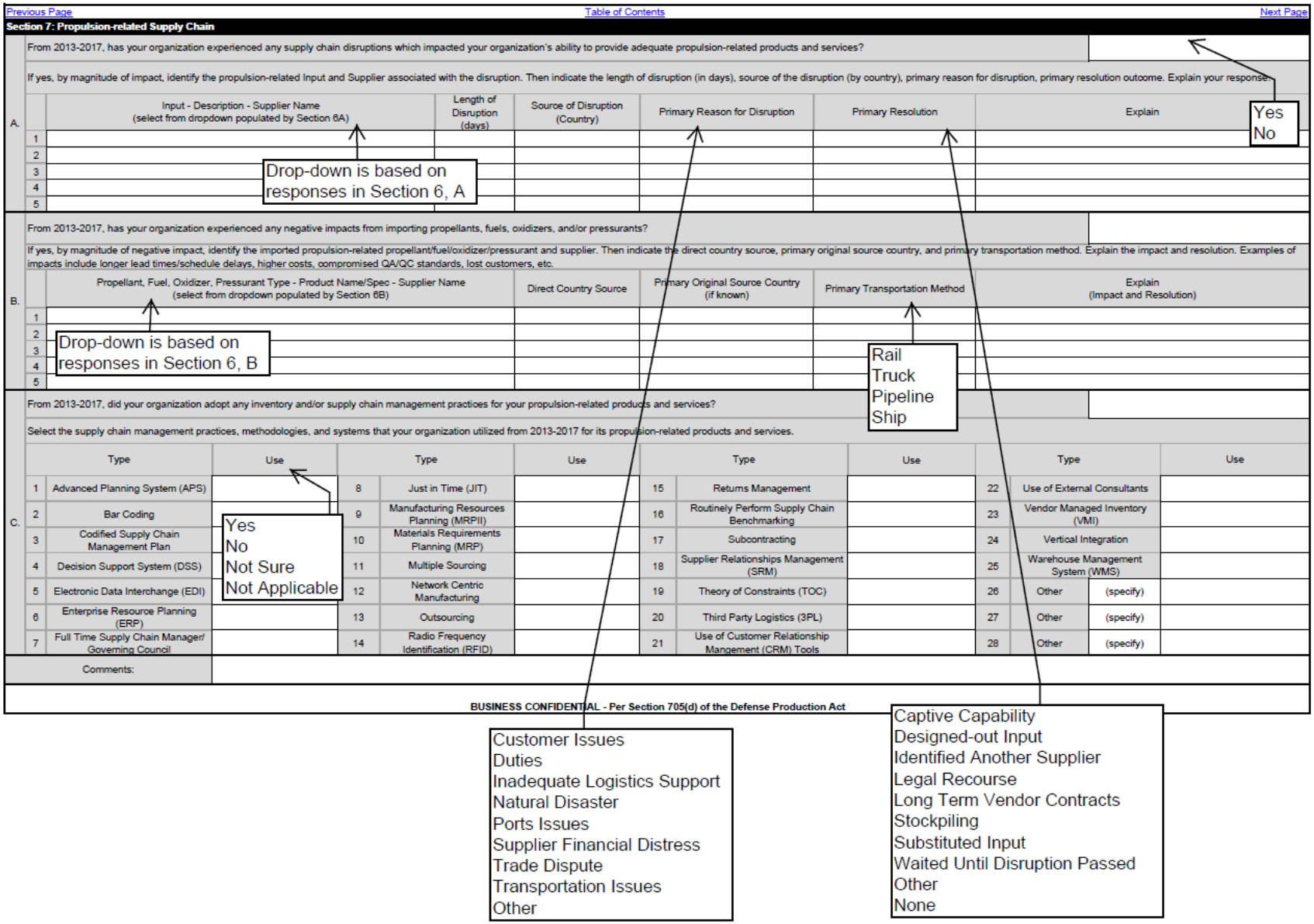
Section 6: Propulsion-related Suppliers
From 2013-2017, record the number of suppliers from which your organization has purchased propulsion-related products/services (excluding propellants, fuels, oxidizers, and pressurants).
Identify your organization's 20 key/critical propulsion-related suppliers (excluding suppliers of propellants, fuels, oxidizers, and pressurants). Make sure to identify suppliers that only support products/services identified earlier in the survey (in Section 4).
If an individual supplier provides more than one product/service area, record the supplier information on two (or more) separate rows and alter the product/service area (and related information) accordingly.
A.
Your organization's Product/Service for which the input is used (From Section 4b)
Input Description (of product/service purchased)
Input Category and Area (of product/service purchased)
Input Category (4a)
Input Area (4b)
Supplier Name
Supplier City
Supplier State (if applicable)
Supplier Country
Single/Sole Source Supplier?
Primary Engine/Motor (if applicable)
Primary Program/System (if applicable)
Dropdown is based on answers in tab 4b, Sections A-F
Dropdown is based on answers in tab 4a, Sections A-F
Dropdown is based on answers in tab 4b, Sections A-F
Dropdown is based on answers in tab 5c, Sections B
Dropdown is based on answers in tab 5b, Sections A-E
Suppliers (Propellants, Fuels, Oxidizers, Pressurants)
From 2013-2017, record the number of suppliers from which your organization has purchased propellants, fuels, oxidizers, and pressurants. If none, proceed to Section 7.
Identify your organization's 20 key/critical propulsion-related propellants, fuels, oxidizers, and/or pressurants suppliers. Make sure to identify suppliers that only support engines/motors and/or programs/systems identified earlier in the survey (in Section 5).
If an individual supplier provides more than one product type, record the supplier information on two (or more) separate rows and alter the product type (and related information) accordingly.
B.
Propellant, Fuel, Oxidizer, Pressurant Type
Product Name/Spec
Annual Quantity Purchased (2013-2016 average, must include unit of measure)
Supplier Name
Supplier City
Supplier State (if applicable)
Supplier Country
Single/Sole Supplier?
Primary Engine/Motor (if applicable)
Primary Program/System (if applicable)
Liquid Propellant
Solid Propellant
Fuel
Oxidizer
Pressurant
Dropdown is based on answers in tab 5b, Sections A-E
Dropdown is based on answers in tab 5c, Sections B
Comments:
BUSINESS CONFIDENTIAL - Per Section 706(d) of the Defense Production Act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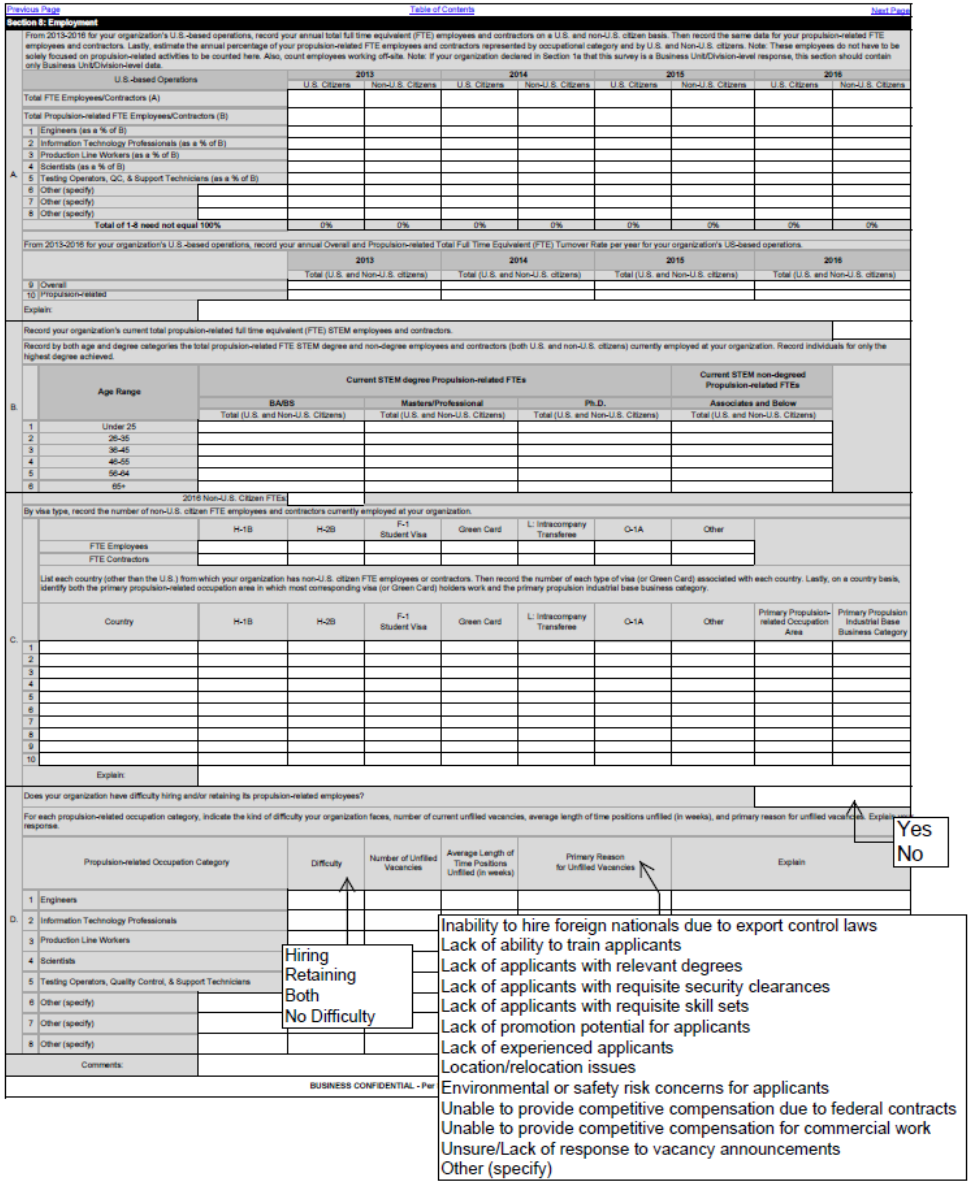
Section 7: Propulsion-related Supply Chain
From 2013-2017, has your organization experienced any supply chain disruptions which impacted your organization's ability to provide adequate propulsion-related products and services?
Yes
No
If yes, by magnitude of impact, identify the propulsion-related Input and Supplier associated with the disruption. Then indicate the length of disruption (in days), source of the disruption (by country), primary reason for disruption, primary resolution outcome. Explain your response.
A.
Input - Description - Supplier Name (select from dropdown populated by Section 6A)
Length of Disruption (days)
Source of Disruption (Country)
Primary Reason for Disruption
Primary Resolution
Explain
Drop-down is based on responses in Section 6, A
From 2013-2017, has your organization experienced any negative impacts from importing propellants, fuels, oxidizers, and/or pressurants?
If yes, by magnitude of negative impact, identify the imported propulsion-related propellant/fuel/oxidizer/pressurant and supplier. Then indicate the direct country source, primary original source country, and primary transportation method. Explain the impact and resolution. Examples of impacts include longer lead times/schedule delays, higher costs, compromised QA/QC standards, lost customers, etc.
B.
Propellant, Fuel, Oxidizer, Pressurant Type - Product Name/Spec - Supplier Name (select from dropdown populated by Section 6B)
Direct Country Source
Primary Original Source Country (if known)
Primary Transportation Method
Explain (Impact and Resolution)
Drop-down is based on responses in Section 6, B
Rail
Truck
Pipeline
Ship
From 2013-2017, did your organization adopt any inventory and/or supply chain management practices for your propulsion-related products and services?
Select the supply chain management practices, methodologies, and systems that your organization utilized from 2013-2017 for its propulsion-related products and services.
C.
Type
Use
1 Advanced Planning System (APS)
2 Bar Coding
3 Codified Supply Chain Management Plan
4 Decision Support System (DSS)
5 Electronic Data Interchange (EDI)
6 Enterprise Resource Planning (ERP)
7 Full Time Supply Chain Manager/ Governing Council
8 Just in Time (JIT)
9 Manufacturing Resources Planning (MRPII)
10 Materials Requirements Planning (MRP)
11 Multiple Sourcing
12 Network Centric Manufacturing
13 Outsourcing
14 Radio Frequency Identification (RFID)
15 Returns Management
16 Routinely Perform Supply Chain Benchmarking
17 Subcontracting
18 Supplier Relationships Management (SRM)
19 Theory of Constraints (TOC)
20 Third Party Logistics (3PL)
21 Use of Customer Relationship Mangement (CRM) Tools
22 Use of External Consultants
23 Vendor Managed Inventory (VMI)
24 Vertical Integration
25 Warehouse Management System (WMS)
26 Other (specify)
27 Other (specify)
28 Other (specify)
Yes
No
Not Sure
Not Applicable
Comments:
BUSINESS CONFIDENTIAL - Per Section 705(d) of the Defense Production Act
Customer Issues
Duties
Inadequate Logistics Support
Natural Disaster
Ports Issues
Supplier Financial Distress
Trade Dispute
Transportation Issues
Other
Captive Capability
Designed-out Input
Identified Another Supplier
Legal Recourse
Long Term Vendor Contracts
Stockpiling
Substituted Input
Waited Until Disruption Passed
Other
None



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Section 6: Employment

From 2013-2016 for your organization's U.S.-based operations, record your annual total full time equivalent (FTE) employees and contractors on a U.S. and non-U.S. citizen basis. Then record the same data for your propulsion-related FTE employees and contractors. Lastly, estimate the annual percentage of your propulsion-related FTE employees and contractors represented by occupational category and by U.S. and Non-U.S. citizens. Note: These employees do not have to be solely focused on propulsion-related activities to be counted here. Also, count employees working off-site. Note: If your organization declared in Section 1a that this survey is a Business Unit/Division-level response, this section should contain only Business Unit/Division-level data.

A.

U.S.-based Operations	2013		2014		2015		2016	
	U.S. Citizens	Non-U.S. Citizens	U.S. Citizens	Non-U.S. Citizens	U.S. Citizens	Non-U.S. Citizens	U.S. Citizens	Non-U.S. Citizens
Total FTE Employees/Contractors (A)								
Total Propulsion-related FTE Employees/Contractors (B)								
1 Engineers (as a % of B)								
2 Information Technology Professionals (as a % of B)								
3 Production Line Workers (as a % of B)								
4 Scientists (as a % of B)								
5 Testing Operators, QC, & Support Technicians (as a % of B)								
6 Other (specify)								
7 Other (specify)								
8 Other (specify)								
Total of 1-8 need not equal 100%	0%	0%	0%	0%	0%	0%	0%	0%

From 2013-2016 for your organization's U.S.-based operations, record your annual Overall and Propulsion-related Total Full Time Equivalent (FTE) Turnover Rate per year for your organization's US-based operations.

	2013	2014	2015	2016
	Total (U.S. and Non-U.S. citizens)	Total (U.S. and Non-U.S. citizens)	Total (U.S. and Non-U.S. citizens)	Total (U.S. and Non-U.S. citizens)
9 Overall				
10 Propulsion-related				

Explain:

B.

Record your organization's current total propulsion-related full time equivalent (FTE) STEM employees and contractors.

Record by both age and degree categories the total propulsion-related FTE STEM degree and non-degree employees and contractors (both U.S. and non-U.S. citizens) currently employed at your organization. Record individuals for only the highest degree achieved.

	Age Range	Current STEM degree Propulsion-related FTEs			Current STEM non-degreed Propulsion-related FTEs
		BA/BS	Masters/Professional	Ph.D.	Associates and Below
		Total (U.S. and Non-U.S. Citizens)	Total (U.S. and Non-U.S. Citizens)	Total (U.S. and Non-U.S. Citizens)	Total (U.S. and Non-U.S. Citizens)
1	Under 25				
2	26-35				
3	36-45				
4	46-55				
5	56-64				
6	65+				

2016 Non-U.S. Citizen FTEs:

C.

By visa type, record the number of non-U.S. citizen FTE employees and contractors currently employed at your organization.

	H-1B	H-2B	F-1 Student Visa	Green Card	L: Intracompany Transferee	O-1A	Other
FTE Employees							
FTE Contractors							

List each country (other than the U.S.) from which your organization has non-U.S. citizen FTE employees or contractors. Then record the number of each type of visa (or Green Card) associated with each country. Lastly, on a country basis, identify both the primary propulsion-related occupation area in which most corresponding visa (or Green Card) holders work and the primary propulsion industrial base business category.

	Country	H-1B	H-2B	F-1 Student Visa	Green Card	L: Intracompany Transferee	O-1A	Other	Primary Propulsion-related Occupation Area	Primary Propulsion Industrial Base Business Category
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

Explain:

D.

Does your organization have difficulty hiring and/or retaining its propulsion-related employees?

For each propulsion-related occupation category, indicate the kind of difficulty your organization faces, number of current unfilled vacancies, average length of time positions unfilled (in weeks), and primary reason for unfilled vacancies. Explain response.

	Propulsion-related Occupation Category	Difficulty	Number of Unfilled Vacancies	Average Length of Time Positions Unfilled (in weeks)	Primary Reason for Unfilled Vacancies	Explain
1	Engineers					
2	Information Technology Professionals					
3	Production Line Workers					
4	Scientists					
5	Testing Operators, Quality Control, & Support Technicians					
6	Other (specify)					
7	Other (specify)					
8	Other (specify)					

Comments:

BUSINESS CONFIDENTIAL - Per

Yes
No

Hiring
Retaining
Both
No Difficulty

Inability to hire foreign nationals due to export control laws
Lack of ability to train applicants
Lack of applicants with relevant degrees
Lack of applicants with requisite security clearances
Lack of applicants with requisite skill sets
Lack of promotion potential for applicants
Lack of experienced applicants
Location/relocation issues
Environmental or safety risk concerns for applicants
Unable to provide competitive compensation due to federal contracts
Unable to provide competitive compensation for commercial work
Unsure/Lack of response to vacancy announcements
Other (specify)

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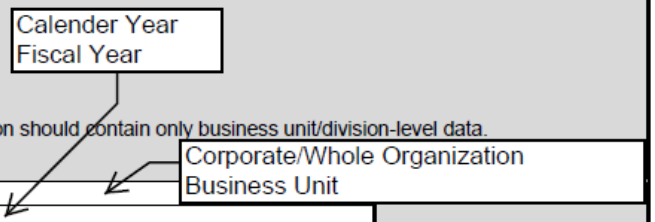
Section 9: Sales

From 2013-2016, record your organization's total sales information to U.S. and non-U.S. customers.

In Part B, indicate your total propulsion-related sales (including commercial and government sales).
In Part C, indicate your total NASA-related sales (including commercial and government sales).
In Part D, indicate your total defense-related sales (including commercial, government, and foreign military sales).

Note: If your organization declared in Section 1a that this survey is a business unit/division-level response, this section should contain only business unit/division-level data.
Note: "U.S." means U.S. domestic sales; "Non-U.S." means export sales from U.S. locations.



Source of Sales Data:
Reporting Schedule:

Record in $ Thousands, e.g. $12,000.00 = survey input $12

	2013		2014		2015		2016	
	U.S.	Non-U.S.	U.S.	Non-U.S.	U.S.	Non-U.S.	U.S.	Non-U.S.
A. Total sales, all customers (in $)								

Lines B-D need not sum to 100%. Estimates are acceptable. Ensure you complete lines B-D for all years with sales.

B.	Total propulsion-related sales (as a % of A)							
C.	Total NASA-related sales (as a % of A)							
D.	Total defense-related sales (as a % of A)							

Comments:

BUSINESS CONFIDENTIAL - Per Section 705(d) of the Defense Production Act

Section 10: Customers

Top U.S.-Based Customers

A. From 2013-2016, record the number of direct U.S.-based customers and propulsion-related direct U.S.-based customers. Direct customers are the immediate entity to which you sell your products or services and may include internal customers (e.g. business units, divisions) within your parent organization.

Total Number of Direct U.S. Customers (2013-2016)	Number of Propulsion-Related Direct U.S. Customers (2013-2016)

B. From 2013-2017 and in descending order by revenue, identify your organization's 10 leading propulsion-related direct U.S.-based customers. Each field must be completed for each recorded customer.

	Direct Propulsion-related U.S.-based Customer Name	Customer DUNS Number	Type of Customer	Customer City	Customer State	Primary Product/Service Provided	Primary Engine/Motor Involved (if known, if applicable)	Primary Propulsion Industrial Base Business Category
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								

U.S. Government Defense
U.S. Government Non-Defense
U.S. Commercial Defense
U.S. Commercial Non-Defense

Drop-down based on responses to Section 4b

Drop-down based on responses to Section 5c, B

Top Non-U.S.-Based Customers

C. From 2013-2016, record the number of direct non-U.S.-based customers and propulsion-related direct non-U.S.-based customers. Direct customers are the immediate entity to which you sell your products or services and may include internal customers (e.g. business units, divisions) within your parent organization.

Total Number of Direct Non-U.S. Customers (2013-2016)	Number of Propulsion-Related Direct Non-U.S. Customers (2013-2016)

D. From 2013-2017 and in descending order by revenue, identify your organization's 10 leading propulsion-related direct non-U.S.-based customers. Each field must be completed for each recorded customer.

	Direct Propulsion-related Non-U.S.-based Customer Name	Customer DUNS Number	Type of Customer	Customer City	Customer Country	Primary Product/Service Provided	Primary Engine/Motor Involved (if known, if applicable)	Primary Propulsion Industrial Base Business Category
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								

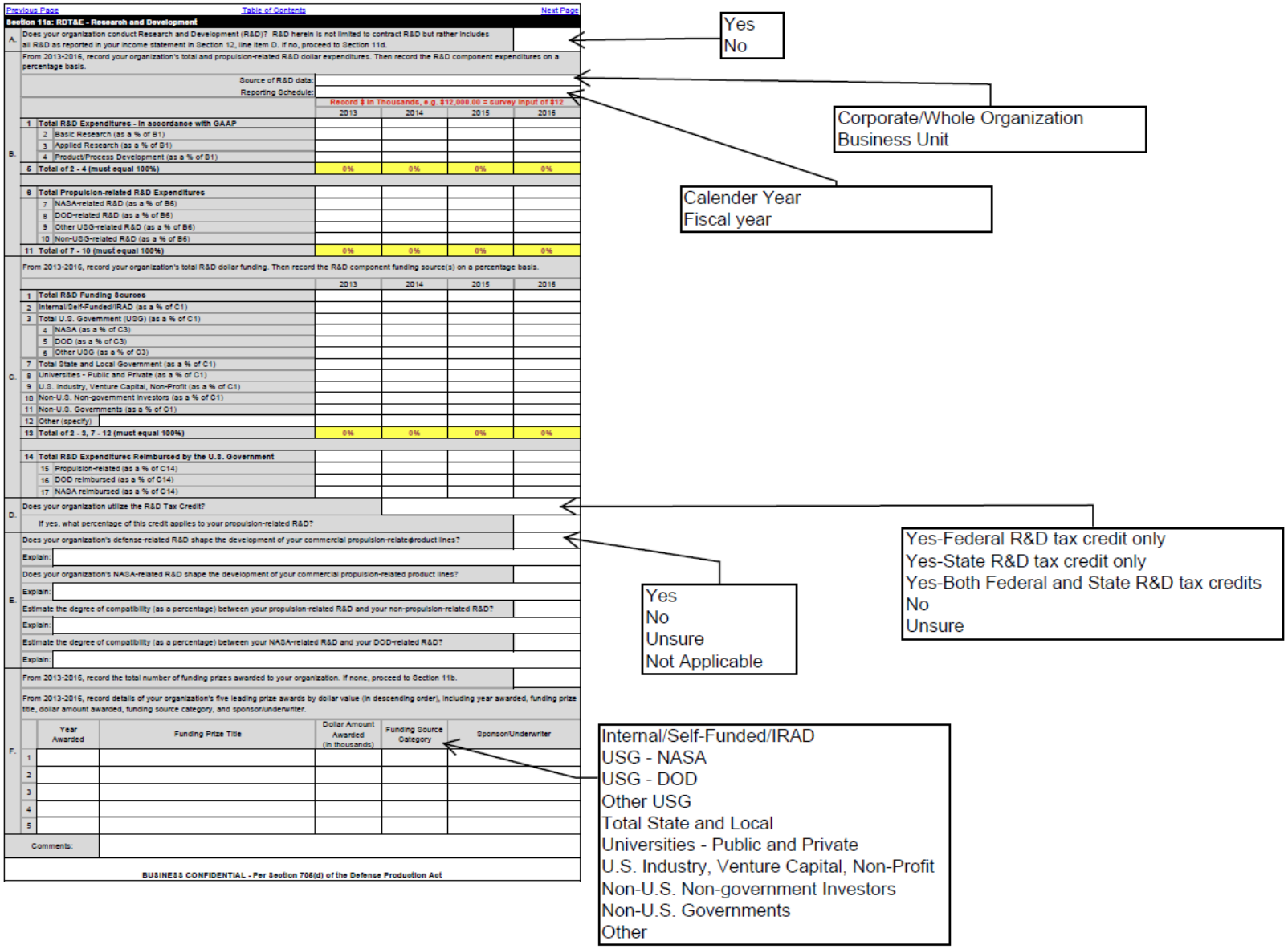
Non-U.S. Government Defense
Non-U.S. Government Non-Defense
Non-U.S. Commercial Defense
Non-U.S. Commercial Non-Defense

Drop-down based on responses to Section 4b

Drop-down based on responses to Section 5c, B

Comments:	

BUSINESS CONFIDENTIAL - Per Section 705(d) of the Defense Production Act



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Section 11a: RDT&E - Research and Development

A. Does your organization conduct Research and Development (R&D)? R&D herein is not limited to contract R&D but rather includes all R&D as reported in your income statement in Section 12, line item D. If no, proceed to Section 11d.

B. From 2013-2016, record your organization's total and propulsion-related R&D dollar expenditures. Then record the R&D component expenditures on a percentage basis.

Source of R&D data:
Reporting Schedule:
Record $ in Thousands, e.g. $12,000.00 = survey input of $12

		2013	2014	2015	2016
1	**Total R&D Expenditures - in accordance with GAAP**				
2	Basic Research (as a % of B1)				
3	Applied Research (as a % of B1)				
4	Product/Process Development (as a % of B1)				
5	**Total of 2 - 4 (must equal 100%)**	0%	0%	0%	0%
6	**Total Propulsion-related R&D Expenditures**				
7	NASA-related R&D (as a % of B6)				
8	DOD-related R&D (as a % of B6)				
9	Other USG-related R&D (as a % of B6)				
10	Non-USG-related R&D (as a % of B6)				
11	**Total of 7 - 10 (must equal 100%)**	0%	0%	0%	0%

C. From 2013-2016, record your organization's total R&D dollar funding. Then record the R&D component funding source(s) on a percentage basis.

		2013	2014	2015	2016
1	**Total R&D Funding Sources**				
2	Internal/Self-Funded/IRAD (as a % of C1)				
3	Total U.S. Government (USG) (as a % of C1)				
4	NASA (as a % of C3)				
5	DOD (as a % of C3)				
6	Other USG (as a % of C3)				
7	Total State and Local Government (as a % of C1)				
8	Universities - Public and Private (as a % of C1)				
9	U.S. Industry, Venture Capital, Non-Profit (as a % of C1)				
10	Non-U.S. Non-government investors (as a % of C1)				
11	Non-U.S. Governments (as a % of C1)				
12	Other (specify)				
13	**Total of 2 - 3, 7 - 12 (must equal 100%)**	0%	0%	0%	0%
14	**Total R&D Expenditures Reimbursed by the U.S. Government**				
15	Propulsion-related (as a % of C14)				
16	DOD reimbursed (as a % of C14)				
17	NASA reimbursed (as a % of C14)				

D. Does your organization utilize the R&D Tax Credit?

If yes, what percentage of this credit applies to your propulsion-related R&D?

E. Does your organization's defense-related R&D shape the development of your commercial propulsion-related product lines?

Explain:

Does your organization's NASA-related R&D shape the development of your commercial propulsion-related product lines?

Explain:

Estimate the degree of compatibility (as a percentage) between your propulsion-related R&D and your non-propulsion-related R&D?

Explain:

Estimate the degree of compatibility (as a percentage) between your NASA-related R&D and your DOD-related R&D?

Explain:

F. From 2013-2016, record the total number of funding prizes awarded to your organization. If none, proceed to Section 11b.

From 2013-2016, record details of your organization's five leading prize awards by dollar value (in descending order), including year awarded, funding prize title, dollar amount awarded, funding source category, and sponsor/underwriter.

	Year Awarded	Funding Prize Title	Dollar Amount Awarded (in thousands)	Funding Source Category	Sponsor/Underwriter
1					
2					
3					
4					
5					

Comments:

BUSINESS CONFIDENTIAL - Per Section 706(d) of the Defense Production Act

Yes
No

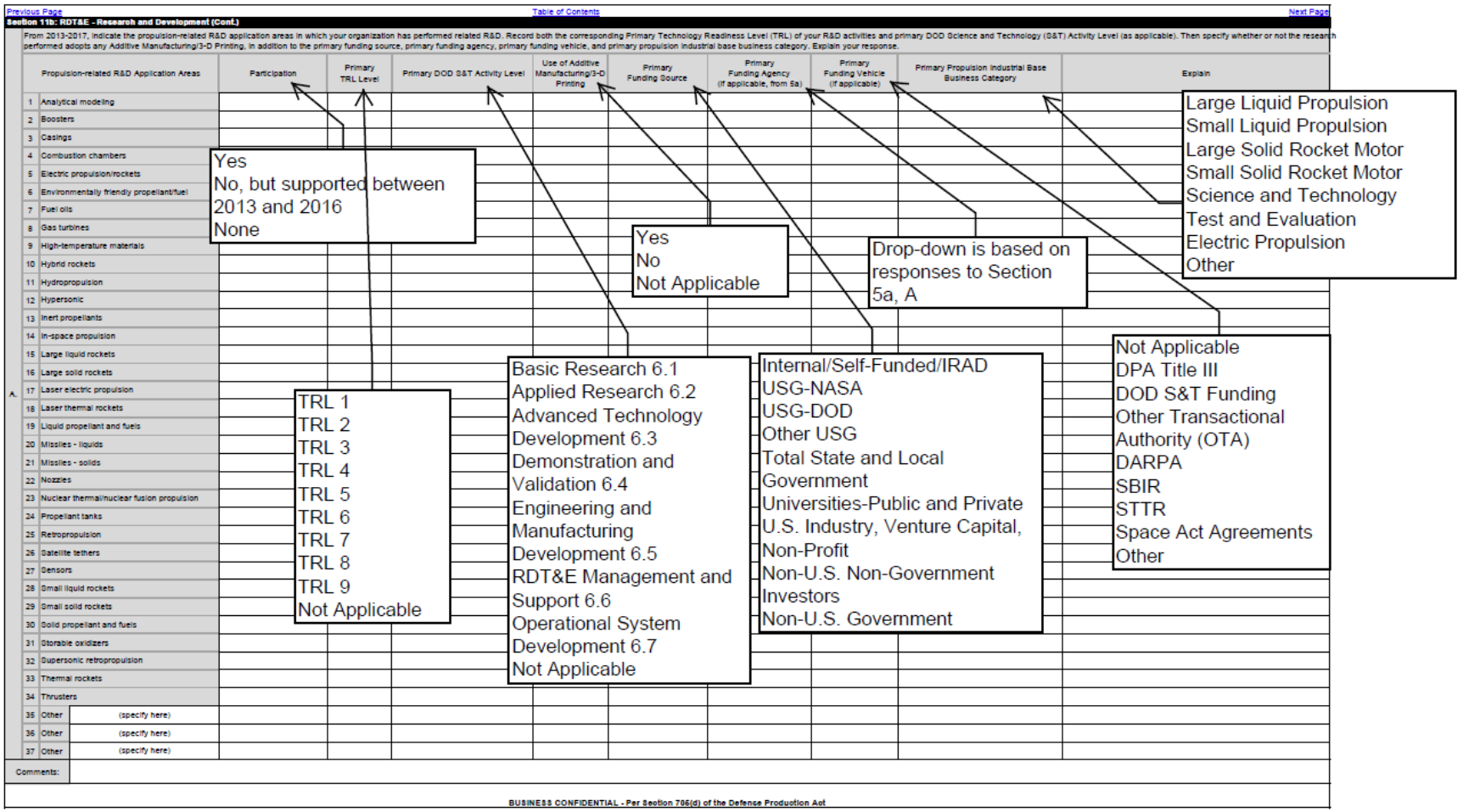
Corporate/Whole Organization
Business Unit

Calender Year
Fiscal year

Yes-Federal R&D tax credit only
Yes-State R&D tax credit only
Yes-Both Federal and State R&D tax credits
No
Unsure

Yes
No
Unsure
Not Applicable

Internal/Self-Funded/IRAD
USG - NASA
USG - DOD
Other USG
Total State and Local
Universities - Public and Private
U.S. Industry, Venture Capital, Non-Profit
Non-U.S. Non-government Investors
Non-U.S. Governments
Other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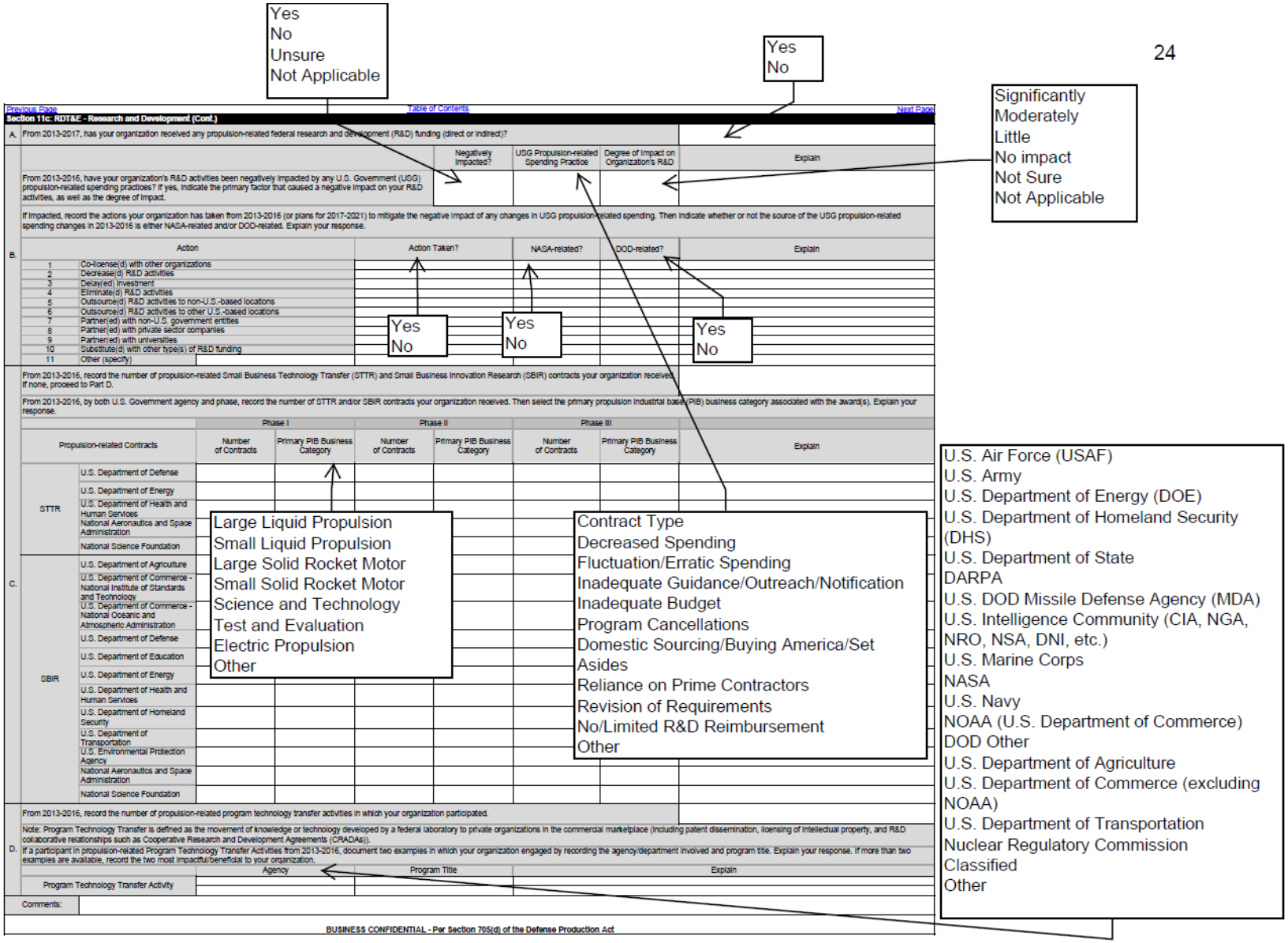
Section 11b: RDT&E - Research and Development (Cont.)
From 2013-2017, indicate the propulsion-related R&D application areas in which your organization has performed related R&D. Record both the corresponding Primary Technology Readiness Level (TRL) of your R&D activities and primary DOD Science and Technology (S&T) Activity Level (as applicable). Then specify whether or not the research performed adopts any Additive Manufacturing/3-D Printing. In addition to the primary funding source, primary funding agency, primary funding vehicle, and primary propulsion industrial base business category. Explain your response.
Propulsion-related R&D Application Areas
Participation
Primary TRL Level
Primary DOD S&T Activity Level
Use of Additive Manufacturing/3-D Printing
Primary Funding Source
Primary Funding Agency (If applicable, from 5a)
Primary Funding Vehicle (If applicable)
Primary Propulsion Industrial Base Business Category
Explain
1 Analytical modeling
2 Boosters
3 Casings
4 Combustion chambers
5 Electric propulsion/rockets
6 Environmentally friendly propellant/fuel
7 Fuel oils
8 Gas turbines
9 High-temperature materials
10 Hybrid rockets
11 Hydropropulsion
12 Hypersonic
13 Inert propellants
14 In-space propulsion
15 Large liquid rockets
16 Large solid rockets
17 Laser electric propulsion
18 Laser thermal rockets
19 Liquid propellant and fuels
20 Missiles - liquids
21 Missiles - solids
22 Nozzles
23 Nuclear thermal/nuclear fusion propulsion
24 Propellant tanks
25 Retropropulsion
26 Satellite tethers
27 Sensors
28 Small liquid rockets
29 Small solid rockets
30 Solid propellant and fuels
31 Storable oxidizers
32 Supersonic retropropulsion
33 Thermal rockets
34 Thrusters
35 Other (specify here)
36 Other (specify here)
37 Other (specify here)
A.
Comments:
BUSINESS CONFIDENTIAL - Per Section 706(d) of the Defense Production Act
Yes
No, but supported between 2013 and 2016
None
TRL 1
TRL 2
TRL 3
TRL 4
TRL 5
TRL 6
TRL 7
TRL 8
TRL 9
Not Applicable
Basic Research 6.1
Applied Research 6.2
Advanced Technology Development 6.3
Demonstration and Validation 6.4
Engineering and Manufacturing Development 6.5
RDT&E Management and Support 6.6
Operational System Development 6.7
Not Applicable
Yes
No
Not Applicable
Internal/Self-Funded/IRAD
USG-NASA
USG-DOD
Other USG
Total State and Local Government
Universities-Public and Private
U.S. Industry, Venture Capital, Non-Profit
Non-U.S. Non-Government Investors
Non-U.S. Government
Drop-down is based on responses to Section 5a, A
Not Applicable
DPA Title III
DOD S&T Funding
Other Transactional Authority (OTA)
DARPA
SBIR
STTR
Space Act Agreements
Other
Large Liquid Propulsion
Small Liquid Propulsion
Large Solid Rocket Motor
Small Solid Rocket Motor
Science and Technology
Test and Evaluation
Electric Propulsion
Other


Yes
No
Unsure
Not Applicable
Yes
No
Significantly
Moderately
Little
No impact
Not Sure
Not Applicable
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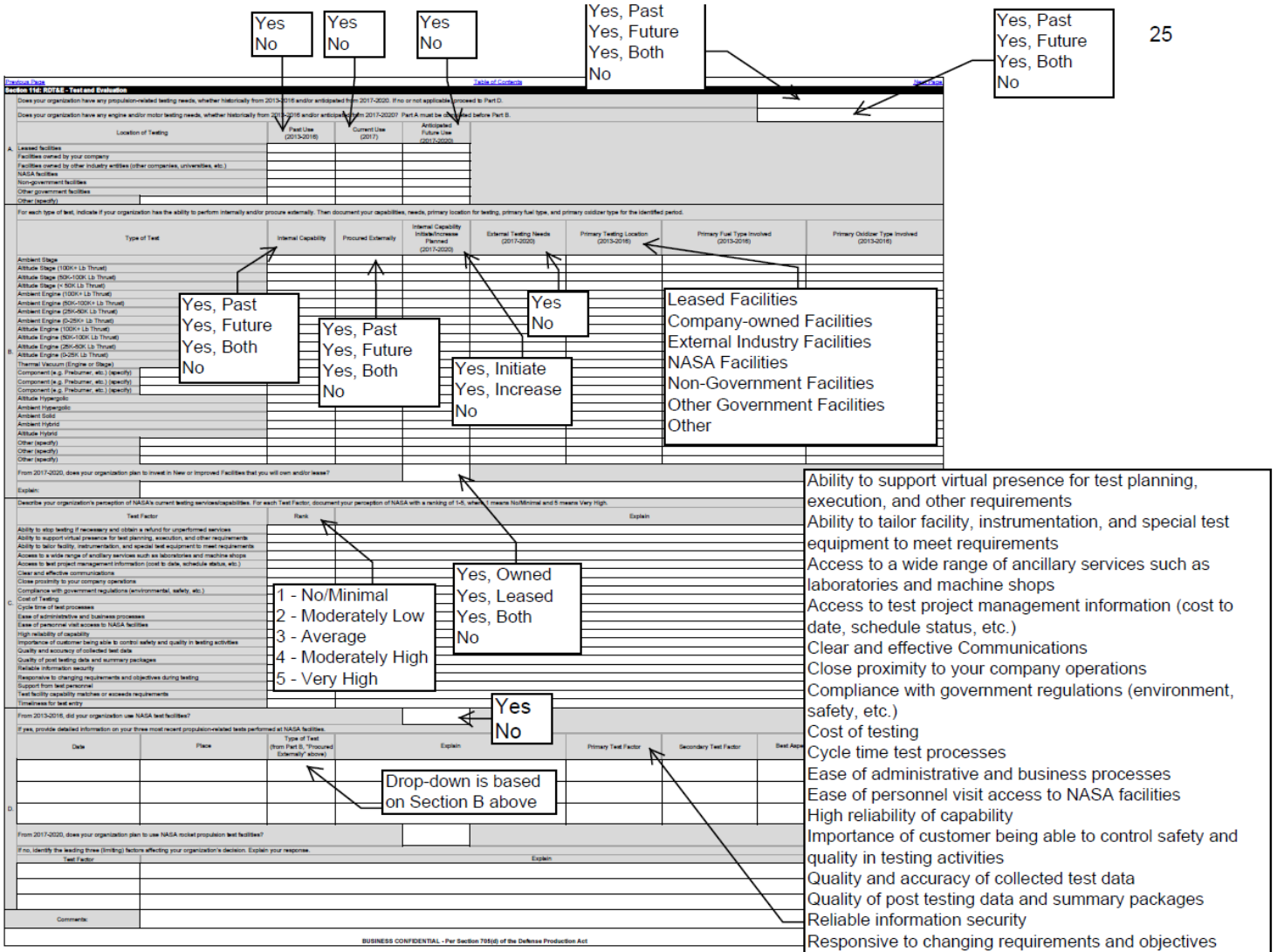
Section 11c: RDT&E - Research and Development (Cont.)
A. From 2013-2017, has your organization received any propulsion-related federal research and development (R&D) funding (direct or indirect)?
B.
From 2013-2016, have your organization's R&D activities been negatively impacted by any U.S. Government (USG) propulsion-related spending practices? If yes, indicate the primary factor that caused a negative impact on your R&D activities, as well as the degree of impact.
Negatively Impacted?
USG Propulsion-related Spending Practice
Degree of Impact on Organization's R&D
Explain
If impacted, record the actions your organization has taken from 2013-2016 (or plans for 2017-2021) to mitigate the negative impact of any changes in USG propulsion-related spending. Then indicate whether or not the source of the USG propulsion-related spending changes in 2013-2016 is either NASA-related and/or DOD-related. Explain your response.
Action
Action Taken?
NASA-related?
DOD-related?
Explain
1 Co-license(d) with other organizations
2 Decrease(d) R&D activities
3 Delay(ed) investment
4 Eliminate(d) R&D activities
5 Outsource(d) R&D activities to non-U.S.-based locations
6 Outsource(d) R&D activities to other U.S.-based locations
7 Partner(ed) with non-U.S. government entities
8 Partner(ed) with private sector companies
9 Partner(ed) with universities
10 Substitute(d) with other type(s) of R&D funding
11 Other (specify)
Yes
No
Yes
No
Yes
No
C.
From 2013-2016, record the number of propulsion-related Small Business Technology Transfer (STTR) and Small Business Innovation Research (SBIR) contracts your organization received. If none, proceed to Part D.
From 2013-2016, by both U.S. Government agency and phase, record the number of STTR and/or SBIR contracts your organization received. Then select the primary propulsion industrial base (PIB) business category associated with the award(s). Explain your response.
Phase I
Phase II
Phase III
Propulsion-related Contracts
Number of Contracts
Primary PIB Business Category
Number of Contracts
Primary PIB Business Category
Number of Contracts
Primary PIB Business Category
Explain
STTR
U.S. Department of Defense
U.S. Department of Energy
U.S. Department of Health and Human Services
National Aeronautics and Space Administration
National Science Foundation
SBIR
U.S. Department of Agriculture
U.S. Department of Commerce - National Institute of Standards and Technology
U.S. Department of Commerce - National Oceanic and Atmospheric Administration
U.S. Department of Defense
U.S. Department of Education
U.S. Department of Energy
U.S. Department of Health and Human Services
U.S. Department of Homeland Security
U.S. Department of Transportation
U.S. Environmental Protection Agency
National Aeronautics and Space Administration
National Science Foundation
Large Liquid Propulsion
Small Liquid Propulsion
Large Solid Rocket Motor
Small Solid Rocket Motor
Science and Technology
Test and Evaluation
Electric Propulsion
Other
Contract Type
Decreased Spending
Fluctuation/Erratic Spending
Inadequate Guidance/Outreach/Notification
Inadequate Budget
Program Cancellations
Domestic Sourcing/Buying America/Set Asides
Reliance on Prime Contractors
Revision of Requirements
No/Limited R&D Reimbursement
Other
U.S. Air Force (USAF)
U.S. Army
U.S. Department of Energy (DOE)
U.S. Department of Homeland Security (DHS)
U.S. Department of State
DARPA
U.S. DOD Missile Defense Agency (MDA)
U.S. Intelligence Community (CIA, NGA, NRO, NSA, DNI, etc.)
U.S. Marine Corps
NASA
U.S. Navy
NOAA (U.S. Department of Commerce)
DOD Other
U.S. Department of Agriculture
U.S. Department of Commerce (excluding NOAA)
U.S. Department of Transportation
Nuclear Regulatory Commission
Classified
Other
D.
From 2013-2016, record the number of propulsion-related program technology transfer activities in which your organization participated.
Note: Program Technology Transfer is defined as the movement of knowledge or technology developed by a federal laboratory to private organizations in the commercial marketplace (including patent dissemination, licensing of intellectual property, and R&D collaborative relationships such as Cooperative Research and Development Agreements (CRADAs)).
If a participant in propulsion-related Program Technology Transfer Activities from 2013-2016, document two examples in which your organization engaged by recording the agency/department involved and program title. Explain your response. If more than two examples are available, record the two most impactful/beneficial to your organization.
Program Technology Transfer Activity
Agency
Program Title
Explain
Comments:
BUSINESS CONFIDENTIAL - Per Section 705(d) of the Defense Production Act



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Section 12: Financial Information

Report line items from your organization's financial statements for years 2013-2016.

Note: If your organization declared in Section 1a that this survey is a Business Unit/Division-level response, this section should contain only Business Unit/Division-level data

Source of Financial Line Items:
Reporting Schedule:
Business Type:

Calender Year
Fiscal Year

Corporation
Limited Liability Company
Partnership
S Corporation
Sole Proprietorship
Other

	Income Statement (Select Line Items)	Record in $ Thousands, e.g. $12,000.00 = survey input of $12			
		2013	2014	2015	2016
A	Net Sales (and other revenue)				
B	Cost of Goods Sold				
C	Selling, General, and Administrative Expense				
D	Research and Development Expense				
E	Total Operating Income (Loss)				
F	Earnings Before Interest and Taxes				
G	Interest Expense				
H	Net Income				

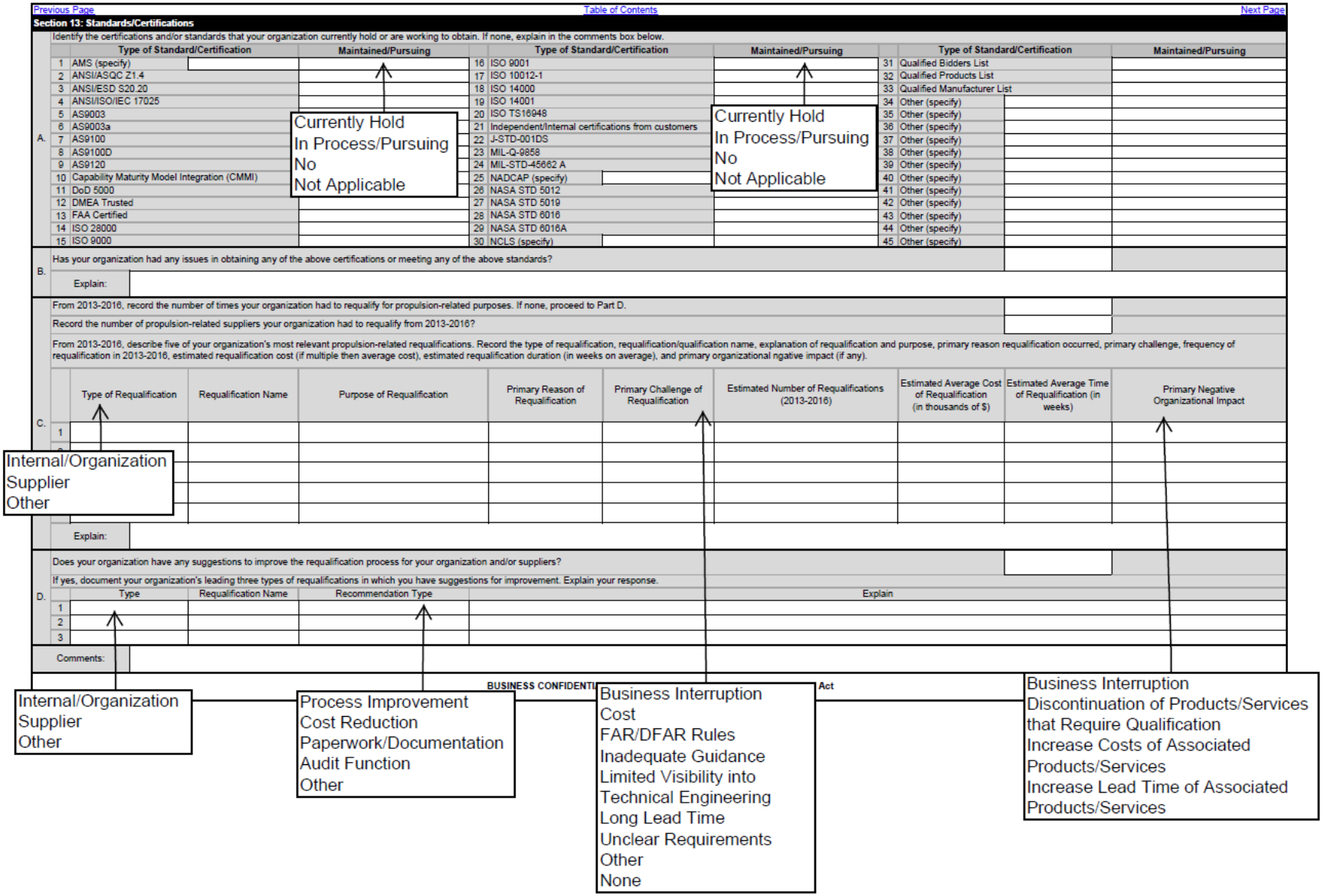
	Balance Sheet (Select Line Items)	Record in $ Thousands, e.g. $12,000.00 = survey input of $12			
		2013	2014	2015	2016
A	Cash and Cash Equivalents				
B	Inventory				
C	Accounts Receivable				
D	Goodwill and Intangibles				
E	Current Assets				
F	Total Assets				
G	Accounts Payable				
H	Current Liabilities				
I	Total Liabilities				
J	Retained Earnings				
K	Total Owner's Equity*				

*Total Owner's Equity (line K in the Balance Sheet) should equal Total Assets (line F in the Balance Sheet) less Total Liabilities (line I in the Balance Sheet)

Use the space provided to qualify with narrative any anomalies, transactions, or non-recurring events reflected in your financial statement line items, e.g. reporting restatement, merger and acquisition, Chapter 11, SEC investigation, etc.

Comments:

BUSINESS CONFIDENTIAL - Per Section 705(d) of the Defense Production Act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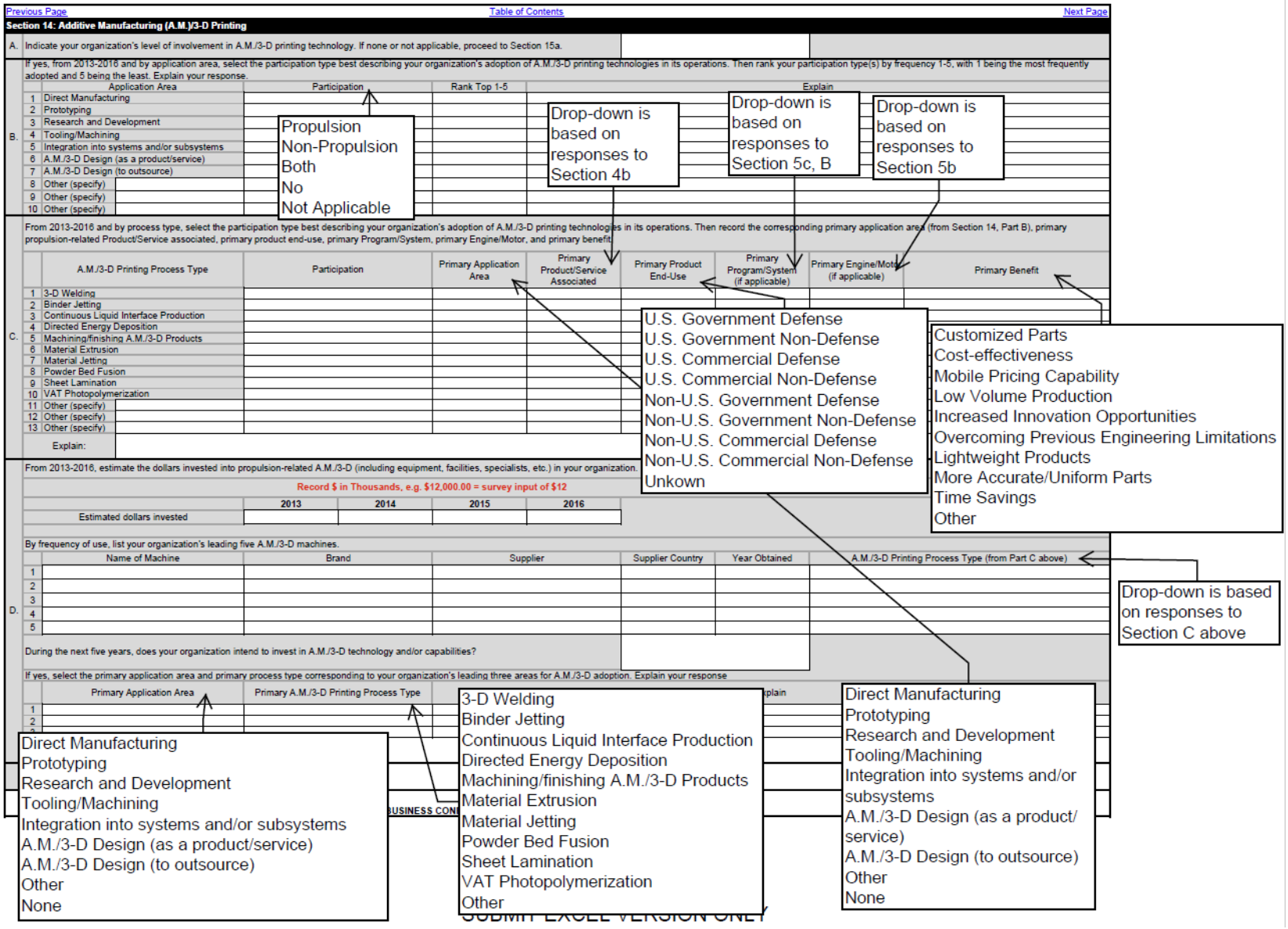
Section 13: Standards/Certifications
Identify the certifications and/or standards that your organization currently hold or are working to obtain. If none, explain in the comments box below.
Type of Standard/Certification
Maintained/Pursuing
1 AMS (specify)
2 ANSI/ASQC Z1.4
3 ANSI/ESD S20.20
4 ANSI/ISO/IEC 17025
5 AS9003
6 AS9003a
7 AS9100
8 AS9100D
9 AS9120
10 Capability Maturity Model Integration (CMMI)
11 DoD 5000
12 DMEA Trusted
13 FAA Certified
14 ISO 28000
15 ISO 9000
16 ISO 9001
17 ISO 10012-1
18 ISO 14000
19 ISO 14001
20 ISO TS16949
21 Independent/Internal certifications from customers
22 J-STD-001DS
23 MIL-Q-9858
24 MIL-STD-45662 A
25 NADCAP (specify)
26 NASA STD 5012
27 NASA STD 5019
28 NASA STD 6016
29 NASA STD 6016A
30 NCLS (specify)
31 Qualified Bidders List
32 Qualified Products List
33 Qualified Manufacturer List
34 Other (specify)
35 Other (specify)
36 Other (specify)
37 Other (specify)
38 Other (specify)
39 Other (specify)
40 Other (specify)
41 Other (specify)
42 Other (specify)
43 Other (specify)
44 Other (specify)
45 Other (specify)
A.
Currently Hold
In Process/Pursuing
No
Not Applicable
B.
Has your organization had any issues in obtaining any of the above certifications or meeting any of the above standards?
Explain:
From 2013-2016, record the number of times your organization had to requalify for propulsion-related purposes. If none, proceed to Part D.
Record the number of propulsion-related suppliers your organization had to requalify from 2013-2016?
From 2013-2016, describe five of your organization's most relevant propulsion-related requalifications. Record the type of requalification, requalification/qualification name, explanation of requalification and purpose, primary reason requalification occurred, primary challenge, frequency of requalification in 2013-2016, estimated requalification cost (if multiple then average cost), estimated requalification duration (in weeks on average), and primary organizational ngative impact (if any).
C.
Type of Requalification
Requalification Name
Purpose of Requalification
Primary Reason of Requalification
Primary Challenge of Requalification
Estimated Number of Requalifications (2013-2016)
Estimated Average Cost of Requalification (in thousands of $)
Estimated Average Time of Requalification (in weeks)
Primary Negative Organizational Impact
Internal/Organization
Supplier
Other
Explain:
D.
Does your organization have any suggestions to improve the requalification process for your organization and/or suppliers?
If yes, document your organization's leading three types of requalifications in which you have suggestions for improvement. Explain your response.
Type
Requalification Name
Recommendation Type
Explain
Comments:
Internal/Organization
Supplier
Other
Process Improvement
Cost Reduction
Paperwork/Documentation
Audit Function
Other
Business Interruption
Cost
FAR/DFAR Rules
Inadequate Guidance
Limited Visibility into
Technical Engineering
Long Lead Time
Unclear Requirements
Other
None
Business Interruption
Discontinuation of Products/Services that Require Qualification
Increase Costs of Associated Products/Services
Increase Lead Time of Associated Products/Services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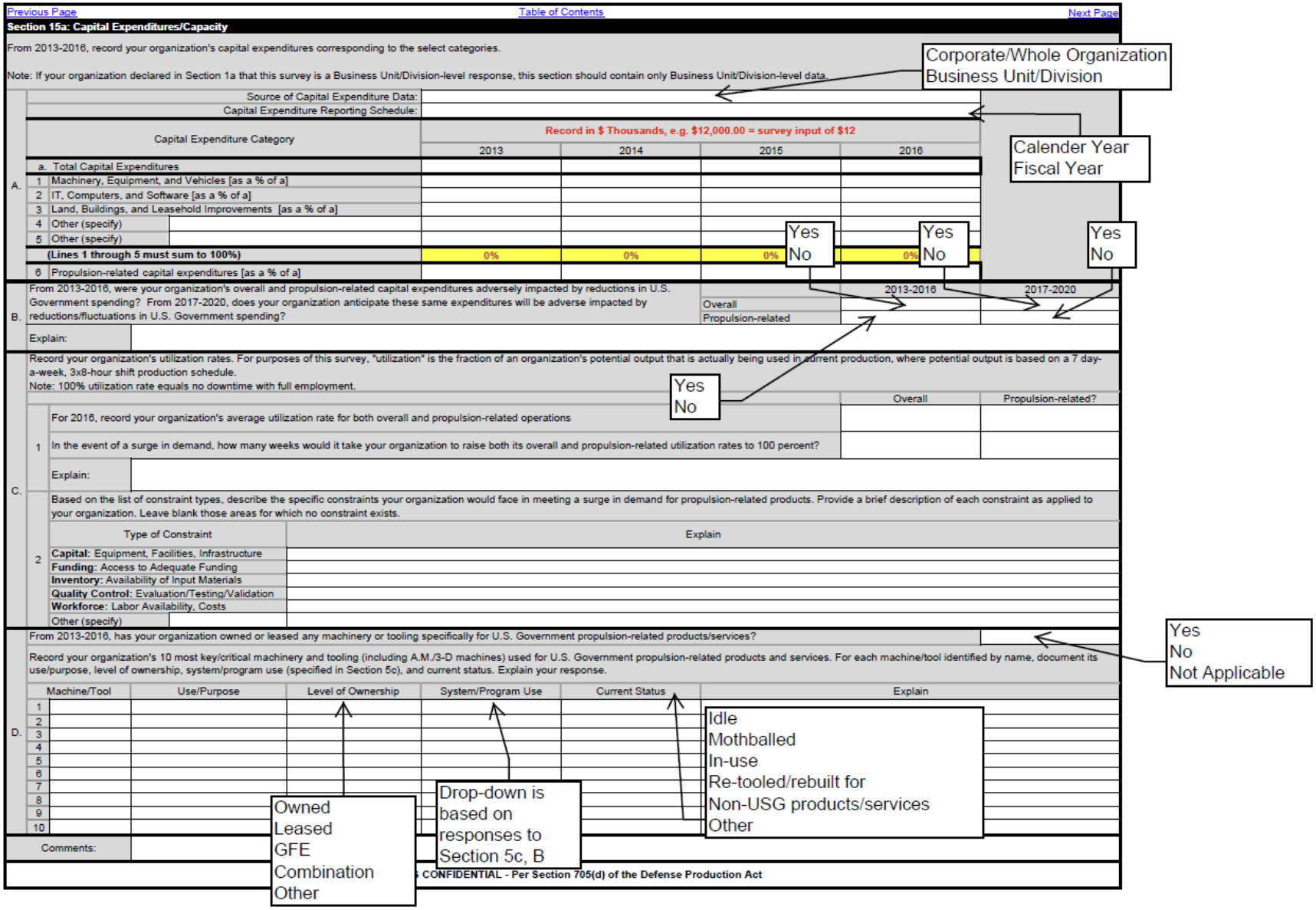
Section 14: Additive Manufacturing (A.M.)/3-D Printing
A. Indicate your organization's level of involvement in A.M./3-D printing technology. If none or not applicable, proceed to Section 15a.
B. If yes, from 2013-2016 and by application area, select the participation type best describing your organization's adoption of A.M./3-D printing technologies in its operations. Then rank your participation type(s) by frequency 1-5, with 1 being the most frequently adopted and 5 being the least. Explain your response.
Application Area
Participation
Rank Top 1-5
Explain
1 Direct Manufacturing
2 Prototyping
3 Research and Development
4 Tooling/Machining
5 Integration into systems and/or subsystems
6 A.M./3-D Design (as a product/service)
7 A.M./3-D Design (to outsource)
8 Other (specify)
9 Other (specify)
10 Other (specify)
Propulsion
Non-Propulsion
Both
No
Not Applicable
Drop-down is based on responses to Section 4b
Drop-down is based on responses to Section 5c, B
Drop-down is based on responses to Section 5b
C. From 2013-2016 and by process type, select the participation type best describing your organization's adoption of A.M./3-D printing technologies in its operations. Then record the corresponding primary application area (from Section 14, Part B), primary propulsion-related Product/Service associated, primary product end-use, primary Program/System, primary Engine/Motor, and primary benefit.
A.M./3-D Printing Process Type
Participation
Primary Application Area
Primary Product/Service Associated
Primary Product End-Use
Primary Program/System (if applicable)
Primary Engine/Motor (if applicable)
Primary Benefit
1 3-D Welding
2 Binder Jetting
3 Continuous Liquid Interface Production
4 Directed Energy Deposition
5 Machining/finishing A.M./3-D Products
6 Material Extrusion
7 Material Jetting
8 Powder Bed Fusion
9 Sheet Lamination
10 VAT Photopolymerization
11 Other (specify)
12 Other (specify)
13 Other (specify)
Explain:
U.S. Government Defense
U.S. Government Non-Defense
U.S. Commercial Defense
U.S. Commercial Non-Defense
Non-U.S. Government Defense
Non-U.S. Government Non-Defense
Non-U.S. Commercial Defense
Non-U.S. Commercial Non-Defense
Unkown
Customized Parts
Cost-effectiveness
Mobile Pricing Capability
Low Volume Production
Increased Innovation Opportunities
Overcoming Previous Engineering Limitations
Lightweight Products
More Accurate/Uniform Parts
Time Savings
Other
D. From 2013-2016, estimate the dollars invested into propulsion-related A.M./3-D (including equipment, facilities, specialists, etc.) in your organization.
Record $ in Thousands, e.g. $12,000.00 = survey input of $12
2013
2014
2015
2016
Estimated dollars invested
By frequency of use, list your organization's leading five A.M./3-D machines.
Name of Machine
Brand
Supplier
Supplier Country
Year Obtained
A.M./3-D Printing Process Type (from Part C above)
1
2
3
4
5
Drop-down is based on responses to Section C above
During the next five years, does your organization intend to invest in A.M./3-D technology and/or capabilities?
If yes, select the primary application area and primary process type corresponding to your organization's leading three areas for A.M./3-D adoption. Explain your response
Primary Application Area
Primary A.M./3-D Printing Process Type
Direct Manufacturing
Prototyping
Research and Development
Tooling/Machining
Integration into systems and/or subsystems
A.M./3-D Design (as a product/service)
A.M./3-D Design (to outsource)
Other
None
3-D Welding
Binder Jetting
Continuous Liquid Interface Production
Directed Energy Deposition
Machining/finishing A.M./3-D Products
Material Extrusion
Material Jetting
Powder Bed Fusion
Sheet Lamination
VAT Photopolymerization
Other
Direct Manufacturing
Prototyping
Research and Development
Tooling/Machining
Integration into systems and/or subsystems
A.M./3-D Design (as a product/service)
A.M./3-D Design (to outsource)
Other
None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Section 15a: Capital Expenditures/Capacity
From 2013-2016, record your organization's capital expenditures corresponding to the select categories.
Note: If your organization declared in Section 1a that this survey is a Business Unit/Division-level response, this section should contain only Business Unit/Division-level data.
Corporate/Whole Organization
Business Unit/Division
Source of Capital Expenditure Data:
Capital Expenditure Reporting Schedule:
Calender Year
Fiscal Year
Capital Expenditure Category
Record in $ Thousands, e.g. $12,000.00 = survey input of $12
2013
2014
2015
2016
A.
a. Total Capital Expenditures
1 Machinery, Equipment, and Vehicles [as a % of a]
2 IT, Computers, and Software [as a % of a]
3 Land, Buildings, and Leasehold Improvements [as a % of a]
4 Other (specify)
5 Other (specify)
(Lines 1 through 5 must sum to 100%)
0%
0%
0%
0%
6 Propulsion-related capital expenditures [as a % of a]
Yes
No
Yes
No
Yes
No
B.
From 2013-2016, were your organization's overall and propulsion-related capital expenditures adversely impacted by reductions in U.S. Government spending? From 2017-2020, does your organization anticipate these same expenditures will be adverse impacted by reductions/fluctuations in U.S. Government spending?
2013-2016
2017-2020
Overall
Propulsion-related
Explain:
C.
Record your organization's utilization rates. For purposes of this survey, "utilization" is the fraction of an organization's potential output that is actually being used in current production, where potential output is based on a 7 day-a-week, 3x8-hour shift production schedule.
Note: 100% utilization rate equals no downtime with full employment.
Yes
No
Overall
Propulsion-related?
1 For 2016, record your organization's average utilization rate for both overall and propulsion-related operations
1 In the event of a surge in demand, how many weeks would it take your organization to raise both its overall and propulsion-related utilization rates to 100 percent?
Explain:
2 Based on the list of constraint types, describe the specific constraints your organization would face in meeting a surge in demand for propulsion-related products. Provide a brief description of each constraint as applied to your organization. Leave blank those areas for which no constraint exists.
Type of Constraint
Explain
Capital: Equipment, Facilities, Infrastructure
Funding: Access to Adequate Funding
Inventory: Availability of Input Materials
Quality Control: Evaluation/Testing/Validation
Workforce: Labor Availability, Costs
Other (specify)
From 2013-2016, has your organization owned or leased any machinery or tooling specifically for U.S. Government propulsion-related products/services?
Yes
No
Not Applicable
Record your organization's 10 most key/critical machinery and tooling (including A.M./3-D machines) used for U.S. Government propulsion-related products and services. For each machine/tool identified by name, document its use/purpose, level of ownership, system/program use (specified in Section 5c), and current status. Explain your response.
D.
Machine/Tool
Use/Purpose
Level of Ownership
System/Program Use
Current Status
Explain
1
2
3
4
5
6
7
8
9
10
Owned
Leased
GFE
Combination
Other
Drop-down is based on responses to Section 5c, B
Idle
Mothballed
In-use
Re-tooled/rebuilt for Non-USG products/services
Other
Comments:
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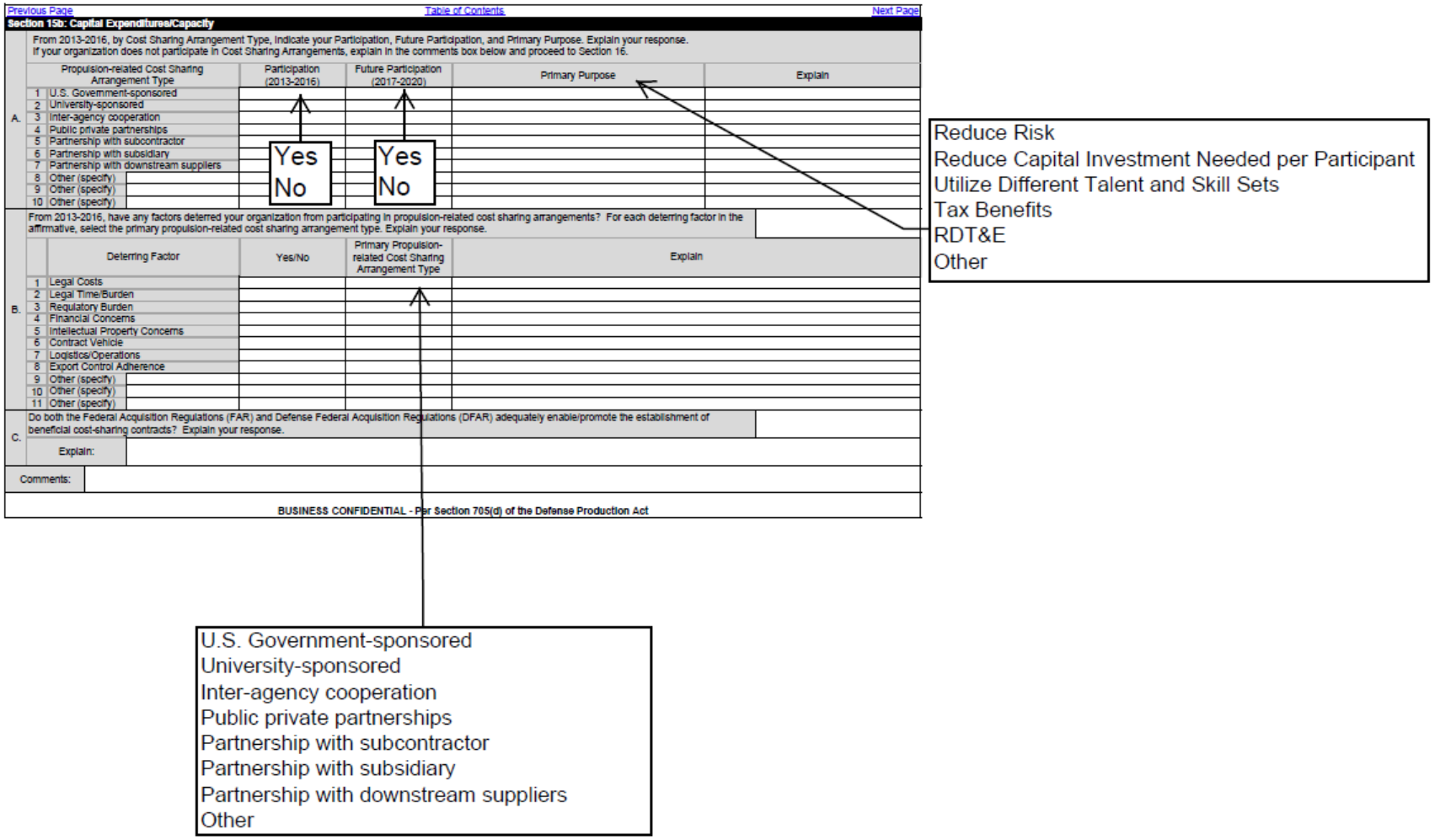

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Section 15b: Capital Expenditure/Capacity

From 2013-2016, by Cost Sharing Arrangement Type, indicate your Participation, Future Participation, and Primary Purpose. Explain your response.
If your organization does not participate in Cost Sharing Arrangements, explain in the comments box below and proceed to Section 16.

A.

	Propulsion-related Cost Sharing Arrangement Type	Participation (2013-2016)	Future Participation (2017-2020)	Primary Purpose	Explain
1	U.S. Government-sponsored				
2	University-sponsored				
3	Inter-agency cooperation				
4	Public private partnerships				
5	Partnership with subcontractor				
6	Partnership with subsidiary				
7	Partnership with downstream suppliers				
8	Other (specify)				
9	Other (specify)				
10	Other (specify)				

Yes / No

Yes / No

B. From 2013-2016, have any factors deterred your organization from participating in propulsion-related cost sharing arrangements? For each deterring factor in the affirmative, select the primary propulsion-related cost sharing arrangement type. Explain your response.

	Deterring Factor	Yes/No	Primary Propulsion-related Cost Sharing Arrangement Type	Explain
1	Legal Costs			
2	Legal Time/Burden			
3	Regulatory Burden			
4	Financial Concerns			
5	Intellectual Property Concerns			
6	Contract Vehicle			
7	Logistics/Operations			
8	Export Control Adherence			
9	Other (specify)			
10	Other (specify)			
11	Other (specify)			

C. Do both the Federal Acquisition Regulations (FAR) and Defense Federal Acquisition Regulations (DFAR) adequately enable/promote the establishment of beneficial cost-sharing contracts? Explain your response.

Explain:

Comments:

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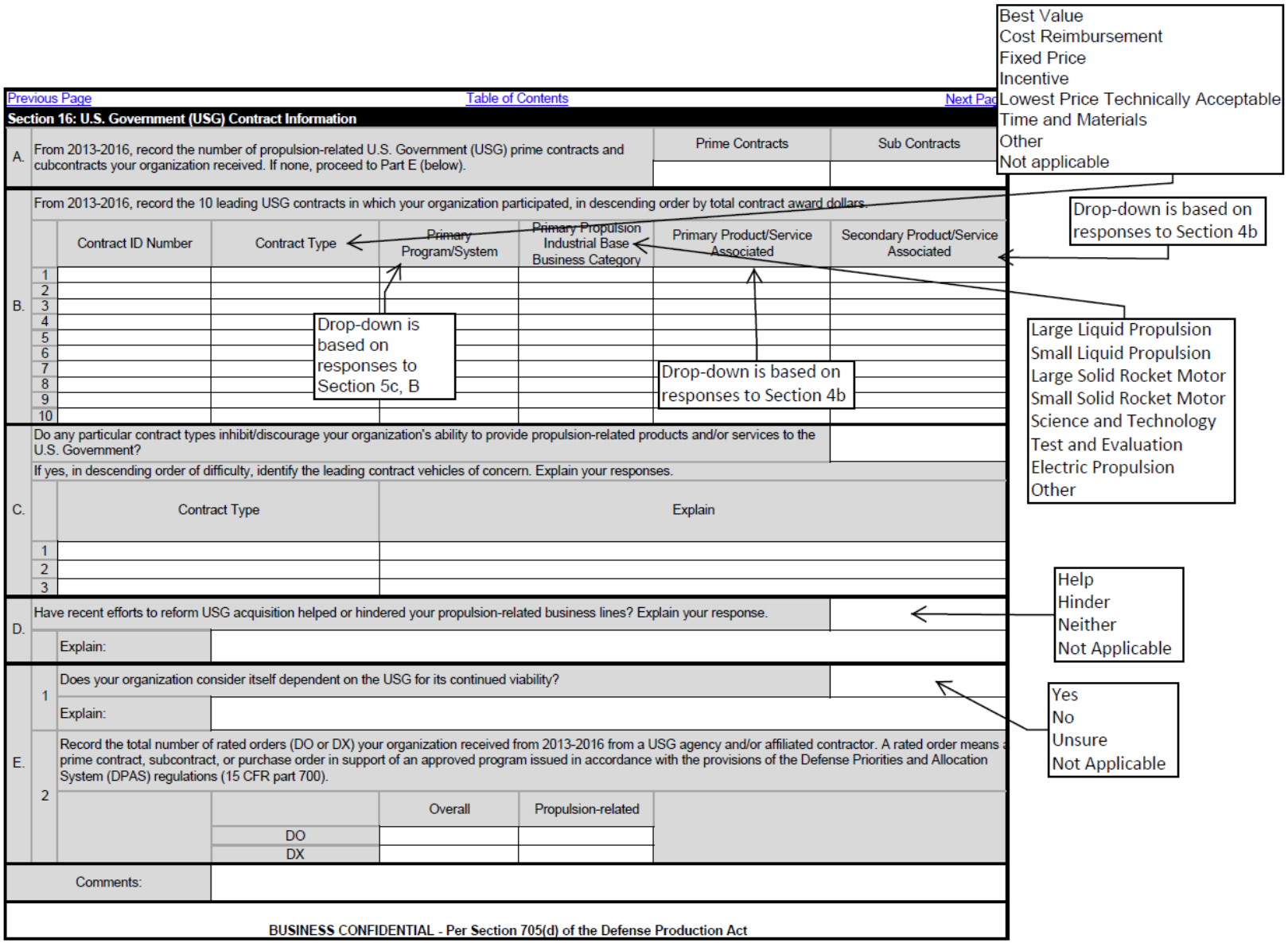
Reduce Risk
Reduce Capital Investment Needed per Participant
Utilize Different Talent and Skill Sets
Tax Benefits
RDT&E
Other

U.S. Government-sponsored
University-sponsored
Inter-agency cooperation
Public private partnerships
Partnership with subcontractor
Partnership with subsidiary
Partnership with downstream suppliers
Other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Section 16: U.S. Government (USG) Contract Information
A.
From 2013-2016, record the number of propulsion-related U.S. Government (USG) prime contracts and cubcontracts your organization received. If none, proceed to Part E (below).
Prime Contracts
Sub Contracts
B.
From 2013-2016, record the 10 leading USG contracts in which your organization participated, in descending order by total contract award dollars.
Contract ID Number
Contract Type
Primary Program/System
Primary Propulsion Industrial Base Business Category
Primary Product/Service Associated
Secondary Product/Service Associated
1
2
3
4
5
6
7
8
9
10
Drop-down is based on responses to Section 5c, B
Drop-down is based on responses to Section 4b
C.
Do any particular contract types inhibit/discourage your organization's ability to provide propulsion-related products and/or services to the U.S. Government?
If yes, in descending order of difficulty, identify the leading contract vehicles of concern. Explain your responses.
Contract Type
Explain
1
2
3
D.
Have recent efforts to reform USG acquisition helped or hindered your propulsion-related business lines? Explain your response.
Explain:
E.
1
Does your organization consider itself dependent on the USG for its continued viability?
Explain:
2
Record the total number of rated orders (DO or DX) your organization received from 2013-2016 from a USG agency and/or affiliated contractor. A rated order means a prime contract, subcontract, or purchase order in support of an approved program issued in accordance with the provisions of the Defense Priorities and Allocation System (DPAS) regulations (15 CFR part 700).
Overall
Propulsion-related
DO
DX
Comments:
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Best Value
Cost Reimbursement
Fixed Price
Incentive
Lowest Price Technically Acceptable
Time and Materials
Other
Not applicable
Drop-down is based on responses to Section 4b
Large Liquid Propulsion
Small Liquid Propulsion
Large Solid Rocket Motor
Small Solid Rocket Motor
Science and Technology
Test and Evaluation
Electric Propulsion
Other
Help
Hinder
Neither
Not Applicable
Yes
No
Unsure
Not Applicable

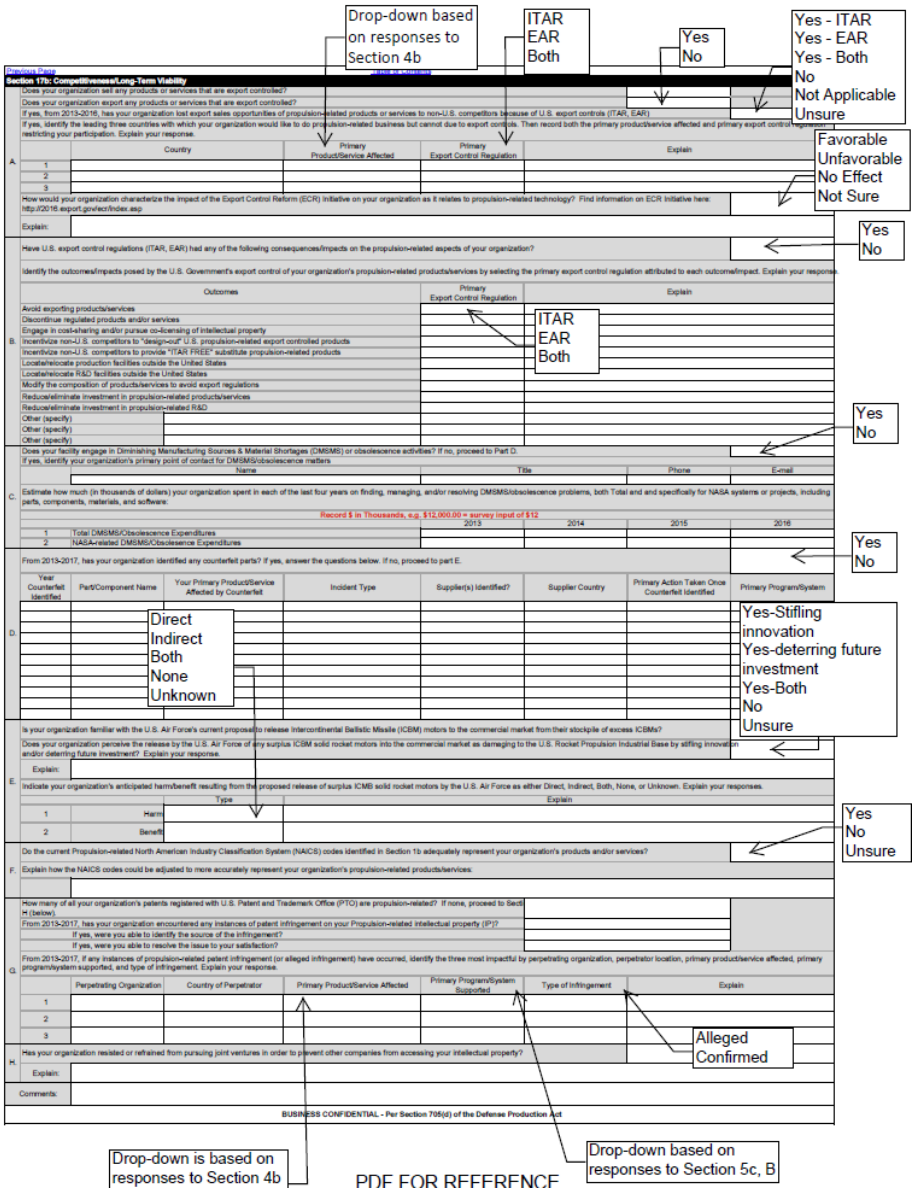
Section 17a: Competitiveness/Long-Term Viability

Identify the issues negatively impacting your organization's propulsion-related operations. Then rank the five issues most negatively impacting your organization (1 = most negative impact) by writing in numbers 1-5 next to only the five most negatively impactful issues. Each number should be recorded only once. Explain each of your five most negatively impactful issues.

	Issue	Negative Impact	Rank (Top 1-5)	Explain
	Access to USG R&D Funding			
	Aging Equipment, Facilities, or Infrastructure			
	Availability of Capital			
	Barriers to Entry in the Commercial Space Market			
	Buy American Act Waivers			
	Competition - Domestic			
	Competition - Foreign			
	Counterfeit Parts			
	Cyber Security Breaches			
	Difficulty Presenting New, Innovative Products to the U.S. Government			
	DMSMS Design-out/Substitution			
	Environmental Regulations/Remediation			
	Export Controls/ITAR Regulations			
	Government Acquisition Process			
	Government Purchasing Volatility			
	Government Regulatory Burden			
	Healthcare			
	High Fixed Costs			
	Import Restrictions/Tariffs			
	Inability to Adopt New Production Methods			
	Labor Availability			
	Labor Costs			
	Labor Skills			
	Material Availability - Non-U.S.			
A.	Material Availability - U.S.			
	Material Price Volatility			
	Non-U.S. Subsidies			
	Pension Costs			
	Physical Security Breaches			
	Program/System Cancellation			
	Proximity to Customers			
	Proximity to Suppliers			
	QA/QC requirements (costs, lead time, standard implementation, etc.)			
	Quality of Inputs			
	Reduction in U.S. Government Demand			
	Requalification/Recertification			
	Research and Development Costs			
	Sequestration			
	Skills Retention			
	Software Assurance			
	Supplier Reliability - Non-U.S.			
	Supplier Reliability - U.S.			
	Taxes			
	Testing (internal)			
	Testing (procured) - Commercial Site			
	Testing (procured) - US Government Site			
	Transportation of End-product			
	Transportation of Supplies			
	U.S. Patent Infringement by Non-U.S. Actors			
	U.S. Patent Infringement by U.S. Actors			
	Other (specify)			
	Other (specify)			
	Other (specify)			

Yes
No
Not Applicable

Comments:	



Internal IT Department
Internal IT department and external U.S. service provider
Internal IT Department and external Non-U.S. service provider
Only U.S. external service provider
Only Non-U.S. external service provider
Both U.S. and Non-U.S. service providers
Not Applicable

Calender Year
Fiscal Year

Yes
No

Internal IT Department
Internal IT department and external U.S. service provider
Internal IT Department and external Non-U.S. service provider
Only U.S. external service provider
Only Non-U.S. external service provider
Both U.S. and Non-U.S. service providers
Not Applicable

Yes
No
Unsure

Yes
No
Unsure
Not Applicable

No
Restrict
Prohibit
Unknown

Yes
No
Unsure
Not Applicable

Yes
No
Unsure
Not Applicable

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Section 18: Cyber Security

A. Estimate your organization's spending on physical and cyber security, in thousands of dollars:

Reporting Schedule:

Record $ in Thousands, e.g. $12,000.00 = survey input of $12

	2013	2014	2015	2016
Cybersecurity Expenditures				
Physical Security Expenditures				

B. Is your organization aware of Defense Federal Acquisition Regulation Supplement (DFARS) 252.204-7009, Limitations on the Use or Disclosure of Third-Party Contractor Reported Cyber Incident Information?
http://www.acq.osd.mil/dpap/dars/dfars/html/current/252204.htm

C.

		Internal Network	External Network
1	What group is responsible for administering your organization's computer networks?		

2	Is the computer or computer network that houses your organization's Commercially Sensitive Information* (CSI) connected to the Internet, either directly or via an intermediary network or server?	
3	Estimate the percentage of your organization's CSI stored with external data/cloud storage provider(s):	
4	Does your organization either restrict or prohibit your external data/cloud storage provider(s) from storing CSI outside of the U.S.?	

5 Indicate whether your organization typically encrypts CSI data in each of the following states:

In storage (at rest):	Transmitted across internal networks	Transmitted outside your organization's networks

*Privileged or proprietary information which, if compromised through alteration, corruption, loss, misuse, or unauthorized disclosure, could cause serious harm to the organization owning it. This includes customer/client information, financial information and records, human resources information, intellectual property information, internal communications, manufacturing and production line information, patent and trademark information, research and development information, regulatory/compliance information, and supplier/supply chain information.

D. Indicate the security measures your organization currently has in place:

Account Monitoring and Control		Inventory of Authorized/Unauthorized Software	
Application Software Security		Limitation/Control of Network Ports and Services	
Boundary Defense		Maintenance, Monitoring, & Analysis of Audit Logs	
Continuous Vulnerability Assessment		Malware Defenses	
Controlled Access Based on Need to Know		Penetration Tests and Red Team Exercises	
Controlled Use of Administrative Privileges		Secure Configurations on Hardware	
Data Protection		Secure Configurations of Network Devices	
Data Recovery Capability		Secure Network Engineering	
Incident Response and Management		Security Skills Assessments and Training	
Inventory of Authorized/Unauthorized Devices		Wireless Access Control	
Other (specify)		Other (specify)	

E.

1	Is your organization able to detect the theft of, or unauthorized access to, Commercially Sensitive Information by cyber means?	
2	Does your organization have defined, written protocols in place for responding to a cyber security breach?	
	Explain:	

3 Identify any impacts or actions resulting from malicious cyber activity from 2013-2016:

Impacts Experienced		Actions Undertaken		
IT downtime		Revised approach to international partnerships		
Costs from damage assessment/remediation		Significant change in R&D strategy		
Loss of sales/business interruption		Exit from foreign markets or market segments		
Exfiltration of CSI data		Exit from product or business line		
Damage to IT infrastructure		Major new investment in cyber security		
Damage to production capabilities or systems		Other	(specify here)	
Theft of software and/or source code		Other	(specify here)	
Other (specify here)		Other	(specify here)	

Note: The FBI encourages recipients to report information concerning suspicious or criminal activity to their local FBI field office or the FBI's 24/7 Cyber Watch (CyWatch). Field office contacts can be identified at http://www.fbi.gov/contact-us/field. CyWatch can be contacted by phone at 855-292-3937 or e-mail at CyWatch@ic.fbi.gov. When available, each report submitted should include the date, time, location, type of activity, number of people, and type of equipment used for the activity, the name of the submitting organization, and a designated point of contact.

Comments:

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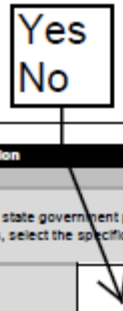

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Section 18: Outreach Information

	Outreach									
	There are many federal and state government programs and services available to assist your organization to better compete in the global marketplace. If your organization would like information regarding these government programs, select the specific areas of interest below. The U.S. Department of Commerce will follow-up with your organization regarding your selections.									
A	Continuous Improvement/ Lean Manufacturing		Export Assistance		Prototyping		Technology Acceleration			
	Cybersecurity		Export Licensing (ITAR/EAR)		Quality Management and Control		Vendor/Material Sourcing			
	Design for Assembly		Government Procurement Guidelines		Research and Development (R&D) Assistance and Partnership		Other	(specify here)		
	Design for Manufacturability		Market Expansion/Business Growth		Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) contracts		Other	(specify here)		
	Energy and Environmentally Conscious Manufacturing		Product Design		Supply Chain Optimization		Other	(specify here)		
	Comments:									

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Section 20: Certification

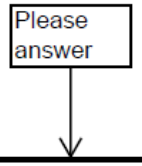
The undersigned certifies that the information herein supplied in response to this questionnaire is complete and correct to the best of his/her knowledge. It is a criminal offense to willfully make a false statement or representation to any department or agency of the United States Government as to any matter within its jurisdiction (18 U.S.C.A. 1001 (1984 & SUPP. 1197)).

Once your organization has completed this survey, save a copy and submit it via the Census portal. Be sure to retain your survey for your records and to facilitate any necessary edits or clarifications.

BIS Survey Website https://www.bis.doc.gov/propulsion

Organization Name	
Organization's Internet Address	
Name of Authorizing Official	
Title of Authorizing Official	
E-mail Address	
Phone Number and Extension	
Date Certified	

In the box below, provide any additional comments or any other information you wish to include regarding this survey assessment.



How many hours did it take to complete this survey?	

BUSINESS CONFIDENTIAL - Per Section 705(d) of the Defense Production Act

Appendix B. Vendor Questionnaire

August 1, 2019

NESC-EE04L-C104

To Whom It May Concern:

As we, at NASA, continually strive to improve ourselves as an organization, we are seeking feedback from our aerospace valve suppliers and system integrators on how we conduct business. We would like to understand how we can improve the aspects of valve development or procurement processes without compromising the quality of the hardware needed for our unique missions.

Representatives from NASA would like to speak with you regarding improvements that could be made in the acquisition practices, how valve development is pursed, the requirements levied on the design, fabrication and testing of valves, and other issues that your company faces that affect the delivery of flight hardware.

Listed below are a series of questions which represent the types of issues that we wish to work on to better understand the vendor's point of view. We would like to know of any issues that you have had so that we may change our practices to better support your needs and requirements.

If possible, we wish to speak with a company representative. The meeting would be approximately 1 hour. However, if a meeting is not possible, we gladly accept written responses.

The questions are as follows:

1. Overall Aerospace Valve Business:
    a. In the past 5 years, has your company experienced any major increases or decreases in its overall workload? If so, please describe any issues the change have caused in terms of being able to deliver aerospace hardware.

    b. Has the lack of steady orders from NASA created problems?

    c. Please describe your company's approach to research and development.

    d. Is there a high turnover rate at your company or your sub tier suppliers, and has it affected your ability to supply hardware?

    e. Has there been an "age-out" of qualified personnel in your facility?

    f. What are the top three challenges that affect your ability to provide top-quality hardware on schedule and on a budget?

2. NASA-Specific Business:
    a. Are there design and construction requirements that NASA levies on flight programs that you feel are non-value added or that do not improve the quality of your product?

    b. Is NASA accepting "heritage" designs without thoroughly assessing their relevance to new requirements?

3. NASA as a Customer: What can we do to improve?
    a. Do you have any recommendations on how NASA could improve the way it currently conducts business or specific requirements for aerospace components?

    b. Do you have any issues or concerns regarding control of intellectual property on NASA related contracts?

    c. Is NASA pushing you to economize scheduling; therefore, leading to reduced quality or performance?

    d. Is NASA or their integrators, to whom they provide hardware, providing inexperienced personnel for insight or oversite; therefore, leading to reduced quality and performance?

If there are other topics that would produce better feedback beyond what is listed above, please let me know. Overall, we wish to improve our processes and communication.

Please email all responses to David Eddleman at David.E.Eddleman@nasa.gov, or contact him by phone at 256-544-6410.

Daniel J. Dorney, Ph.D.
NASA Technical Fellow for Propulsion

cc:
HQ/Office of the Chief Engineer/Mr. Roe
NESC/102/Mr. Wilson
NESC/EE04L-C104/Dr. Dorney
MSFC/ER33/Mr. Eddleman

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
03/27/2020	Technical Memorandum	

4. TITLE AND SUBTITLE
Aerospace Valve Industrial Base and Acquisition Practices Assessment

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Dorney, Daniel J.; Eddleman, David E.; Richard, James A.; Ward, W. Kevin; Johnson, Dexter; Dube, Michael

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER
869021.03.07.01.10

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
NASA Langley Research Center
Hampton, VA 23681-2199

8. PERFORMING ORGANIZATION REPORT NUMBER
L-21132

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Aeronautics and Space Administration
Washington, DC 20546-0001

10. SPONSOR/MONITOR'S ACRONYM(S)
NASA

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
NASA/TM-2020-220577

12. DISTRIBUTION/AVAILABILITY STATEMENT
Unclassified - Unlimited
Subject Category 16 Space Transportation and Safety
Availability: NASA STI Program (757) 864-9658

13. SUPPLEMENTARY NOTES

14. ABSTRACT
Based on some recent valve issues, it was requested that the NASA Engineering and Safety Center assess the aerospace valve industrial base. A three-pronged approach was used to accomplish the assessment. Based on survey data and subject matter expert evaluations, it was determined that the industry as a whole does not appear to be eroding or in decline.

15. SUBJECT TERMS
Valves; Industrial Base; Design; Standards; Department of Commerce

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			STI Help Desk (email: help@sti.nasa.gov)
U	U	U	UU	58	19b. TELEPHONE NUMBER *(Include area code)* (443) 757-5802