A Report by a Panel of the

NATIONAL ACADEMY OF PUBLIC ADMINISTRATION

for the United States Department of Commerce

Space Traffic Management

NATIONAL ACADEMY OF PUBLIC ADMINISTRATION®

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For the Office of Space Commerce, the Department of Commerce

Space Traffic Management:

Assessment of the Feasibility, Expected Effectiveness, and Funding Implications of a Transfer of Space Traffic Management Functions

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Established in 1967 and chartered by Congress in 1984, the Academy continues to make a positive impact by helping federal, state, and local governments respond effectively to current circumstances and changing conditions. Learn more about the Academy and its work at www.napawash.org.

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Foreword

Space satellites serve a myriad of vital terrestrial purposes connected with national security, scientific research, and commercial aims. As the space domain becomes increasingly congested with space objects and debris, there is a corresponding increase in the risk of orbital collisions. There is general agreement within the space community on actions that can address the complex underlying space traffic management issues facing the world of stakeholders deploying orbital assets. However, there are questions regarding where the responsibility for space traffic management should ultimately reside.

At the direction of Congress, the Office of Space Commerce, within the Department of Commerce, contracted with the National Academy of Public Administration (the Academy) to complete this independent and unbiased review to identify the best organization to assume the mission of space traffic management. This research was led by a five-member Panel of Academy Fellows, supported by an Academy study team.

This report identifies the federal organization best suited for this critical mission and calls for urgent action by Congress to authorize and appropriate adequate funding to it to accomplish the space traffic management function. This agency should work collaboratively and creatively across government and non-government sectors, both domestic and international, to help identify and shape effective strategies to mitigate these risks across the space ecosystem.

As a congressionally chartered, independent, non-partisan, and non-profit organization with over 900 distinguished Fellows, the Academy has a unique ability to bring nationally recognized public administration experts together to help government agencies address challenges. We greatly value the constructive engagement of the more than 100 individuals representing a broad array of stakeholders who provided important observations and context to inform this report.

I am deeply appreciative of the work of the five Academy Fellows who served on this Panel. I also commend the Academy study team that researched, analyzed, and contributed valuable insights and expertise throughout the project.

This report provides clear recommendations on how Congress and the stakeholder community should expeditiously proceed to address the looming crisis in space. Taking prompt action will serve to greatly enhance important commercial and research enterprises connected with the endless expanse that lies above us.

Teresa W. Gerton
President and Chief Executive Officer

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Acronyms and Abbreviations

Acronym or Abbreviation	Definition
Academy	National Academy of Public Administration
AFRL	Air Force Research Laboratory
AIAA	American Institute of Aeronautics and Astronautics
AST	Office of Commercial Space Transportation (FAA)
ASTM	American Society for Testing and Materials International
AVC/ESC	Bureau of Arms Control, Verification, and Compliance, Office of Emerging Security Challenges (State Department)
CA	Conjunction assessment
CCSDS	Consultative Committee for Space Data Systems
CNES	*Centre National D'Etudes Spatiales* (National Centre for Space Studies)
COMSTAC	Commercial Space Transportation Advisory Committee
CONFERS	Consortium for the Execution of Rendezvous and Servicing Operations
CoE	Center of Excellence for Commercial Space Transportation (FAA)
CSpOC	Combined Space Operations Center
COPUOS	United Nations Committee on the Peaceful Uses of Outer Space
CPR	Common pool resource
CRS	Commercial remote sensing
DME	Design, modernization, and enhancement
DOC	Department of Commerce
DoD	Department of Defense
DOT	Department of Transportation
ECSS	European Cooperation for Space Standardization
ESA	European Space Agency
EU	European Union
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FAA	Federal Aviation Administration
FCC	Federal Communications Commission
FFRDC	Federally Funded Research Development Center

FTE	Full-time equivalent
FY	Fiscal Year
GAO	Government Accountability Office
GEO	Geostationary *or* Geosynchronous Orbit
IAD	Institutional Analysis and Design
IADC	Inter-Agency Space Debris Coordination Committee
ISO	International Organization for Standardization
ISS	International Space Station
ITU	International Telecommunications Union
LEO	Low Earth orbit
LRP	Launch regulatory process
MEO	Medium-Earth orbit
NASA	National Aeronautics and Space Administration
NEPA	National Environmental Policy Act
NESDIS	National Environmental Satellite, Data, and Information Service
NIEM	National Information Exchange Model
NIST	National Institute of Standards and Technology (DOC)
NOAA	National Oceanic and Atmospheric Administration
NPD	NASA Policy Directive
NPR	NASA Procedural Requirement
NPRM	Notice of proposed rulemaking
NSF	National Science Foundation
NTIA	National Telecommunications and Information Administration (DOC)
NTIS	National Technical Information Service (DOC)
NWS	National Weather Service (NOAA)
OADR	Open Architecture Data Repository
OD	Orbit Determination
OECD	Organization for Economic Cooperation and Development
O&M	Operations and maintenance
OSC	Office of Space Commerce (NOAA)
R&D	Research and Development

RF	Radio frequency
RFI	Radio frequency interference
RSO	Resident space object
SDA	Space Data Association
SDTC	Search, discover, track, and characterize
SIA	Satellite Industry Association
SMC	Space and Missile Systems Center (DoD)
SPD-3	Space Policy Directive-3
SSA	Space situational awareness
SSN	Space Surveillance Network
SST	Space Surveillance and Tracking
STM	Space traffic management
SWPC	Space Weather Prediction Center (NOAA)
UDL	Unified Data Library (DoD)
UNOOSA	United Nations Office for Outer Space Affairs
U.S.C.	United States Code
USGS	United States Geological Survey
USSF	United States Space Force

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Executive Summary

As space becomes increasingly congested with ever larger numbers of domestic and foreign commercial companies, researchers, universities, and military/intelligence agencies launching orbital assets, the issue of space traffic management (STM) becomes ever more salient. With the risk of orbital collisions growing astronomically, we face a crisis that must be urgently addressed in order to facilitate orbital safety and enhance commercial and research advances using this important domain. At the request of the Congress, this report identifies a civilian government agency best suited to lead the STM function outside of the national security sphere. This agency should be authorized and funded with all due haste by Congress in order to improve the safety and sustainability of orbital space, and to bolster American leadership in this commercially strategic domain.

The appropriations act for Fiscal Year (FY) 2020 in the Senate Amendment to H.R. 1158, Division B (116th Congress) provided appropriations to the Department of Commerce (DOC) to contract with the National Academy of Public Administration (the Academy) to conduct an independent review. The legislative language calls for the independent review to include:

1. An assessment of which department or agency and entity within the department or agency is best suited for responsibility for space traffic management;
2. Any statutory, regulatory or licensing authorities necessary to facilitate such a transfer;
3. Funding implications, including infrastructure and personnel costs;
4. Consultation with appropriate officials from the Departments of Defense, Commerce, and Transportation, NASA, the Director of National Intelligence, other relevant Federal agencies, industry, and other stakeholders; and
5. Data integrity, information technology, and national security considerations.

This report of an Academy Panel of Fellows provides an assessment to consider which of the following four agency candidates is best suited to take on the STM task: (1) the Office of Space Commerce (OSC), a part of National Oceanic and Atmospheric Administration (NOAA) inside the Department of Commerce (DOC); (2) Office of Commercial Space Transportation (AST), part of the Federal Aviation Administration (FAA) inside the Department of Transportation (DOT); (3) the National Aeronautics and Space Administration (NASA); or (4) the Department of Defense (DoD). The report examines strengths and challenges of each agency in its respective current roles, and potential future roles, in space situational awareness (SSA) and STM. There is a clear emphasis throughout this report, based on this assessment, that these and other agencies must continue to work collaboratively now, and in the future, to achieve a safer space domain. In that sense, the report addresses the congressional mandate practically and holistically, recognizing that these agencies play important roles in the space domain going forward. Utilizing those capabilities (and those of other entities) will enable this task to be carried out with greater speed, efficiency, and effectiveness.

The assessment and decision-making approach approved by the Panel is guided by the following integrated set of research principles:

a. Implement an independent, unbiased assessment, bearing in mind that there are recent decisions and other developments within and outside of government that merit consideration in an appropriate manner.

b. Describe specific features of an optimal operating model for STM based on extensive research with a broad array of documentary sources and interviews with actors operating in the domain. In this respect, the Panel determined that SSA is a precursor to performing the STM function. As such, SSA and STM should be combined and conceptualized as an ecosystem, and thus the operating model and evaluation includes both functions.

c. Identify specific technical and non-technical skills and characteristics that can be assessed in order to compare candidate agencies to perform STM.

d. Consider all reasonable candidate federal agencies that might perform this task.

e. Map and then compare agencies against the list of skills and characteristics in order to evaluate each agency's suitability and potential ability to do this task optimally.

f. The Panel's decision-making process is as follows: select the agency deemed to be closest to building the ideal operating model, exhibiting the technical and non-technical skills as best as can be ascertained, and guided by skills and capabilities needed to perform this function with a focus on both domestic and international dimensions.

The functions of SSA and STM are complex and varied, posing a challenge to any agency that seeks to arrive at anything other than a dynamic list that may change frequently over time as technologies and the emerging industry rapidly advance. Considering how SSA and STM functions are connected with scientific and data technological advancements that are changing rapidly with respect to this domain, it is right to be cautious about detailing a one-time list of capabilities. In this dynamically changing domain and marketplace, the only thing that is certain is that the STM function is centrally important and will require flexibility and creativity by an agency that will take the main STM role.

In light of the complexities and diversity of STM tasks and functions, it is difficult to conclude in a simple manner that there is one agency to take on this function. The optimal approach in considering an agency to take the lead in STM is to, first, avoid building a "one stop shop." There cannot be, and should not be, a stand-alone provider of STM services. However, one agency needs to take the lead in STM, albeit with a light touch, in order not to forestall the learning and adaption needed in this dynamic, rapidly evolving domain. Given this situation, it is difficult to confirm one agency that is "best suited" for this function, which is the congressional language used in the genesis of this report. Like many complex policy areas in the federal government, several agencies must coordinate and collaborate in order to perform this critical work.

Notwithstanding these challenges, an important contribution of this report is to present an ideal operating model that encompasses several features. The primary aim of a civilian agency coordinating STM should be to advance commercial and research uses of space, separate from that part of the space domain that is a focus of national security. To do so, the agency should adopt a network model, with major focus both on working collaboratively with all actors engaged in this domain, both domestic and international, and enhancing safe orbital operations in this increasingly congested environment so as to foster innovation and a growing space economy that effectively and efficiently serves terrestrial life. Over time, this agency should lead domestic and international efforts to collaboratively formulate "rules of the road" that can build a safer operating environment for the diverse universe of space actors.

The Panel incorporates an analytical model to include a systematic review of technical and non-technical capabilities required to perform SSA and STM, an assessment of departmental support for this work, and an evaluation of an operating model for those agencies actively willing to be considered to perform this function (neither DoD nor NASA, for example, expressed an interest to perform SSA/STM across the commercial space domain). In order to minimize the potential for subjectivity, the report describes weights and evaluative criteria used that yielded comparative scores as to the suitability of these four agency candidates. It is recognized that some readers might evaluate certain components of this evaluative matrix differently than what is presented. That said, it is important to provide transparency that might enable a clearer understanding of the report's conclusion.

Following its evaluative criteria, the Panel determines OSC to be best suited to perform STM tasks within the federal government. In performing the STM function, OSC consistently describes its concept of operations with a main purpose to work collaboratively with military, non-military, domestic, and international actors in order to maintain a sustainable space domain in which commercial and research activities may thrive. OSC views its STM responsibilities principally as a data management function, rather than principally as a task of managing space traffic. Furthermore, its operating plan to move forward is not defined by a vision to build a large bureaucratic structure, but rather is intended to set about its organizational development following a collaborative model that places the highest priority on serving as a trusted convener, coordinator, and provider of respected leadership for the larger domestic and international community. Flexibility and creativity are core features of the OSC vision to serve in this capacity, as innovation, new discoveries, and allowing creative commercial companies to thrive will best serve the strategic interests of the Nation, and the international space community. Thus, OSC must have an adaptive leadership style—tantamount to managing a nimble, federal agency start-up operation—recognizing that the nascent concept of STM will change over the coming years as the space domain becomes more congested, and the commercial appetite for a greater facilitation role leads to increasing demand for coordination, and even space traffic "management." OSC, no matter how the future unfolds, must work closely with its inter-governmental partners and effectively tap the many supporting resources available within its Department.

There are important technical capabilities that accompany this work which must be built with appropriate funding and robust engagement with external and other government stakeholders. In addition, several other DOC components, particularly within NOAA and the National Telecommunications and Information Administration (NTIA), are already providing critical, state-of-the-art support to OSC. These intra-departmental resources provide timely, essential, technical expertise and support to the new tasks required to be performed, serving as both force and resource multipliers. This strong support from the Department as a whole, along with a proven ability to serve as a manager of diverse, enormous and highly complex datasets under NOAA, contribute to the Panel's confidence that OSC is best suited to perform this function.

In this analysis, the Panel identified AST and NASA as potentially attractive candidates to perform the STM function. Indeed, there are many strong features and contributions to the commercial space environment provided by AST, including its proven track record of regulating pre-launch and re-entry of private sector space vehicles. It is critical that AST maintain its able leadership in the sphere of regulating launch and reentry, especially as it faces an upsurge in the volume of launches. In addition, NASA should continue in its important role to serve the nation and the world in its work in research, scientific development, and discovery. Thus, the Panel recognizes the important roles that AST and NASA play in the space domain and stresses the criticality of a continued close collaboration between OSC and these agencies going forward.

The role of DoD also remains critical to mission success in STM. OSC must find ways to leverage the DoD data and capabilities to produce them in order to advance this important mission. DoD and other national security agencies have capabilities that are classified and should remain so, but there is opportunity for OSC to use these while safeguarding national security to benefit the commercial space sector appropriately.

OSC must also remain actively engaged with the Department of State, FCC, and all other agencies with important roles to ensure there is close collaboration that enhances confidence in U.S. government leadership across all actors, friend and even foe. Indeed, the national security interests of the United States are well served when this agency can take a leading role as a gatherer and provider of trusted SSA and STM for all stakeholders from all countries.

As a next step, the Panel requests that the Congress enact, without delay, appropriations and any required authorities for OSC to build this critical capability with requisite personnel, office infrastructure, and authorities, as needed, to carry out the task of integrating whole of government capabilities to provide SSA and STM. Congressional action should ensure that the OSC has the requisite on-orbit authority allowing it to promulgate STM regulation(s), as and when appropriate, for orbital operations that fall outside the current licensing and continuing supervision framework. The Congress should also act without delay to provide DOC with the correct mix of appropriated funds and the authority to assess and utilize fees. With respect to transition of SSA information to non-U.S. Governmental entities from both DoD and DOC, OSC already has the authority to collect, share, analyze and disseminate data. That said, the Panel calls on the Congress to make this existing authority (embedded in 10 USC 2274) even clearer in statute in order to benefit the entire space sector.

Should the Secretary of Commerce deem it appropriate, the Panel would endorse and support a decision to elevate the OSC from its current place, as a part of NOAA, into the Office of the Secretary. Having the OSC as a direct report to the Secretary is an important signal of senior level Departmental support to the SSA and STM missions. It would also enhance OSC's ability to engage and leverage important external audiences, both domestic and international.

The Panel recognizes the dynamic and evolving nature of the STM function. As a result, OSC should continue on a path to adopt the Panel's operating model and allow it to guide the changes that may be reasonable in order to enhance its work both within the federal government and within the broader constellation of stakeholders active in building the commercial space industry.

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Chapter 1: Introduction and Scope of Work

There is an old adage: “out of sight, out of mind.” That phrase does not apply to the issue of the thousands of individual space assets and debris orbiting Earth. There is increasing risk of space collisions (called conjunctions) that impinges upon the safety of satellites that serve a myriad of vital terrestrial purposes connected with national security, scientific research, and commercial aims. By all accounts, there is a crisis in space. There is also basic clarity within the space community as to the actions to address the complex, underlying risk issues facing a world of stakeholders with orbital assets.

This report calls for urgent action by Congress to authorize and appropriate adequate funding to a federal agency that should take the lead to work collaboratively and creatively across government and non-government sectors, both domestic and international, to help identify and shape effective strategies to mitigate these risks across the space ecosystem.

Issues addressed herein are inextricably intertwined with the current proliferation and expected exponential growth of the civilian space industry, which shares space with militaries and intelligence agencies of many different countries. Thus, the context of this report is squarely set upon an increasingly crowded space environment beginning at about 100 miles above the surface of Earth, and extending tens of thousands further—a domain increasingly populated but well beyond what can easily be observed. The hazards associated with the increasing population in orbit are significant, threatening both objects in orbit and terrestrial life should a collision of sufficient scale or proper position yield debris that place other satellites and objects surrounding the earth at risk of collision. Whether it be the GPS network becoming compromised or the International Space Station (ISS) suffering a critical impact that endangers astronauts, orbital conjunctions pose a multitude of potential disastrous consequences.

While it may be difficult to imagine, this cosmic environment is every bit as real as the sometimes-congested air and road traffic observed every day on Earth. Even if the size and expanse of space may be the closest concept there is to infinity, facts belie naive suggestion that there is no limit to this seemingly endless realm now that it is increasingly congested. There has been increasingly rapid growth in the number of trackable items in earth orbit (referred to hereafter as the space population). Even more challenging, elements of the space population travel at high rates of speed and at altitudes that require advanced technology to track. Objects travel at relative velocities of 27,300-53,000 kilometers per hour (17,000-33,000 miles per hour) at orbital altitudes. In contrast, commercial aircraft, on average, cruise at speeds of around 885 kilometers per hour (550 miles per hour) at an altitude of around nine or ten kilometers (six or seven miles). Therefore, it is essential to focus more concerted efforts to enhance security of a commercial space population that encompasses seamless collaboration among many different actors: national security organizations, international governments, academic institutions, commercial actors, and others. Doing this well should serve to advance mankind’s ability to utilize the domain peacefully and identify and manage inherent operating risks. This complex task is more critical for today than ever before.

The space commercial industry has grown exponentially during the past few decades, and it is forecasted to continue growing ever more rapidly in the coming years. By 2025, as many as 1,100 satellites could be launched per year, quickly eclipsing the approximately 2,800 active satellites that are currently in orbit.[1] Several types of objects are whirling in orbit, including manned and unmanned space vehicles and active and inactive satellites. There is also an enormous collection of space debris and satellites, estimated to be more than 500,000 in total—both human-generated and not. Technology currently employed to monitor the space environment is not capable of identifying the complete array of space objects, but only a relatively modest portion of it.

It stands to reason, therefore, that the ever-increasing population of objects in the space environment leads to greater risk of potential collisions in space. Collectively, future explosive growth in the number of new space objects, along with the existing space population, will also increase the number of active-on-active spacecraft near conjunctions to an all-time high. This will make robust, protected, and verifiable information pooling, exchange, and standardization a vital element to the long-term viability of future space operations.

Notwithstanding the challenges of this operating environment, there is little doubt that the future growth of the space commercial sector has enormous potential. With the increase in quality of space situational awareness (SSA) data, and the potential for enhanced coordination of traffic in the space environment, both governmental and nongovernmental actors will be able to plan operations characterized by a lower potential for collision risk. Thus, it is time to identify, plan, and implement future coordinated actions that help build and sustain a vibrant space industry that can ably serve governmental, societal, commercial, and research purposes. The focus of this report is to address an expressed need to enhance safety and security, and to establish over time "rules of the road and norms" that can benefit this industry through improved space traffic management (STM) focused specifically on the ever-growing commercial and research sectors sharing space.

1.1 Study Origin and Scope

At the behest of Congress, the National Oceanic and Atmospheric Administration (NOAA) of the Department of Commerce (DOC) requested the National Academy of Public Administration (the Academy) to undertake an independent review related to the transfer of space traffic management functions from the Department of Defense (DoD) to a civilian agency. The text of the scope of this review is provided in the appropriations act for Fiscal Year (FY) 2020 in the Senate Amendment to H.R. 1158, Division B (116th Congress), providing appropriations to DOC. Specifically, the legislative language calls for the review to address:

> (1) An assessment of which department or agency and entity within the department or agency is best suited for responsibility for space traffic management;

[1] From Celestrak Active Satellites directory.

(2) Any statutory, regulatory or licensing authorities necessary to facilitate such a transfer;

(3) Funding implications, including infrastructure and personnel costs;

(4) Consultation with appropriate officials from the Departments of Defense, Commerce, and Transportation, NASA, the Director of National Intelligence, other relevant Federal agencies, industry, and other stakeholders; and

(5) Data integrity, information technology, and national security considerations.

1.2 Report Methodology

This report of a five-member Panel of distinguished Academy Fellows calls for Congress to resolutely address an urgent need to authorize and appropriate adequate funding to a civilian federal agency to enhance STM. The Panel provided oversight to a professional study team. Information about the five-member Panel as well as the study team is provided in Appendix A.

The Panel directed the study team to address this work with as much technical rigor and disciplined evaluation as possible given the complex nature of the research questions. Furthermore, while the factors characterizing space commerce and the related work of SSA and STM, are laced with highly technical scientific expertise, the Panel (whose members have the requisite experience and expertise to comprehend technical challenges consumed in this industry) urged the study team to address project research questions from the point of view of public administration. As such, the study team set out to evaluate both the tasks required of this civilian agency to perform the STM function, as well as formulate an optimal operating model, and then assess which civilian agency, among various civilian agencies, is best positioned to adapt quickly to meet the task. The required hard and soft skills, resources, and organizational culture needed among contending agencies are therefore reviewed in some depth.

It is important to stress that the Panel's charge to the study team was to avoid any penchant to accept a preconceived answer as to which agency should take the lead for STM. As per the congressional charge to the Academy, this report concludes with one principle recommendation: which civilian agency should perform STM. That answer is arrived at independently, through a rigorous set of evaluative steps guided by the Panel and outlined in the report, consistent with sound social science research principles, and following best practices guiding research.

However, it is impossible to ignore relevant pre-existing work on this topic by the Executive Branch that serves as an important touch point. Space Policy Directive-3 (SPD-3) entitled "National Space Traffic Management Policy," prepared by the White House National Space Council, and signed by President Trump on June 18, 2018, comprises an inter-governmental unanimous agreement articulating a clear answer to the question of which civilian agency should have responsibility for STM. The text in SPD-3, Section 6 c, states: "The Secretary of Commerce, in coordination with the Secretaries of Defense and Transportation, and the NASA Administrator, shall lead efforts to encourage and facilitate continued U.S. commercial leadership in SSA, STM, and related S&T [science and technology]."[2] To some, therefore, the research question of this report—which agency should manage STM?—has already been settled through an appropriate, open, and thorough inter-agency decision-making process. With all due respect for the careful work invested into preparing SPD-3 by the inter-governmental team, the Panel urged the study team to appropriately incorporate this important work in the research findings, without concluding that the SPD-3 outcome should unduly influence a fact-based and independent research undertaking.

In summary, the assessment and decision-making approach the Panel adopts in this report are guided by the following integrated set of research principles:

(a) Implement an independent, unbiased assessment, bearing in mind that there are recent decisions and other developments within and outside of government that merit consideration in an appropriate manner.

(b) Describe specific features of an optimal operating model for STM based on extensive research with a broad array of documentary sources and interviews with actors operating in the domain. In this respect, the Panel determined that SSA is a precursor to the performing the STM function. As such, SSA and STM should be combined and conceptualized as an ecosystem, and the operating model and evaluation includes both functions.

(c) Identify specific technical and non-technical skills and characteristics that can be assessed in order to compare candidate agencies to perform STM.

(d) Consider all reasonable candidate federal agencies that might perform this task.

(e) Map and then compare agencies against the list of skills and characteristics in order to evaluate each agency's suitability and potential ability to do this task optimally.

(f) The Panel's decision-making is as follows: select the agency deemed to be closest to building the ideal operating model, exhibiting the technical and non-technical skills as best as can be ascertained, and guided by skills and capabilities needed to perform this function with a focus on both domestic and international dimensions.

With respect to research methods, this report's recommendation captures and distills both documentary research, as well as active engagement with a broad variety of stakeholders, including U.S. government agencies, commercial companies, industry associations, academic institutions, and several foreign space agencies.

Documentary research (see Appendix B) includes many publicly available governmental and other research reports, speeches, and congressional testimony. The study team received several documents from agencies and other sources to enhance understanding of important issues related

[2] National Space Council 2018

to segments of this report, such as open architecture data repository (OADR), budget estimates, and legal and regulatory reviews.

The study team also interviewed over 100 individuals to explore essential research topics. The list of interviewees, found in Appendix C, includes current and former employees of federal agencies, academic research institutes, Congress, commercial companies, and foreign space agencies. All interviews were conducted on an off the record not for attribution basis. The Panel wishes to express appreciation to all those who invested their time and contributed insights into this report.

1.3 Organization of the Report

In addition to this chapter, the report contains the following four chapters:

- **Chapter 2: The Changing Commercial Space Domain –** this chapter provides contextual information of the commercial space environment, including important background information on space traffic management and related topics that set guidelines for the report's analysis and recommendation.
- **Chapter 3: Toward a Civilian Agency for Space Traffic Management** – building off of the previous chapter, this chapter provides the optimal operating model for an agency to embrace and guide STM operations. This model is used to evaluate candidate agencies for this work.
- **Chapter 4: Data, Financial, and Regulatory Components of Agency Space Traffic Management Operations** – this chapter offers insights into three important components explicitly incorporated in the scope of work in order to identify any distinctive features of candidate agencies connected with the operating model.
- **Chapter 5**: **Final Space Traffic Management Agency Evaluation** – this chapter presents the analytical framework used to determine which agency is best suited to perform the STM task and provides reasons for the report's conclusion.

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Chapter 2: The Changing Commercial Space Domain

The space economy is in a state of rapid growth and flux with the introduction of new technologies, entrants, and commercial possibilities. The increased activity and debris created by this growth place new stress on the shared domain of orbital space. The challenge for policymakers is to create a new governance structure for the space economy that will yield sustainable resource use, technological innovation, and continued economic growth.

This chapter examines the growth and disruption in the space economy, which has led to recent policy proposals emanating from the private and public sector. Guided by the methodology of the Institutional Analysis and Design framework that is described in this chapter, the broader context of the physical environment and rules-in-use are drawn out by identifying the actors and activities in play and describing emerging policy initiatives. Drawing on the public administration literature, the final section outlines two approaches to governing the space economy.

2.1 Growth and Disruption in the Space Economy

The space economy is significant in scope and size. In broad terms, it consists of "the full range of activities and the use of resources that create and provide value and benefits to human beings in the course of exploring, understanding, managing, and utilizing space."[3] Estimates of the international space economy vary. The OECD reports global space activity to be worth $415 billion in 2019 with commercial revenues making up some 80 percent of this activity.[4] Adopting a more restrictive definition of the space economy—including only the value of goods and services provided to governments, households, and businesses *from space* or used to support activities *in space*—the Science and Technology Policy Institute of the Institute for Defense Analyses estimates that the total value of goods and services from and in space at $155.7 billion in 2013 and $166.8 billion in 2016.[5]

The commercial space sector is also innovative, reducing costs and bringing new products and services to the market. The Congressional Research Service describes the commercial space industry in terms of "economic activities related to the manufacture and delivery of components that go into Earth's orbit and beyond."[6] In recent years, commercial space companies as well as those that provide services and products to space agencies have sped up development cycles and reduced the costs of activities such as rocket launches, space situational awareness, on-orbit servicing, and space exploration. Notably, commercial companies have invested in innovations in

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[3] Tina Highfill, Patrick Georgi, and Dominique Dubria, "Measuring the Value of the U.S. Space Economy," Survey of Current Business, BEA, December 2019.

[4] OECD, *The Space Economy in Figures: How Space Contributes to the Global Economy*, (OECD Publishing, 2019).

[5] Kevin Crane, et al., *Measuring the Space Economy: Estimating the Value of Economic Activities in and for Space*, (Institute for Defense Analyses, March 2020).

[6] *The Commercial Space Industry and Launch Market* (R42492), Congressional Research Service, April 20, 2012.

areas such as miniaturization, satellite mass-production, and use of commercial off-the shelf components, to produce capable lightweight satellites.

Taken together, the space economy is creating new markets and value networks. Lower cost launch and mass production of lightweight satellites now makes it possible to deploy them at scale, "meaning that many hundreds can be launched and operated, and provide round the clock simultaneous multi-point imagery of any place on Earth or in space for scientific, national security, and commercial purposes."[7] SpaceX, a commercial leader and leading innovator, has, for example, developed lower cost launch vehicles and is deploying a large network or "mega-constellations" of Starlink satellites to provide broadband internet services.[8] Competitors, such as Amazon's Kuiper Project, have similar ambitions. The lowered barriers to entry have also spurred an increase in the number of countries and non-state actors conducting activities in space.[9]

As commercial activities in space increase, so, too, does the number of objects permanently in orbit of the Earth. From satellites and discarded spacecraft stages, to rocket fairings and paint chips, the frontier to the universe is quickly becoming a densely populated destination. While only one permanently inhabited station, the International Space Station (ISS), occupies Earth's orbit, over 2,600 active satellites and thousands of more inactive payloads and rocket bodies share the neighborhood with up to six astronauts that call the ISS home for months at a time. The collision between any of these objects could cause significant physical damage and disruption to national and international commerce and communications systems. Collisions also serve to raise the cost of insurance incurred by companies launching assets into orbit, a critical issue impacting operational costs, the cost of capital to finance these projects, and potential profitability for investors.

These developments create new challenges for the governance of Earth orbital space. New actors and the rapid growth in the population of objects—both active assets as well as debris—in the space environment is overwhelming those capabilities currently in place to observe, analyze and warn operators, raising the probability of collisions in space. For the space economy to continue to grow and innovate, there is an urgent need to describe, analyze, and solve the underlying challenge of facilitating safe commercial growth through crafting new rules and platforms for space traffic coordination.

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[7] Bhavya Lal, "*The Commercial Space Landscape: Innovation, Market, and Policy,*" Testimony before the House Committee on Science, Space, and Technology Subcommittee on Space and Aeronautics. IDA Science and Technology Policy Institute, July 25, 2019.
[8] Patrick Stiennon, "Disruptive technology in space transportation," *The Space Review*, October 22, 2018.
[9] Brian Weeden, "China's Pursuit of Global Space Leadership," Testimony before the U.S.–China Economic and Security Review Commission, April 25, 2019.

2.2 Earth Orbital Space as a Common Pool Resource

As the long-term sustainable use of earth's orbital space emerges as a significant strategic and economic issue in the United States, it becomes necessary to understand the principles underlying its governance and to adapt this framework to accept new realities and embrace future opportunities. Considering this, the analysis is reframed from that of a "public goods" problem to a challenge of governing "common pool resources."

In economic terms, space has often been thought of as a public good. Public goods and services are those that are: (1) consumed jointly by individuals, (2) and where consumption is non-rivalrous (i.e., use by one does not subtract from the availability of the good to others). This vision is enshrined in the Outer Space Treaty, which states that outer space is free for exploration and access by all countries and is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means. Given the physical characteristics of the space environment and the physics of orbital mechanics, the use of space is also traditionally thought to be non-rivalrous. While a satellite placed into orbit moves in an elliptical path, the immense volume of space around the earth was believed to mean that the placement of a satellite into orbit by a public or private actor would not impede, in any significant way, the placement of a satellite into orbit by another actor.

This view is now being challenged. Although space is vast, some commercially usable venues are limited. For example, current and expanding deployments of satellite constellations that provide broadband need to be positioned in low Earth orbit so that the latency—the time required for data to travel to the satellite and back—can be at speeds that are sufficiently fast for gaming, navigation, and other internet applications. Congestion is the result as new satellites and other assets crowd into specific earth orbits and parts of the electromagnetic spectrum.

Deployment in commercially viable orbital space is further limited by the presence of debris. Space debris consists of dead satellites, spent rocket stages, and fragments associated with six decades of space exploration and activity by the United States and other space-faring nations. Currently, the U.S. Air Force tracks about 1,000 active satellites as well as close to 21,000 pieces of human-generated debris. The Air Force also tracks objects larger than 10 centimeters, each of which could destroy an active satellite in a collision. Research done by scientists and space agencies indicates there is also a population of another 500,000 pieces of space debris sized between 1 and 10 centimeters, each of which could severely damage an active satellite in a collision.[10]

For these reasons, it may be more useful to think of some regions of orbital space as a common pool resource (CPR). As with public goods, it is difficult to exclude potential beneficiaries from the use of common pool resources. But unlike public goods, one actor's use of the shared resource *does* subtract from what is available to others. In the context of space, the heavily used regions of

[10] Nayef Al-Rodhan, "Space traffic control: technological means and governance implications," *The Space Review*, April 16, 2018.

low Earth orbit (LEO) and geosynchronous orbit (GEO) are both rivalrous and congestible and can be thought of as CPRs.

Indeed, GEO and LEO offer an increasingly limited number of valuable orbital slots for satellites. If, for example, a communications satellite launched by Company A takes up a particular orbital slot, Company B's satellite cannot be placed in the same orbital position without stringent coordination with Company A to avoid any interference or conflict. With the rapid growth of opportunities in space commerce, there is a rush to occupy the remaining slots. This race to deploy objects in space, along with the accumulation of space debris, leads to congestion and increases risks of collision. One significant concern, sometimes called the Kessler syndrome, describes debris colliding with satellites or other debris, creating more debris, and leading a dangerous snowball effect.

Additionally, all objects in space must use portions of the electromagnetic spectrum to perform their functions and communicate with the earth, with certain portions of the spectrum being more suitable than others for various applications. Thus, there is also a crowding of space users into similar or overlapping frequencies.

When each party interested in space access acts in their own self-interest, the unintended result is a polluted orbital space environment. These physical and electromagnetic crowding issues are the primary allocation and provision problems in the near-Earth orbit, with the orbital slots and frequency bands comprising the primary resource units.

How can common pool resources be sustainably governed? Traditional economic analysis predicted that where exclusion is difficult, users will overharvest the CPR, potentially destroying it in the process. Garrett Hardin so dramatically captured this situation as the "tragedy of the commons" that many officials, scholars, and activists assumed that CPRs should be regulated top-down by the state.[11] A growing body of theoretical and empirical findings, documented by Nobel Laureate Elinor Ostrom, however, demonstrates that the dismal outcome that Hardin's prediction does not emerge in many cases. Ostrom and others identified numerous CPR situations where the users of resource developed effective governance mechanisms that combine bottom-up or local initiative with top-down or overarching governance frameworks for sustainably managing CPRs over time.[12] In key respects, the discussion of alternative governance structures for space traffic coordination reflect these different visions of command and control versus a market-based, systems approach.

Having identified the appropriate analytical construct, a systematic study of governing space as a common pool resource can proceed. This chapter's analysis draws on the Institutional Analysis

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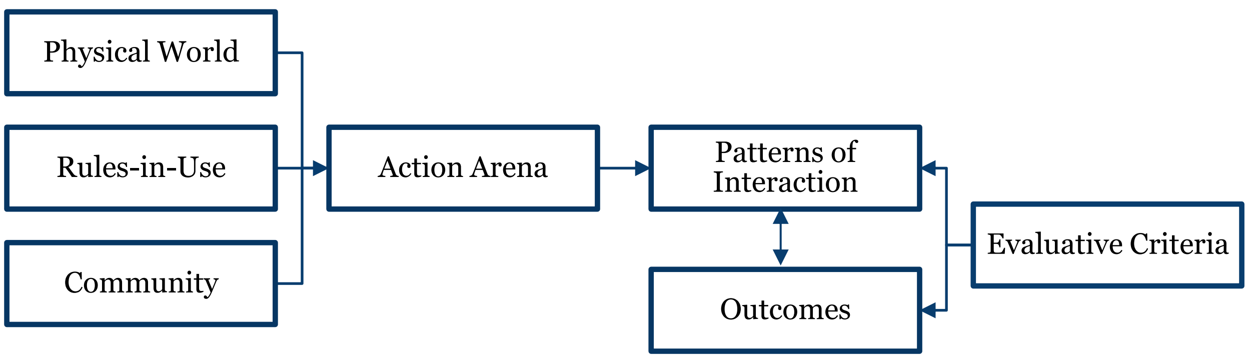
[11] Garrett Hardin, "The Tragedy of the Commons," *Science*, December 13, 1968.
[12] Elinor Ostrom, *Governing the Commons: The Evolution of Institutions for Collective Action*, Cambridge University Press, 1990.

and Design (IAD) framework, a tool developed to analyze CPRs.[13] IAD considers first the broader context (including the physical environment and existing formal and informal rules-in-use) before examining the action arena with its numerous actors, intentions, and interactions. Understanding that the behavior of these actors—shaped by their physical and institutional contexts—create a pattern of observable outcomes, it is possible to perform a more rigorous analysis of the desired governance structure for space traffic based on the types of outcomes. The types of observable outcomes include sustainable resource use, growing markets, rapid innovation, and broad public benefits—all of which the Panel would like to see emerge over time. Figure 2.1 provides a simplified schematic of the IAD framework, guiding the exposition of the remainder of this chapter.

As the long-term sustainable use of earth's orbital space emerges as a significant strategic and economic issue in the United States, it becomes necessary to understand the principles underlying its governance and to adapt this framework to accept new realities and embrace future opportunities.

Figure 2-1. Institutional Analysis and Development (IAD) Framework



Source: Adapted from Ostrom, Gardner, and Walker (1994, 37)

The IAD framework serves as a map as this chapter describes each element of the framework in terms of the challenge of managing the space commons.

2.3 The Physical World

Institutional analysis begins with a description of the natural features of the environment. Space is a unique domain and while parallels between atmospheric flight and space travel are commonplace, the differences are significant. At the threshold of outer space—as the air thins and the sky darkens from a faint blue to a deep black—the laws of motion described by Sir Isaac Newton take on increasing importance.

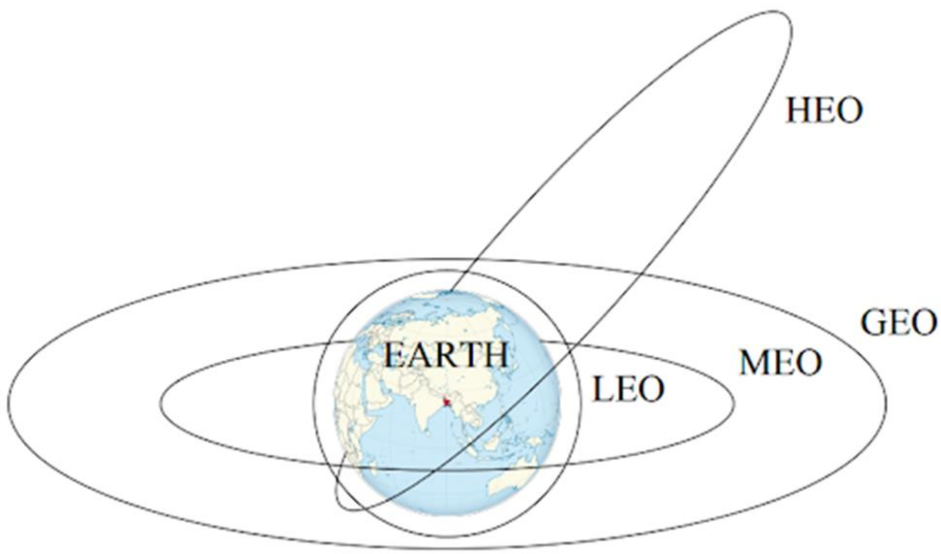
[13] Margaret M. Polski, *Institutional Framework for Policy Analysis and Design (W98-27)*, Indiana University, 1999.

Orbital Space

Earth's orbital space is almost incomprehensibly vast. While the limits of Earth's orbit are somewhat more complex than a simple cutoff point, almost all geocentric satellites (Earth-orbiting satellites) are found between altitudes of approximately 160 km (100 miles) and 37,000 km (23,000 miles) (geostationary orbit). A lesser number of spacecraft fly in highly elliptical orbits with apogees well above the geostationary orbit regime, out to just before the moon. In this zone, one may find some highly specialized scientific spacecraft, such as the Geotail satellite (launched in 1992) with an apogee that crests at 191,450 km (118,962 miles).

- **Low Earth Orbit (LEO):** Referring to the orbital territory below 2,000 km (approximately 1,242 miles) above Earth's surface, LEO is home to several of the most famous objects in space, including the Hubble Space Telescope and the ISS. LEO is the closest orbital sector to Earth, and involves some of the fastest objects, with velocities generally around 7.8 km/s (28,080 km/h; 17,448 mph). Satellites in this orbit revolve around the Earth multiple times per day.
- **Medium Earth Orbit (MEO):** MEO orbits may begin at an altitude of approximately 2,000 km, and go as high as 65,000 km. MEO encompasses a large swath of territory that includes geostationary or geosynchronous orbit. Most objects in MEO are found at approximately 20,000 km, enabling an orbit period of 12 hours. GPS satellites are typically found at MEO.
- **Geostationary/Geosynchronous Orbit (GEO):** At GEO altitudes (approximately 35,786 km), satellites and objects orbit at or about the same speed as the Earth, completing an orbit once every 24 hours. This results in the object in question staying over a specific location on the planet below. In this orbital range, one may find a variety of telecommunications, scientific, and Earth-observation satellites.
- **Highly Elliptical Orbits**: Objects in a highly elliptical orbit traverse multiple altitudes. This orbit enables satellites to linger at specific points in the sky for extended periods, posing benefits for communications satellites and others that require lengthy periods of visibility over the ground.
- **High Earth Orbit:** Beginning at roughly 80,000 km (approximately 9,700 miles) above the planet, and extending as far out as the Moon, is used almost solely for scientific platforms, like deep-space telescopes.
- **Deep Space:** Referring to space outside of the Earth-Moon system, deep space encompasses the expanse of the solar system and beyond. While objects here do not generally orbit the earth, those on the periphery of the Earth-Moon system and deep space will remain geocentric. Others, such as those at Earth's LaGrange Points, will also be placed relative to the planet so as to maintain station.

Figure 2-2. Visualized General Orbits



Source: International Journal of Networks and Communications [14]

These orbits do not have clean delineations, nor are they binding upon the satellites within them. The weight, size, inclination (alignment relative to the equator), and eccentricity (shape of an orbit) of an object will dictate where it may naturally go during its lifecycle. Orbits may be elliptical, dipping closer to and further away from the Earth regularly; orbits may be polar, with objects not only moving around the Earth relative to the equator, but also between the north and south poles (as in the case of surveillance satellites). The complexity and dynamic nature of the orbital environment is such that, though the distances between satellites may be significant, the constant motion of objects means the potential for diversion from safe, predicted orbits can be high.

While the number of launches has been steadily increasing (97 successful orbital or deep space launches were catalogued in 2019 alone),[15] the payloads they carry have also become more complex. Satellite constellations, in which a network of satellites is deployed to provide data transmission or conduct another purpose, are becoming more widely desired by private industry. As payload capacity increases and demand for constellations rises, individual launches can send 60 or more satellites into LEO. As noted earlier, SpaceX is conducting multiple launches of satellite constellations to enable its "Starlink" satellite-based internet utility, with about 300

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[14] S. M. Rezaul Karim et al., "A Review of Communications Satellite by Focusing on 'Bangabandhu Satellite-1', the First GEO Communications Satellite of Bangladesh," *International Journal of Networks and Communications*, 2018.
In this graphic, HEO stands for Highly Elliptical Orbit, and not High Earth Orbit.
[15] Ed Kyle, "2019 Launch Vehicle/Site Statistics," Space Launch Report, December 27, 2019. https://spacelaunchreport.com/log2019.html

satellites currently in orbit at time of writing.[16] These satellites will be entering a rapidly crowding territory, already filled with existing platforms and launch vehicles passing through this thickening field of hardware.

Space Hazards

As Earth's atmosphere thins out as altitude increases, eventually ending in vacuum, the amount of atmospheric drag caused by the friction between an object and the thinning air surrounding it decreases. But the atmosphere at any given altitude in LEO is not a constant. When the Sun is active, extra energy expands the local atmosphere at rapid rates and results in the spacecraft flying through a higher density layer and experiencing a stronger drag force. Drag is the most variable force and primary contribution to orbit errors. Last-minute orbital maneuvers using solar forcing information are important for collision avoidance; these maneuvers require that some satellites conduct orbital corrections, whereby they fire thrusters guided by gyroscopes to move back to a higher altitude; the effect of drag on small objects, like screws, paint chips, fragments of metal, or other resultant products of collisions in space, is far less pronounced. This lower drag, combined with Newton's First Law of Physics, means that those small objects may remain in orbit for years—potentially, even centuries, or millennia.

Without drag, an object in motion will truly remain in motion, and at significant velocities. Collisions between objects, at those speeds, occur with the force of high-yield explosives—a ballistic screw colliding with the ISS could, for example, yield catastrophic damage to the station and loss of the lives of any orbiting astronauts. The collision of two satellites, or between a satellite and a piece of debris, could not only result in the destruction of the objects involved, but also, create even more debris that will continue to circle the Earth at roughly the same velocity the now-destroyed objects were travelling at time of impact.

Also contributing to the creation of space debris is the conduct by some nations of anti-satellite missile tests. Recently, India conducted a test of its PDV Mk.II anti-ballistic missile platform, resulting in the successful destruction of an Indian telecommunications satellite.[17] In 2013, debris from the Fengyun FY-1C satellite, destroyed during a Chinese anti-satellite missile test in 2007, impacted a Russian satellite, moving it out of alignment and rendering it unusable.[18]

Whole satellite collisions are less common than debris events. Perhaps the most famous collision, and the first one to be recorded, is the 2009 collision of Russia's Cosmos 2251 satellite, then defunct, into an Iridium Communications Inc. satellite, resulting in the destruction of both objects. The two satellites orbits intercepted over northern Russia, with the Iridium craft making a polar transit southward, and Cosmos 2251 moving southeast toward the equator from the Arctic Ocean, at an altitude of approximately 800 kilometers. The collision produced over 2,000 pieces

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[16] An overview of Starlink and the rapidly growing mega constellation trend:
https://www.space.com/spacex-starlink-4-launch-success-misses-rocket-landing.html.
[17] "Narendra Modi announces success of Mission Shakti, India's anti-satellite missile capability," *The Hindu*, March 27, 2019.
[18] "Russian Satellite Hit by Debris from Chinese Anti-Satellite Test," Space.com, March 8, 2013.

of debris larger than 4 inches in diameter, projected by the Secure World Foundation to remain in orbit for "decades or longer."[19]

Manmade debris is not the only threat in orbit: micrometeoroids pose a potential threat to any orbiting object. Micrometeoroids are generally several orders of magnitude smaller than the bolide that extinguished dinosaurs on Earth but share similar characteristics. These shards of metal and rock have been observed to travel at speeds of up to 72 km/s (4,320 km/h, or 2,684 mph), but can potentially go much faster, and can cause significant damage to other objects in orbit. NASA has recognized damage to the ISS and the now-decommissioned Space Shuttle fleet from objects as small as 2 millimeters (~0.08 inches).[20] A sufficiently large impact, or a blow to the unshielded part of a satellite's structure, could not only destroy a satellite, but result in a cloud of debris that could endanger others for years to come.

The natural space environment also poses a threat to orbiting objects. During space weather storms, satellites are subject to increased microelectronic upset and failure rates. The effects from space weather on satellites can range from minor annoyance to total loss of the satellite. For example, a solar storm can disrupt a spacecraft's ability to communicate with ground controllers leaving the satellite hazardous, uncontrolled, and potentially drifting toward orbits occupied by another spacecraft.

2.4 The Rules in Use

The IAD framework next takes inventory of the existing international treaties and domestic legislation that shape policymaking related to the space economy. Since the early days of human spaceflight, nation states have sought to implement policies to govern activities in space. These have primarily been a mixture of military and scientific endeavors, given that commercial activities have burgeoned only since the 1990s. As a result, space-related policymaking has been largely conducted through international agreements focused on the militarization of space, the claiming of territory, and the conduct of national space activities. In contrast, national governments have not taken an active approach to the commercial regulation of space. In recent years, as the commercial sector has grown in the United States, there is new interest in designing a viable regulatory framework.

Currently, space activities in the United States are managed by multiple federal entities. While NASA and DoD conduct the bulk of the nation's space endeavors, private and commercial space activities are overseen by the Department of Transportation (DOT), DOC, and the Federal Communications Commission (FCC). Each federal entity holds control over different elements of the space enterprise, descriptions of which can be found later in this chapter. The regulatory

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[19] Brian Weeden, "2009 Iridium-Cosmos Collision Fact Sheet," Secure World Foundation, 2010.
[20] Eric Christiansen and Dana Lear, "Micrometeoroid and Orbital Debris Environment and Hypervelocity Shields," NASA Johnson Space Center, 2012.

control over the enterprise exercised by these entities is derived from a body of law that has evolved over the last century. Essential pieces in that canon are described below.

- **Communications Act of 1934:** Passed 27 years before the launch of America's first satellite, the Communications Act of 1934 created the Federal Communications Commission to oversee the burgeoning telephone, telegraph, and radio industries. Over the coming decades, the Communications Act of 1934 was amended to be inclusive of satellite telecommunications, expanding to provide requirements for commercial satellite operations, licensing of satellites, and radiofrequency interference avoidance.
- **Commercial Space Launch Act of 1984:** The Commercial Space Launch Act of 1984 recognized the private sector as a legitimate entity capable of conducting space activities and tasked the Department of Transportation with the oversight and permitting of commercial launches and reentry through the atmosphere.
- **Land Remote-Sensing Commercialization Act of 1984 and Land Remote-Sensing Policy Act of 1992:** These acts empowered the Department of Commerce to license and regulate the private remote-sensing industry, and to contract the development and production of Landsat satellites and services to private providers.[21]
- **U.S. Commercial Space Launch Competitiveness Act of 2015:** This act seeks to bolster the growth of the U.S. commercial space sector. It requires DOT to report to Congress on ways to streamline launch licensing and permitting, restricted the scope of regulation that may be imposed upon the sector until 2023, extended indemnity with regards to third-party damages for commercial spaceflight companies until 2025, and granted property rights to private entities for resources gathered in space (as in the case of asteroid mining). Crucially, this act also reformed the Department of Commerce's Office of Space Commercialization into its current form, as the Office of Space Commerce.

Multiple international agreements have also been established within the aegis of the United Nations and between nation states.

- **The Outer Space Treaty of 1967:** Formally titled the "Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies," the agreement was introduced by the United Nations' legal subcommittee in 1966 and adopted by the General Assembly in 1967. As of 2020, 109 countries have ratified the treaty, and an additional 23 are signatories. The treaty is mostly concerned with restricting the militarization of space. It consists of three core elements:
    - **Non-Militarization of Space:** The OST forbids the deployment of nuclear weapons and other weapons of mass destruction in space or on celestial bodies. It further declares that the Moon and "other celestial bodies" shall be used "exclusively for peaceful purposes."

[21] A program operated by NASA and the United States Geological Survey to conduct Earth observation and imaging activities.

- **For All Mankind:** The OST declares that space, its exploration, and its use shall be carried out "for the benefit and in the interests of all countries and shall be the province of all mankind." As such, the treaty further forbids the appropriation of extraterrestrial territory by States.
- **State Liability:** Under the OST, Nations are liable for the activities of governmental and non-governmental entities operating in space, if those entities are associated with them. Nations are also liable for any damages caused by objects they have placed in space or hazardous conditions they create.

- **Convention on Registration of Objects Launched into Outer Space:** The 1974 UN Convention on Registration of Objects Launched into Outer Space empowers the Secretary General of the United Nations to maintain a registry of objects launched into space. This registry is inclusive of the launching state, name or designator of the object, date and location of its launch, basic orbital and location data, and the purpose of the object. The United States is a signatory of the convention and submits objects to the register.

2.5 The Community

The next category in this inventory of institutional variables is the space economy community. Individuals associated with policy-making bodies, diverse government agencies, private companies, and research organizations make up the space economy community. This section briefly identifies some of the leading participants below, sketching out their current roles as they apply to civilian and commercial space policy and management.[22]

The Department of Defense

The Department of Defense (DoD) is the government authority tasked with coordinating and supervising all agencies and functions of the government directly related to national security and the U.S. Armed Forces.[23] Many entities within DoD have an important stake in military space activities. The services, the Joint Staff, the intelligence community, and the Office of the Secretary of Defense all play significant roles in the acquisition, operation, and governance of military space.

Of relevance to the civilian and commercial space sectors, DoD is responsible for the maintenance and operation of the Space Surveillance Network (SSN), which is a combination of optical and radar sensors used to support the mission of the Combined Space Operations Center (CSpOC). Currently, DoD maintains a catalog of space objects. From this list, those objects that are not

[22] For a detailed list and description of space actors and their roles, see James G. Alver and Michael P. Gleason, "Space Policy Primer: Key Concepts, Issues, and Actors," The Aerospace Corporation, November 2018.
[23] "Our Forces," U.S. Department of Defense. June 11, 2020. https://www.defense.gov/Our-Story/Our-Forces

sensitive to national security are made accessible to the public through the Space-Track.org website. At present, DoD also notifies satellite operators of potential conjunctions—encounters between objects in space that are worryingly close—so that satellite operators have the opportunity to make a risk assessment and make avoidance maneuvers if they choose.

The Civil Space Sector

- **The Department of Commerce:** The Department of Commerce (DOC) is a government department concerned with promoting job creation and economic growth through providing data and research necessary to support commerce, and by setting standards that foster innovation.[24] Commerce is organized across 13 Bureaus and 15 Offices, including the National Oceanic and Atmospheric Administration (NOAA).[25] NOAA's National Environmental Satellite, Data, and Information Service (NESDIS) program is the nation's primary source of space-based meteorological and climate data. NOAA-NESDIS spacecraft produce the satellite weather photos the public associates with television weather forecasts and Internet satellite weather maps. The Office of Space Commerce currently sits within NOAA. The mission of this office is to foster an economic and policy environment that ensures the growth and international competitiveness of the U.S. commercial space industry. More information about DOC is found in Appendix D.
- **The Department of Transportation:** The Federal Aviation Administration (FAA) at the Department of Transportation (DOT) regulates all aspects of civil aviation and the movement of space vehicles through the atmosphere (more information about DOT is found in Appendix D).[26] Established under the Commercial Space Launch Act of 1984, the Office of Commercial Space Transportation (known by the initials AST) was tasked to:
    - Regulate the U.S. commercial space transportation industry, to ensure compliance with international obligations of the United States, and to protect the public health and safety, safety of property, and national security and foreign policy interests of the United States;
    - Encourage, facilitate, and promote commercial space launches and reentries by the private sector;
    - Recommend appropriate changes in federal statutes, treaties, regulations, policies, plans, and procedures; and

[24] "About Commerce," U.S. Department of Commerce, June 11, 2020. https://www.commerce.gov/about
[25] "Bureaus and offices," U.S. Department of Commerce, June 11, 2020. https://www.commerce.gov/bureaus-and-offices
[26] "What we do," Federal Aviation Administration, June 11, 2020. https://www.faa.gov/about/mission/activities/

- Facilitate the strengthening and expansion of the United States space transportation infrastructure.[27]

Currently, AST conducts launch and re-entry permitting and licensing for commercial space flights.

- **The Federal Communications Commission:** The FCC is an independent government agency that regulates interstate and international radio, television, wire, satellite, and cable communication.[28] Through the Communications Act of 1934, the FCC licenses the radio frequencies that most satellites use to transmit data.[29] Considering orbital debris mitigation plans to be within its responsibilities and obligations, FCC has issued regulations that state that unless the FCC has already authorized a satellite system, the satellite system must submit a description of the design and operational strategies it will use to mitigate orbital debris. This includes calculating the probability that the spacecraft will become debris using the NASA Debris Assessment Software and providing a plan for how space operators will respond to a conjunction warning.
- **The National Aeronautics and Space Administration:** Along with its broad responsibilities for civilian space travel and aeronautics and space research, NASA tracks space debris associated with the protection of NASA assets in space and conducts a broad portfolio of basic research about the use of space for research and commercial purposes.
    - NASA also develops technical requirements to limit orbital debris generation. Its Orbital Debris Program Office creates and maintains numerous software modeling tools used in debris mitigation analysis and the tracking of debris in the orbital environment. NASA's research and development work also supports the space related activities of other federal agencies: For example, and as noted above, the NASA Debris Assessment Software calculates collision and casualty risk for the FCC. NASA also provides robotic and human spaceflight support to NOAA and the U.S. Geological Survey (USGS).
- **Department of State:** The State Department is the external facing federal entity that discusses and mediates international space policy. Its Office of Space and Advanced Technology handles international space issues and represents the United States in the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) and the United Nations and the United Nations Office for Outer Space Affairs. This office also maintains the official United States registry of objects launched into outer space, oversees implementation of the Intergovernmental Agreement on the International Space Station, and supports U.S. civil space entities in upholding international agreements. In addition,

[27] "About the Office of Commercial Space Transportation," FAA. July 8, 2020. https://www.faa.gov/about/office_org/headquarters_offices/ast/
[28] "About the FCC," Federal Communication Commission. June 11, 2020. https://www.fcc.gov/about/overview
[29] "Mitigation of Orbital Debris in the New Space Age," FCC, April 24, 2020. https://docs.fcc.gov/public/attachments/FCC-20-54A1.pdf

the State Department's Bureau of Arms Control, Verification, and Compliance (AVC), Office of Emerging Security Challenges (AVC/ESC) pursues transparency and confidence building measures meant to reduce tensions and enhance cooperation in space. AVC/ESC also participates in the formulation of military and intelligence-related space policy.

Space Policy Generators

- **The National Space Council:** The National Space Council operates as an office of policy development and handles a portfolio of civil, commercial, national security, and international space policy matters. Composed of cabinet-level members and supported by the Users Advisory Group, the council is chaired by the Vice President. The Advisory Group of the NSC represents the interests of the U.S. commercial space industry and the civilian weather satellite enterprise operated by NOAA.[30] It convenes relevant government agencies and stakeholders to coordinate policy development.
- **The United States Congress:** Some 12 designated Senate and House subcommittees serve as patrons for the space related activities of the diverse federal agencies under their oversight. Authorizing subcommittees provide a policy framework for space activities and oversee their implementation. Appropriations subcommittees review civil space funding requests and appropriate funds to agency budgets. The work of the leading Congressional committees and subcommittees are described here.

  Among these, the Senate Committee on Commerce, Science, and Transportation has jurisdiction *inter alia* over transportation as well as nonmilitary aeronautical and space sciences. Its Subcommittee on Space, Science, and Competitiveness provides oversight over NASA, NOAA, and the National Science Foundation (NSF). The Senate Armed Services Committee has purview over issues related to the military's use of space. Appropriations for civil space in the Senate are handled by the Appropriations Subcommittee on Commerce, Justice, Science, and Related Agencies, while appropriations for military space are under the jurisdiction of the Appropriations Subcommittee on Defense.

  In the House of Representatives, the Subcommittee on Space and Aeronautics takes the lead role concerning issues related to NASA, NOAA, and commercial space activities. It is a subcommittee of the Committee on Science. The Strategic Forces subcommittee of the House Armed Services Committee handles military space issues. Appropriations for civil space are handled by the House Appropriations Subcommittee on Commerce, Justice, Science, and Related Agencies, while appropriations for military space are under the jurisdiction of the Appropriations Subcommittee on Defense.[31]

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[30] "National Space Council," Office of Space Commerce, June 11, 2020. https://www.space.commerce.gov/category/national-space-council/
[31] James G. Alver and Michael P. Gleason, *A Space Policy Primer: Key Concepts, Issues, and Actors*, The Aerospace Corporation, November 2018.

The Commercial Industry

According to Alver and Gleason, commercial space refers to space activities with four characteristics: "(1) private capital is at risk in development and operation, (2) there are existing or potential non-governmental customers, (3) market forces determine viability, and (4) the primary responsibility and management resides with the private sector."[32] The aerospace industry has grown significantly in recent decades: by 2018, commercial space activities accounted for 76 percent of total space spending. Table 2-1, assembled in a publication by The Aerospace Corporation, illustrates the scope of activities in the commercial space sector and provides examples of companies investing in these spaces. The examples provided are not exhaustive, a notable omission being the firms in the space safety industry.

Venture investment is encouraging innovation and expansion in the commercial space sector. According to the Space Investment Quarterly, cumulatively, there has been $109.2 billion of equity investment into 822 unique companies in the space economy since 2004. Another $5.4 billion was invested into space companies in the first quarter of 2020, which is already one third of the total funding for the full year 2019.[33]

[32] *A Space Policy Primer*.
[33] *Space Investment Quarterly*, *Q1*, 2020.

Table 2-1. Examples of Current and Planned Commercial Space Activities

Activity Type	Example Companies
Satellite manufacturing	Northrop Grumman, Lockheed Martin, Boeing, SSL
Launch vehicle subsystem manufacturers	Aerojet Rocketdyne
Launch service providers	Arianespace, SpaceX, ULA, Northrop Grumman, Blue Origin
Telecommunication	Iridium, Intelsat, Eutelsat, DirectTV, Sirius XM
Earth observation	Planet, Digital Globe
Vehicle tracking	ORBCOMM, Spire
Space tourism	Virgin Galactic, Blue Origin
Satellite servicing	MDA, Northrop Grumman
Space station logistics	SpaceX, Sierra Nevada, Boeing, Northrop Grumman
Space stations	Axiom, NanoRacks, Bigelow Aerospace
Smallsat manifesting	Spaceflight Industries, NanoRacks
Lunar delivery and space resources	Astrobotic, Moon Express, Planetary Resources

Source: Alver and Gleason, 2018

New Space Companies

The U.S. space sector is being reinvigorated by the emergence of a decentralized set of space companies, generally known as "New Space." They are a varied set of actors, including "space access" companies, whose focus is on launching people and payload into space; the "remote sensing" companies that provide images of Earth; and the "satellite data and analytics" companies that serve this and a range of other customers. Joining these are the "habitats and space stations" companies that plan to provide secure facilities for manufacturing, research, and even tourism in so-called "low Earth orbit." The "beyond low Earth orbit" companies have goals ranging from space manufacturing to asteroid mining to colonization of the Moon and Mars.[34]

In many cases these New Space actors have been funded by high-profile entrepreneurs—Elon Musk, Jeff Bezos, Richard Branson, Paul Allen, and others—who have used their wealth to overcome high fixed-cost barriers to entry, launching companies based on new approaches to the technology and management of space access. In many cases, these investments have proceeded with limited if any government investment, making them less amenable to government regulation. As they open the commercial potential of space, revenues in the sector have rocketed in recent years, with the vast majority of that activity related to satellite technology for telecommunications and other services.

[34] Christopher D. Johnson, ed., *Handbook for New Actors in Space*, Secure World Foundation, 2017. Tim Fernholtz, *Rocket Billionaires: Elon Musk, Jeff Bezos, and the New Space Race*, 2018.

Industry Associations

This diverse and competitive set of firms is complemented by industry associations that enhance shared research and the promotion of best practices across their industry. The Space Data Association (SDA), for example, "brings together satellite operators to support the controlled, reliable and efficient sharing of data critical to the safety and integrity of the space environment."[35] Operated by SDA's trusted technology partner, AGI, SDA's Space Data Center combines "flight dynamics information from the member companies as well as other available sources of space object information to provide conjunction assessment and warning services."[36]

Other industry organizations promote safe and sustainable space operations. For example, the Space Safety Coalition in 2019 introduced a set of best practices for the sustainability of space operations. In addition, the Satellite Industry Association, which is a trade association representing satellite operators, satellite and launch service providers, and manufacturers published a set of "Principles of Space Safety" emphasizing the importance in prioritizing safety and sustainability in space operations.

The World Economic Forum's Global Future Council on Space Technologies developed the "Space Sustainability Rating," which scores companies' missions based on their adherence to international guidelines and their sustainability regarding debris mitigation. Lastly, operational-specific organizations such as the Consortium for Execution of Rendezvous and Servicing Operations have created standards and recommendations for proximity operations, commercial rendezvous, and on-orbit servicing.

The Research Community and Non-Profits

Universities create a pipeline of educated professionals who have the skillsets necessary to work in the public and private space commerce sectors. Universities are also at the forefront of research and development of new space technologies and analytical tools, conducting groundbreaking studies on debris mitigation, object detection and characterization, and accurate mapping systems. Centers affiliated with universities, such as the George Washington University Space Policy Institute, also analyze current developments, policies, and strategic needs.

Non-profit policy institutes and industry associations (representing suppliers and manufacturers of spacecraft and information technology companies) also provide technical and policy advice. Organizations such as the Secure World Foundation and The Aerospace Corporation, a Federally Funded Research and Development Center, provide advice on critical issues regarding the space industry and the promotion of investments and policies that encourage innovation and safety.

[35] Space Data Association, Homepage, Space-data.org Space-data.org.
[36] Space-data.org.

International Actors

The space policy environment is also influenced by variety of multilateral organizations as well as national space organizations. The international organizations include:

- **International Telecommunication Union (ITU).** The ITU is a UN agency that governs the use of the radio frequency spectrum. ITU assigns physical satellite orbital slots in geostationary orbit. Through the FCC and NTIA, the United States applies ITU rules to all U.S. spacecraft and satellites that use radio spectrum.
- **United Nations Committee on the Peaceful Uses of Outer Space (COPUOS).** COPUOS was established in 1959 as a forum for discussing international governance of outer space. In recent years, COPUOS members have discussed issues like space debris management, creating guidelines for the long-term sustainability of space, and determining if more concrete solutions are necessary or possible.
- **Inter-Agency Space Debris Coordination Committee (IADC).** Composed of national space agencies, IADC's facilitates research on space debris and fosters international cooperation on responses and mitigation techniques.
- **The United Nations Office for Outer Space Affairs (UNOOSA).** The Office assists UN Member States to establish legal and regulatory frameworks to govern space activities. It also works to strengthen the capacity of developing countries to use space science technology and applications for development.

In addition, the space community includes a number of national and regional organizations covering activities in the European Union, Russia, China, and India. For example, CNES, the French National Center for Space Studies, promotes that nation's space operations and industry. It also cooperates with the European Space Agency on advancing a wide portfolio of civil as well as security and defense space programs.

In the commercial space industry, technological developments are enabling new commercial actors or helping existing actors to compete in new ways. In the launch market, for example, the rise of affordable launch vehicles has improved U.S. competitiveness on the global market. Competitors, including the space agencies of Europe, Russia, China, and India, to name only a few, continue to offer commercial launch services on the international market, at times at rates that competitors argue are subsidized.

2.6 The Action Arena

Having so far described the scenery and stage settings and having introduced the *dramatis personae* as a part of the IAD framework-led exposition, it is now time to set the play in motion through a description of the Action Arena. The expansion of the space economy, the degradation of the orbital environment, the limitations of current technologies and governance processes, and the emergence of new global actors have created new dynamics and pressure to craft a new U.S. policy framework.

The Introduction of New Technologies

Advances in information and communications technologies, including artificial intelligence and cloud computing, have changed the price/performance ratio for small satellites and other space technologies, and this has stimulated innovation and new commercial interest. This dynamic is being accelerated by significant capital flows into the commercial space sector, which has grown to include new capabilities such as satellite servicing, private space stations, and resource extraction and utilization.

The growing deployment of innovative technologies creates new realities, outpacing the existing U.S. policy and regulatory framework in critical areas. In one manifestation of this change, agencies such as NOAA and AST face a deluge of new licensing applications.[37] Often, innovative commercial space activities do not clearly fit into any of the existing regulatory frameworks, licensing categories or authorities, hindering further investment.

While the United States already has a national framework for providing oversight to some categories of commercial space activities, this capacity must grow relative to the pace of change in the commercial sector. Meanwhile, other countries—such as Luxembourg and the United Arab Emirates, to name just a few—are aggressively moving to put in place their own national frameworks to court new commercial space companies.[38]

Growing Congestion in Space

The rapid expansion of the space economy has brought the issue of orbital congestion to the forefront. This congestion is made worse by the concentration of orbital debris in the most heavily used regions of Earth orbit where many active satellites also reside. These regions include the LEO and the GEO regions.

Congestion in GEO is acute, due in part to the need for all satellites in the region to use the same or similar portions of the radiofrequency spectrum. However, international and national legal exclusion mechanisms have so far led to a fairly efficient use of GEO and there is correspondingly less of a space debris problem.

Of the two regions, LEO currently presents the most pressing challenge for long-term sustainability and increasing collision threats to satellites from orbital debris. Of the two, LEO is the more crowded and has a relatively low entry cost.

Advancements in space observation and analytics have improved mapping and prediction, effectively opening room for more activity in LEO. In the absence of a reliable and credible

37 Wayne Monteith "AST Update Letter - April 3, 2020," https://www.faa.gov.
38 Paul Voosen, "Outer Space may have just gotten a bit closer" *Science*, July 24, 2018.

governance system, there is a scramble by satellite companies and others to "squat" or occupy parts of the orbital space and spectrum.

Many of these companies also seek to create new rules that reinforce their claims and advantages in this policy vacuum, as well as to establish standards of sustainable use of orbital space that are in their common interest.[39]

The Changing Role of the Department of Defense

DoD has long maintained and operated the Space Surveillance Network (SSN) through a combination of optical and radar sensors. This function "originated as part of a missile warning system in an era where there were relatively few objects in space, typically operating in predictable orbits and engaging in predictable activities."[40] It was designed to accomplish national security functions, like missile warning, and protecting DoD satellites. While SSN has been used by the commercial space industry for many years, DoD space surveillance systems were not created with the needs of the burgeoning space commercial industry in mind.

As the space economy expands and new pressures confront the orbital environment, commercial space operators increasingly turn to the services of a growing space safety industry to provide the surveillance and warning systems needed to achieve safe operations. Meanwhile, with the growth of offensive challenges to U.S. space assets from other nations, DoD has in recent years sought to focus on its core missions in security and defense. For these reasons, DoD is seeking to exit its role in directly supporting the civilian space sector, a shift revealed in current and past policy directives.

New Challenges to Global Policy Leadership

With the dramatic increase expected in the number of active satellites in LEO, and stalled expansion in DoD-led monitoring capabilities, there is a growing need for global capabilities to allow continued access to orbits and ensure their sustainability. Recognizing this opportunity, the European Union is seeking to become a global leader in this domain, offering to work both in cooperation and competition with the United States.[41]

The European Union (EU) established in 2014 the Space Surveillance and Tracking (SST) Support Framework, foreseeing the creation of an SST Consortium of, initially five EU Member States (France, Germany, Italy, Spain and UK). This was enlarged to eight states in 2018 with the addition of Poland, Portugal, and Romania.

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[39] Christian Davenport, "Thousands more satellites could soon be launched into space. Can the federal government keep up?" *Washington Post,* July 23, 2020.
[40] Bhavya Lal et al., *Global Trends in Space Situational Awareness and Space Traffic Management*, IDA Science & Technology Policy Institute, 2018.
[41] European Space Policy Institute, *Towards a European Approach to Space Traffic Management*, January 2020.

The SST Consortium and the European Union Satellite Centre have been working together to develop a European SST capability in a series of EU-funded projects, known as "EUSST." "The EU Member States of the SST Consortium have designated national Operational Centres for the provision of operational SST services to SST Users via the EUSST Service Provision Portal for the implementation of the SST Support Framework."[42]

Recognizing the shared interest with the United States in the need to lead in space to counter perceived threats from Russia and China, some commentators see that the EU is seeking to prove its "value as a partner and advocate for international cooperation as the best way for both parties to achieve state goals and maintain the stability of orbit."[43]

Policy Uncertainty and Commercial Risk

New technological advances, pushing the uses and utilization of orbital space, are creating new opportunities as well as uncertainties for commercial space actors. While these actors—providing products and services ranging from launch services to space data analysis—may have different, sometimes opposing, commercial interests, they increasingly see a common advantage in developing shared rules and norms for operations in space. This convergence in interest has, in turn, propelled policy action in the United States.

2.7 Outcomes

The final element of the IAD framework reviews the outcomes that result from the existing features, incentive systems, and dynamics within the system. In this instance, the pressures created by a growing space economy and stagnation in the DoD-administered systems that monitor and ensure orbital safety have led to new policy initiatives that seek to commit the United States to improve the safety and sustainability of space as well as encourage more competition and innovation in the commercial uses of space.

A core aspect of the revival of the policy debate in the United States on the commercial use of space has focused attention on two vital aspects related to shared used of this common pool resource: the trusted monitoring of the shared resource and the actions (drawing on this information) needed to ensure its sustainable use.

Since the start of the Space Age, DoD has played a critical role in SSA, meaning the knowledge and characterization of space objects and their operational environment. As noted earlier, this work continues through today; using its network of radar and telescopes, the Air Force tracks objects in space and provides warnings to space operators about potential conjunctions. This information is vital to STM, which encompasses the planning, coordination, and on-orbit

[42] From eusst.eu homepage.
[43] Alexandra Stickings, *The Future of EU-U.S. Cooperation in Space Traffic Management and Space Situational Awareness*, Chatham House, August 2019.

synchronization of activities to enhance the safety, stability, and sustainability of operations in the space environment.

Current policy debates center on these two concepts and the tasks and responsibilities inherent in these terms.

Move to a Civilian SSA/STM System

The effort to solve the emerging jam between growing use of orbital space and the limits to the effective management of this domain was to move existing SSA and STM services, as currently being provided by DoD, to a civilian agency.

Under the 2013 National Space Transportation Policy, DOT was directed to take a larger role in the management of the commercial space enterprise and directed to coordinate with DOC on the promotion of commercial space activities. FAA was further directed to work with NASA on a "comprehensive safety regime for human spaceflight", intended to be shared between governmental and commercial activities with "minimal regulatory overlap."[44]

This policy was subsequently overtaken by four Space Policy Directives issues by the Executive Office of the President, by way of the National Space Council. As of July 2020, these are:

- **Space Policy Directive – 1** commits the United States to "Lead an innovative and sustainable program of exploration with commercial and international partners to enable human expansion across the solar system and to bring back to Earth new knowledge and opportunities."[45]
- **Space Policy Directive – 2** sets out a series of instructions intended to reduce the regulatory burden on commercial space entities. Those instructions include:
    - The review and appropriate streamlining of launch and re-entry licensing by the Department of Transportation.
    - The review and streamlining of regulations by the Secretaries of Defense and Transportation, and NASA Administrator, with regards to commercial space launch and re-entry associated with federal launch sites. This effort would be to bring those regulations in line with the similarly streamlined ones to be issued by the Department of the Transportation.
    - The review and streamlining of regulations by the Secretary of Commerce on the matter of Commercial Remote Sensing.

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44 Executive Office of the President, "National Space Transportation Policy," November 21, 2013.
45 Executive Office of the President, National Space Council, "Presidential Memorandum on Reinvigorating America's Human Space Exploration Program," December 11, 2017.

- The review and streamlining of regulations by the Secretary of Commerce in coordination with the Director of the Office of Science and Technology Policy, and FCC, with regards to radiofrequency spectrum.
- The review by the National Space Council of export licensing regulations that impact commercial space activities and to issue recommendations to streamline those regulations.

In addition to these tasks, SPD-2 directs DOC to consolidate, within the Office of the Secretary, "the responsibilities of the DOC with respect to the Department's regulation of commercial space flight activities," and to submit to OMB a legislative proposal to create an entity tasked with "administering the Department's regulation of commercial space flight activities."[46]

- **Space Policy Directive – 3** calls for the establishment of a "new approach" to STM to address the rising congestion and complexity of space and directs the Department of Commerce to be the focal point of those efforts. SPD-3 sets out eight principal goals to successfully bolster safety and U.S. commercial leadership in space:
  - Advance SSA and STM Science and Technology.
  - Mitigate the effect of orbital debris on space activities.
  - Encourage and facilitate U.S. commercial leadership in S&T, SSA, and STM.
  - Provide U.S. government supported basic SSA data and basic STM services to the public.
  - Improve SSA data interoperability and enable greater SSA data sharing.
  - Develop STM standards and best practices.
  - Prevent unintentional radio frequency (RF) interference.
  - Improve the U.S. domestic space object registry.
  - Develop policies and regulations for future U.S. orbital operations.

  To achieve these goals, SPD-3 designated DOC as the civilian agency to conduct the data sharing and collision avoidance support services required by the developing orbital environment. SPD-3 also assigns various associated duties, such as tasking NASA to assess and develop updates to the already existing Orbital Debris Mitigation Standard Practices, and interagency efforts to develop best practices and standards with regards to multiple entities of the commercial space enterprise.

- **Space Policy Directive – 4** establishes the U.S. Space Force as the sixth branch of the U.S. Armed Forces. The Space Force, to be housed within the Department of the Air Force, is to undertake all efforts by the United States toward addressing space as a warfighting domain.

[46] "Presidential Memorandum on Reinvigorating America's Human Space Exploration Program."

2.8 Toward Civilian Management of Space

It is clear that recent space policy initiatives seek to refocus the efforts of DoD to its core mission of protecting the security of the nation. Moreover, they call for a civil agency to bolster safety and U.S. commercial leadership in space. Even though commercial industry is not obviously viewed as part and parcel with national security interests, there is a clear sense that the space commercial domain should be seen as such. Thus, the U.S. government agency involvement is seen as vital not only for commercial growth for the American economy, but also is seen to take on broader meaning with a national security dimension attached.

But how should this civilian agency be best structured to address its mission? The following section considers two contrasting approaches to the challenge of governing the commons.

Centralized Governance for Space

To be effective, the civilian agency that governs the orbital commons must overcome the central challenge of the Tragedy of the Commons. As noted earlier, the traditional approach to solving this predicament calls for CPR to be managed top-down by the state.[47] This approach calls for the development of a centralized bureaucratic structure, focused on a safety mission, that can procure and field up-to-date technologies for SSA and STM.

A centralized approach to advancing national missions in space is not new. Economists have long argued that public goods such as national security and basic science are typically underprovided if left to the market, and NASA was founded to provide them during the Cold War. NASA's command-and-control structure grew naturally from that objective, as the merits of decentralization took a back seat to the imperatives of the Moonshot and other objectives.

While the economic logic for the centralized model for the Apollo missions was accepted at the time, private-sector leaders increasingly warned that a centralized model undermined progress on public and, especially, commercial priorities in space.[48] Even so, NASA applied largely the same centralized approach to the missions of the Space Shuttle. After two tragic accidents, with the Challenger shuttle in 1986 and the Columbia shuttle in 2003, momentum turned away from the Shuttle and the centralized model of space it represented.

Given the new realities of a differentiated and distributed space economy and the dynamism of New Space entrants making sizeable investments with private resources, it is not clear that a centralized approach to governing orbital space would be effective. The alternative may be a hybrid approach that is broadly market-oriented, but where government frames and, if needed,

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[47] Garrett Hardin, 1968.

[48] Matthew Weinzierl, "Space, the Final Economic Frontier," *Journal of Economic Perspectives—Volume 32, Number 2—Spring 2018—Pages 173–192.*

enforces the rules governing the market (often with the participation of the users) to foster competition among firms, technological innovation, and sustainability of the CPR.

New Incentives for Collective Action

The shift from public to private priorities in space is especially significant because commercial space's new leaders have sought to create a large-scale, largely self-sufficient, developed space economy—one that is fiercely competitive and resistant to a government-led regulatory approach. However, these actors do share a motivation to cooperate to avoid steeply rising costs of operating in space arising from increased congestion. While the expected value of destroyed wealth because of collisions is currently small because of the low probability of a collision, this price-tag can quickly become significant if future collisions result in runaway debris growth.

Commenting on this issue, Levin and Carroll note, "Given the possibility of high future costs, private and public actors should, for their own benefit, direct attention to the space debris problem now. Global satellite revenue in 2014 totaled $195.2 billion. That stream of economic activity is most threatened by significantly increased concentrations of space debris in orbit."[49] Likewise, Muelhaupt and colleagues aver that operators of very large LEO constellations "have a significant vested interest in maintaining the space environment, and in protecting investments that will run into the billions of dollars. Indeed, some of the new operators are among the strongest proponents advocating for increased regulation and scrutiny."[50]

Over-regulation is always to be avoided, as that might stifle innovation. Instead, in the competitive environment emerging in this industry, certain minimum standards will be essential to facilitate, encourage, incentivize and catalyze (if necessary, through regulation) space operators (both public and private) to develop industry common standards and best practices.

Declaring their commitment to being "good citizens," New Space companies are increasingly willing to share information and maintain good practice in sustaining the orbital commons. These activities include developing more reliable plans for post-mission disposal, investments in automated collision avoidance, and building in the capability of high-precision orbit knowledge. Some are willing, even seeking, to share position and maneuver data. A challenge for these "good citizens" is to encourage broader acceptance and observance of orbital hygiene among other commercial and international actors.

This is all to be welcomed and paired with enlightened regulations. As the lead custodian of the common pool resource of space, the U.S. government has a primary role to ensure that these orbital hygiene standards are developed, adopted, and evolved to pace developments in space commerce and technologies, thus guaranteeing the viability of the CPR for future generations.

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[49] Eugene M. Levin and Joseph A. Carroll, "The Cost of Future Collisions in LEO12– 15," *Star Technology and Research*, 2012.
[50] Theodore J. Muelhaupt et al., "Space traffic management in the new space era," *The Journal of Space Safety Engineering (6)*, 2019.

The changing needs of space companies is also spurring the growth of a space safety industry. New SSA companies are operating networks of telescopes (e.g., ExoAnalytics) and radars (e.g., LeoLabs). Companies like Analytical Graphics, Inc. (AGI) are offering conjunction prediction and collision avoidance services. And the Space Data Association (SDA) was created as an industry consortium to coordinate and deconflict its members' operational plans.

Some Design Elements for Distributed Space Governance

Given the limited potential for a top-down regulatory approach to governing space, especially given the intentions of New Space actors, a public-private partnership arrangement for governing the space commons is considered instead. Considering alternative institutional arrangements to govern outer space, numerous analysts have looked to see if insights from Ostrom's framework for institutional design could—as an alternative to Hardin's regulatory solution to the Tragedy of the Commons—provide a robust governance regime that promotes the optimal management and long-term safety and sustainability of the Space Commons for current and future space appropriators.[51]

Elinor Ostrom identified the characteristics of situations where the users of a common pool resource themselves develop effective self-management mechanisms. Based on observations of successfully managed terrestrial common pool resources such as forests, irrigation systems, and fisheries, she found that such user-developed systems best emerge in circumstances where the users can, inter alia, identify clear boundaries, participate in the formulation of collective-choice agreements and operational rules, sufficiently monitor the behavior of each other to limit cheating, and respond to such violations with penalties that are proportional to the severity of the infraction. Such user-developed mechanisms for governing CPR also call for easily accessible conflict resolution mechanisms.[52]

While the domain of space is unique in many respects, public and private users of space could come to terms with many of the conditions that Ostrom found to support sustainable self-governance mechanisms. Bringing owners and operators into the management and rule-making process, for example, increases their understanding and support for the rules and further reduces pushback when it comes to enforcing them.

One example of shared rulemaking is the "25-year rule" that was developed cooperatively through the work of the Inter-Agency Debris Coordination Committee (IADC). This rule recommends that satellite operators remove spacecraft and orbital stages from useful and densely populated orbit regions no longer than 25 years after mission completion.

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[51] See, for example: Brian C. Weeden and Tiffany Chow, "Taking a common-pool resources approach to space sustainability: A framework and potential policies," *Space Policy 28,* 2012, 166-172.
Rebecca Reesman, Michael Gleason, et al. *Slash the Trash: Incentivizing Deorbit, Center for Space Policy and Strategy*, The Aerospace Corporation, April 2020.
Shane Chadda, "Elinor Ostrom Goes to Outer Space—An Association of Space Appropriators," July 2013.
[52] Ostrom, *Governing the Commons*, 1990.

A variety of associations have been formed to govern the space commons including the three noted here:

- The Consortium for the Execution of Rendezvous and Servicing Operations (CONFERS) is creating industry consensus on standards and norms of behavior for on-orbit satellite servicing.
- The Space Safety Coalition, an ad hoc coalition of companies, organizations, and other government and industry stakeholders, is taking a lead in developing best practices for sustaining of the space domain.
- The Space Data Association shares information on orbital positions and notifies commercial and government members of collision risk.

These common pool resource management structures are a rich blend of "private-like" and "public-like" institutions. Multiple consortia can coexist, covering a broad spectrum of activities. As Reesman and colleagues point out, "An industry consortium is a bottom-up approach that creates buy-in from stakeholders and enables voluntary, consensus-based standards, guidelines, and best practices for safe deorbiting. A successful industry consortium needs participation from major companies that own and operate the majority of commercial satellites around the world to foster equity and support for the system."[53]

Governments play an important role in developing these institutions. They can encourage the formation of public-private partnerships through enabling legislation and early public investments. They can also develop the regulatory frameworks and contract enforcement mechanisms to encourage the adoption of new standards. For example, the federal government could use the launch regulatory process (LRP), as a lever to encourage U.S. companies to subscribe to common standards relating to SSA. Here, for example, the launch approval could be made contingent upon a certification that the launch company has subscribed with an "approved" SSA provider company.

As the landscape of space is rapidly changing with new actors and new challenges of sharing an increasingly congested CPR, there is a fresh impetus to design new and effective governance mechanisms that enhance commercial opportunities and ensure the sustainability of orbital space. This report takes up this challenge, looking next to the how the capabilities inherent in the management of space traffic can be organized through innovative institutions for collective action.

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[53] Rebecca Reesman, Michael Gleason, et al. *Slash the Trash: Incentivizing Deorbit, Center for Space Policy and Strategy*, The Aerospace Corporation, April 2020.

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Chapter 3: Toward a Civilian Agency for Space Traffic Management

The challenge of sustainably managing the orbital commons calls for a new vision of space traffic management (STM)—one that acknowledges the growing challenges of cooperating in earth orbital space, one that draws in the emerging technological innovations and the market opportunities that it creates for a growing cast of actors, and one that takes into account a myriad of technical and functional capabilities related to the lifecycle of satellites and other space borne assets. Harnessing these competing challenges, the opportunity at hand is to envision an agency that can manage the space commons, promote commerce, and provide and provision services for the public as well as commercial users.

The first part of this chapter focuses on the required capabilities—technical skills that are necessary for an agency to fulfill mission objectives in space situational awareness (SSA) and STM—which are distributed across the federal government, commercial actors, and academia.[54] This discussion centers around a list of capabilities compiled and summarized in Table 3-1. The components of each of these capabilities are described in turn, as are the roles played by a variety of public, private, and international stakeholders in their production and provision.

The second part of this chapter addresses the broader set of organizational characteristics of an agency that can marshal these functional capabilities, coupled with effective organizational capabilities and support. Examples of such competencies include effective coordination and collaboration, communications, facilitation, stakeholder engagement, fostering innovation, and teamwork. In order to be successful in the capabilities, these soft skills are critical. Part of an organization's ability to perform the capabilities is also the nature and extent of organizational support within its parent department or agency.

The chapter concludes with an operational model for space traffic management, pulling together the key characteristics required of the agency that will perform this task, and the Panel's broader vision for its success.

3.1 Tasks and Capabilities

A successful SSA and STM mission depends on a suite of technical capabilities. However, a single organization does not need to possess all the required capabilities on its own. Based on its core competencies, an organization can acquire additional capabilities by procuring them (i.e., bringing in expertise from elsewhere in the organization) or partnering with other public and private sector organizations that have the required expertise. As a result, as part of the analysis, particular attention is given to the relationships and roles that exist currently and that may need to exist in the future to perform the SSA and STM mission effectively—thereby providing an

[54] For the purposes of this study, the definition of capability is used broadly as the collective set of skills, abilities, and expertise.

enterprise view of SSA and STM. Given the dynamic and evolving SSA and STM landscape, a high level of coordination is required among the many different entities involved. The government agency tasked with leading the STM function must serve as a nexus of this coordination as well as serving the public good.

In addition to the critical role stakeholders play, the functional list of capabilities requires a supporting framework of policy, regulations, and standards. Given that the space commercial industry is in its infancy, that orbital space environment is increasingly congested, that technology is in rapid development, and given the changing dynamics among actors, this policy regime will need to be highly adaptable.

Methodology

With the rapidly evolving nature of the domain, there is widespread variation in definitions of core terms. Moreover, a comprehensive list of widely agreed upon capabilities that constitute SSA/STM functions is not available.

As a result, the report provides a list of vital capabilities to perform the task. This list draws on three main sources: SPD-3, other directives, studies and reports, and stakeholder inputs. Discussions with subject matter experts, in particular, provided insight into how some current capabilities need to evolve and what advanced capabilities will be required in the future.

The documentary research provides a baseline assessment of the required mission objectives to perform SSA and STM. While SPD-3 provides a basic direction for which entities should be responsible for leading or coordinating certain capabilities, the studies and reports also offer insight into which entities have the organizational capacity to fulfill the SSA and STM mission objectives.

The study team prepared a draft list of capabilities and their relevant components and sent it to a variety of stakeholders, including individuals from government entities, the private sector, and academia, for comment. Through an iterative and collaborative process, the stakeholders offered new information, drawing out the descriptive list, the relevant components associated with each capability, the separation between basic and advanced services, the role of the lead organization in each capability, and the participation of other entities in fulfilling each capability.

Key Considerations

Scope

The list of SSA/STM capabilities is based on the lifecycle of satellite operations. This format, moreover, ensures a holistic view to identify dependencies among capabilities, if any. The scope of the capabilities is intentionally defined broadly to encompass the SSA and STM functional areas.

Starting with elements identified in SPD-3 this list was expanded through inputs from key stakeholders along with research from relevant studies and reports. As a result, this list of capabilities reflects the dynamism of this evolving landscape.

The primary focus for capabilities is on the role of government agencies—in particular, based on the purpose of this study, to identify the U.S. government lead agency role. However, as described earlier, since the list is based on a lifecycle view of satellite operations, it invariably includes an enterprise view and includes core activities, some of which will be performed by commercial actors and other stakeholders.

Basic and Advanced Services

There is broad agreement among stakeholders that the currently provided situational awareness information is limited and insufficient. As a result, there is an urgent imperative for the lead STM agency to expeditiously seek to improve the quality of information to reduce the risk to the space ecosystem and enable safer and more sustainable operations in the space environment.

The Panel foresees a hybrid funding model that combines both a fee for service and a no cost basis to provide SSA and STM services. Basic services will provide accurate location of space objects including small debris.

Advanced services are more complex and provide increased accuracy, coverage and timeliness. As the satellite population increases, it is likely that operators will need to purchase advanced services as a condition of license. The exact nature of these services and obligations for use will largely be defined by the STM manager, by industry capabilities, and shaped by market dynamics.

However, given the dynamic changes in space technology and the impending crisis with space debris and satellites, it is urgently critical that current commercial services are engaged, and further advanced services are developed and offered expeditiously. This will be an important priority for the STM agency. This agency should act to facilitate development of the commercial marketplace to enable rapid development of advanced services. Ultimately, the Government bears an obligation to the public to ensure safety and sustainability while also fostering innovation.

If established properly, and if supporting authorities are enacted by Congress, a differentiation between advanced and basic services will provide a revenue stream based on a fee for service model to be adopted that is independent of the annual appropriations process. While more consideration should be given to this question, one opportunity for the lead STM agency to introduce and implement a fee for services model may occur at the time when an entity applies to the AST for a license to launch an asset into space. The fee for service model seems a reasonable approach to apply when noting that the majority of entities seeking launch approval intend to fund the project by charging fees to customers.

Notwithstanding the foregoing, the precise demarcation between basic and advanced services is intentionally not defined in this report. The demarcation should be driven by STM needs and market dynamics and should be the responsibility of the lead civil SSA/STM agency as part of its program definition and planning. It will be critical to define basic services with input from industry and other stakeholders to ensure it meets stakeholder needs and avoids creating disincentives for market development of advanced services. Once basic services are defined, it will be equally important to communicate the scope and boundary of basic services the Government intends to provide – this will enable industry innovation of advanced services. In so doing, the lead STM agency can serve the commercial space industry by helping to stimulate evolution of high-quality services. Given the rapid acceleration of technological advances in this domain, the lead STM agency must be outward focused in order to observe changes in the marketplace and its underlying technologies, and consider how these developments might shift the demarcation between basic and advanced services as time goes on.

Current and Future State

In addition to the above considerations, the list of capabilities includes a description of the current state of the landscape, including the required capabilities and key stakeholder roles and activities. Since it is not possible to predict technology changes in the future, the description of future capabilities and stakeholders constitute some general expectations and should not be considered to be comprehensive. While SPD-3 identified OSC as the lead agency, the Panel urged the study team to conduct an empirical, and independent research undertaking—considering the important work of the inter-agency process. As a result, the key organization is explicitly identified as the "lead civil agency" in the future state.

Summary of Capabilities

As described in Figure 3-1 below, the list of capabilities is organized around key areas, with each capability divided into its individual components.

Figure 3-1. Organization of the Capabilities

*U.S. government and military, commercial actors, academia and research, international actors

Source: National Academy of Public Administration

The capabilities list includes the following areas:

- Capability: A capability is the collective set of skills, abilities, and expertise. The scope of the capability includes a short summary description.
- Component: A capability is composed of one or more components—sub parts that together define the capability. Included in the list is a short definition to describe the scope of each component. In addition, a few components include basic and advanced services as examples.
- Tasks and Activities: Tasks and activities are a granular description.
- Policy, Regulations, and Standards Regime: Each component includes an associated policy, regulations, and standards regime.
- Key U.S. Federal Organizations and their Roles: For each component, the key organization involved in the current state is identified, in addition to the role the lead civil agency is expected to play in the future state. The primary focus is identifying the role of U.S. Federal agencies, and, as per this study's objective, this list identifies the role the civil lead agency is expected to play in the future state.

- Key Stakeholder Roles: Key stakeholders include U.S. civil government agencies, U.S. national security agencies, the private sector, academia, and international government and organizations. It includes a brief description of the role of each stakeholder.

The below listed capabilities are essential to performing the SSA and STM functions and should be viewed in the strategic context: they support the core mission objectives of protecting national security interests, ensuring space safety, enabling commercial growth, establishing U.S. leadership, and promoting international coordination.

Table 3-1 provides a summary view of the capabilities, mapped to the relevant SSA and STM functions they enable. Notifications and Space Technology, for example, are fundamental capabilities that enable both SSA and STM.

Table 3-1. Capabilities Summary View

CAPABILITIES	**COMPONENTS**			
Notifications	Notification Database & Channels		Notification Dissemination	
Space Technology	Open Network & Data Architecture		Research & Development	
Space Situational Awareness (SSA)	Surveillance & Tracking	Conjunction Assessment Screenings & Catalog Maintenance	Environmental Data	
Orbital Debris Management	Debris Modeling and Measurements		Debris Protection & Mitigation	
Space Traffic Operations Coordination & Management	Space Traffic Coordination & Safety	Collision Avoidance Risk Assessment	Collision Mitigation	Frequency Deconfliction
Design and Launch	Satellite & Constellation Design	Pre-Launch and Launch Support	Spectrum Management & Use	Early Orbit
Disposal and Reentry	Safing, Repositioning, De-Orbit/Reentry		Disposal and Debris Removal	

LEGEND

SSA	Both SSA and STM	STM

Source: National Academy of Public Administration

Key Takeaways

As it can be seen from Table 3-2, most capabilities can be mapped discretely to the function they enable: SSA or STM, along with a couple of fundamental capabilities (such as Space Technology and Notifications, which enable both SSA and STM), are intertwined. However, it is important to note that SSA capabilities are prerequisite to enabling STM functions.

The analysis of the core capabilities reveals the following insights:

The Important Role of Stakeholders in Enabling a Successful SSA/STM Mission

Successful SSA/STM will involve coordination and synchronization between all stakeholders, including U.S. civil agencies, U.S. military agencies, the private sector, academia and the research community, and international governments and actors. Each stakeholder brings important contributions to the value chain to enable successful SSA/STM capabilities. As a result, each stakeholder has an important role, as further discussed below.

The Lead Civil STM Agency Needs to Partner with a Number of U.S. Federal Agencies

Currently, a number of U.S. federal organizations have authority over, and support multiple parts of, the SSA/STM mission. As an example, consider Debris Protection and Mitigation: NASA provides standards and requirements; FAA has authority over debris mitigation of launch vehicles and upper stages (the most massive objects on orbit); FCC has adopted rules regarding orbital debris mitigation for Commission-authorized satellites and recently issued a Notice of Proposed Rulemaking;[55] and as part of its licensing requirements for CRS, NOAA requires the licensee to assess and minimize the amount of orbital debris.[56]

This current state is not expected to change, and it is imperative for the lead civil agency to work with and partner effectively with the relevant U.S. federal agencies based on the capability.

Private Sector Must Play an Active, Engaged Role

A critical component of this space enterprise is the private sector. Achieving a safe, stable, and sustainable space operating environment will require effective data exchange and ongoing interactions among private sector space operators. In fact, in the future, successful STM may involve more communications between operators than between operators and government SSA/STM organizations. Therefore, the lead civil agency must facilitate and set the conditions to enable this coordination and communications. More importantly, the private sector brings advanced capabilities to the space enterprise and it is vital to incorporate these advanced technologies in support of establishing a safe operating environment. Facilitating the growth of the commercial marketplace will incentivize innovation and private sector engagement.

International Coordination and Cooperation Are Essential

Space has no geopolitical boundaries, and no sovereign country can claim ownership—the Outer Space Treaty forbids the appropriation of extraterrestrial territory by States.[57] Given the global

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[55] 2004 FCC Rules and 2020 Notice of Proposed Rulemaking.

[56] 15 CFR Section 960.11

[57] Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, January 27, 1967, Res.2222 (XXI)

nature of the space operating environment, it is important to highlight the important role of international governments and other agencies. As can be seen from this analysis, international governments and actors support a number of activities in the value chain. These activities include providing and consuming, operating satellites, setting standards and rules of the road, supervising and monitoring international spectrum use, maintaining the global registry of space objects, and many more. As a result, international coordination and cooperation is a fundamental component of each capability.

Academia and the Research Community

The academic and research community has a significant role to play and can define the art of possible. Not only is the community a critical technical research partner, it contributes to multiple parts of the value chain, such as providing some sensor data, evaluating and refining predictive algorithms, developing standards, and building payloads, to name a few. In addition, the academic and research community can assist in policy, legal, and economic analysis. Quality engagement with this community will yield significant benefits.

Key Capability Areas – Definitions and Description

This section provides an overview of each capability and its components. Where applicable, examples of basic and advanced services are included, along with a description of detailed tasks and activities. Finally, each section includes the key U.S. federal organizations in the current and future state, along with roles of the other key stakeholders.

Notifications

SSA and STM notification services establish safe, stable, and sustainable space operations to enable operators to minimize the impact to a consumer's mission. Components include:

Notification Database and Channels and Notification Dissemination: This includes the notification of owners/operators of potential conjunctions. Some examples of what may be considered Basic and Advanced services are included below. The notification service is just the starting point for what could be extensive interaction between operators on an upcoming conjunction.

<u>Basic Services</u> could include free-of-charge notifications related to conjunction and reentry, static content, and post-maneuver notifications could flow back into the SSA system.

<u>Advanced Services</u> could be made available to system users through a marketplace or brokerage which might provide access to innovative advanced services to more users, incentivizing innovation in the provider community. They could include tailored commercial services notifications related to advanced conjunctions; dynamic content, for example related to collision avoidance notifications made possible by on-board transponders; refined modeling of continuous thrusting; and reentry and launch safety services. In the future, this could lead to more extensive operator-operator interactions. In addition, some missions will be dynamic, such as space tourism

and Rendezvous and Proximity Operations (RPO), and these will lend themselves to more active monitoring than just an e-mail notification service.

- Database to provide notifications; notification channels (email, website, automated machine-machine, phone etc.) Note: some of the notification channels are relevant for future. Ideally, operators notify affected operators of the outcome of their decisions and, if appropriate, the post-maneuver location of their satellite.
- Basic notifications include conjunction and reentry notifications. Advanced notifications should include tailored commercial services.

Notification Database and Channels and Notification Dissemination	
Key U.S. Federal Organizations & their Roles	**Other Key Stakeholders and their Roles**
Current: DoD **Future:** U.S. Civil Government Agency Lead	• Civil: Department of State (Registry); Sources include NOAA and NASA. U.S. and mission partner civil spacecraft receive the same level of support from DoD as it provides to national security spacecraft. • Military: Currently provided by DoD. • Private Sector: Operators as providers (Space Data Association) and as consumers – they receive emergency notifications from DoD via SSA sharing agreement. Commercial SSA and STCM data analytics service providers provide Advanced SSA Services. • Academia: Academia receive emergency notifications from DoD; advanced notifications via SSA sharing agreement. • International: United Nations (Space Object Register); International Governments as data providers and consumers - International Governments (operators) receive emergency notifications from DoD; advanced notifications via SSA sharing agreement.

Space Technology

Space Technology includes the data repository, infrastructure, platform, software, products and services to gather, store, manage, and enable access to SSA data, and to perform and disseminate basic and advanced STM services. It enables and improves SSA data interoperability and sharing via secure technology and data standards. Research and Development (R&D) advances SSA and STM and informs the Open Network and Data Architecture component.

Open Network and Data Architecture: Includes data repository (OADR), infrastructure, platform, software, products, and services based on an open network architecture. It includes design, modernization, and enhancement (DME); operations and maintenance (O&M); and archival services.

- Technology DME and O&M; data ingestion and processing (collect, catalog, and fuse government/commercial data); data classification and markings, data integrity and protection (collection, vetting, categorizing, storing, protecting SSA data); data standards; data normalization constructs (timing systems, element set conversions, coordinate frames, units). One approach could be a marketplace for advanced services: providing access to innovative advanced services to more users, incentivizing innovation in provider community.

A Note on Information Sharing:

- Data and information are fundamental components of the space technology capability and while they are described in later sections of this report, it is important to highlight their critical role. For successful SSA/STM, data integrity, protection, and data sharing mechanisms must be supported by an incentive structure that promotes those mechanisms. Data security and competitive interests must be balanced.

<table>
<tr><th colspan="2">Open Network and Data Architecture</th></tr>
<tr><th>Key U.S. Federal Organizations & their Roles</th><th>Other Key Stakeholders and their Roles</th></tr>
<tr><td><u>Current:</u>
None

<u>Future:</u>
U.S. Civil Government Agency Lead</td><td>• <u>Civil:</u> DOC (NOAA, NIST, large data bureaus)
• <u>Military:</u> DoD provides public access point for unclassified data.
• <u>Private Sector:</u> Commercial cloud services, commercial technologies and commercial data.</td></tr>
<tr><td colspan="2">Policy, Regulations, and Standards Regime:
• Standards, Best Practices and Guidelines: could include setting up incentives to promote sharing data among actors.</td></tr>
</table>

Research and Development (R&D): Includes R&D related to the advancement of SSA and STM in an environment that enables interaction between academia and industry and FFRDCs. R&D influences and informs the Open Network and Data Architectures component.

- Develop new hardware and software to support data processing and observations and risk assessment methodologies. Visibility and trackability, advanced propulsion systems, active debris removal technologies; develop innovative techniques to maximize use of frequency spectrum and minimize interference.

Research and Development	
Key U.S. Federal Organizations & their Roles	**Other Key Stakeholders and their Roles**
Current: NASA; DoD; DOC (NOAA & SWPC) **Future:** NASA; DoD; DOC (NOAA & SWPC); U.S. Civil Government Lead Agency	• Civil: Federally Funded Research Development Centers (FFRDCs); FAA Center of Excellence (CoE) for Commercial Space Transportation. • Military: Air Force Research Laboratory (AFRL) Unified Data Library (UDL), Space and Missile Systems Center (SMC), United States Space Force (USSF). • Private Sector: Partner in R&D. • Academia: Partner in R&D. • International: European Union Space Surveillance & Tracking (EUSST) Consortium, various countries.
Policy, Regulations, and Standards Regime: • Standards and best practices - FAA Center of Excellence for Commercial Space Transportation and Satellite Industry Association (SIA) - recommendations on practices in general.	

Space Situational Awareness (SSA)

According to SPD-3, SSA includes sufficient knowledge and characterization of space objects and their operational environment to support safe, stable, and sustainable space activities. Based on stakeholder inputs, this definition is expanded. SSA can be described as the sufficient knowledge and characterization of the entire near-earth space environment including: resident space object (RSO) location and physical characteristics, the natural space environment such as space weather data forecasts and analyses, and monitoring close approaches between RSOs in order to ensure safe, stable, and sustainable space activities. It supports decision-making processes with a quantifiable and timely body of evidence (predictive/imminent/forensic) of behavior(s) attributable to specific space domain threats and hazards.

SSA includes the following major components:

Surveillance and Tracking: It includes managing the space catalog which requires the maintenance of positional information for space objects by synchronizing the aggregate sensor contributor network, including frequency tracking and interference mitigation. Information is provided by sensor networks.

- Sensor Information: Sensor information is provided by sensor networks which use different sensor types (optical, radar, radio frequency (RF), laser) and sensor systems (ground-based and space-based) to search, discover, track and characterize (SDTC) space objects. It includes tasking of sensors, collection of observations, processing observations, and creating resolution of information inconsistencies.

- Frequency Tracking: Includes tracking assigned frequencies and interference mitigation measures.

<table>
<tr><th colspan="2">Surveillance and Tracking</th></tr>
<tr><th>Key U.S. Federal Organizations & their Roles</th><th>Other Key Stakeholders and their Roles</th></tr>
<tr><td><u>Current:</u>
DoD

<u>Future:</u>
U.S. Civil Government Agency Lead; using DoD and commercial SSA information from sensor/SSA data companies and operator shared data</td><td>
<u>Civil:</u> Data consumers and providers - NASA, NOAA, USGS. NIST (Standards).
<u>Military:</u> Data consumer and providers - DoD (sensor information provision - unclassified data).
<u>Private Sector:</u> Data providers - SSA Operators and SSA commercial tracking companies (optical, radar and RF); Data consumers - Operators, others. In addition, private sector is involved in standards development and best practices. Other entities include: United Nations Committee for the Peaceful Use of Outer Space, International Organization for Standardization (ISO), The Consultative Committee for Space Data Systems (CCSDS), CONFERS, American Institute of Aeronautics and Astronautics (AIAA).
<u>Academia:</u> Data providers - provide some sensors and sensor data; research and development.
<u>International:</u> Data providers and consumers - United Nations (UN) Committee on the Peaceful Uses of Outer Space (COPUOS), European Space Agency (ESA), Centre National D'Etudes Spatiales (CNES), European Cooperation for Space Standardization (ECSS).
</td></tr>
<tr><td colspan="2">Policy, Regulations, and Standards Regime:
Policy & Regulations:
Department of State has authority over International non-compliance of spectrum use.
FCC is charged with domestic non-compliance of spectrum use.

Standards and best practices - commercial, international and SDOs (Committee) and Satellite Industry Association (SIA) - recommendations on practices in general.
</td></tr>
</table>

Conjunction Assessment (CA) Screenings and Catalog Maintenance: For static orbit mission type, it includes Orbit Determination (OD) and data ingestion, which includes operator sharing of data, operational conjunction assessment screening, and catalog updates and maintenance; dynamic orbit missions require more proactive measures.

- Orbit Determination: The computation of orbital parameters, including manual orbit determination for difficult situations, covariance realism, and ephemeris generation.

- Data Ingestion: The ingestion of spacecraft operator data includes maneuver plans, ephemerides, observations, object dimensions, and attitude rules. Dynamic operations require real-time monitoring and communications. Also, data ingestion includes sharing data among operators.
- Catalog Updates and Maintenance includes sensor calibration and sensor observation association.
- CA Screenings: includes screening and catalog updates, reevaluation, refinement screening; risk assessment and management.

Conjunction Assessment (CA) Screenings & Catalog Maintenance	
Key U.S. Federal Organizations & their Roles	**Other Key Stakeholders and their Roles**
Current: DoD; NASA (for NASA conjunctions) **Future:** U.S. Civil Government Agency Lead; NASA (for NASA conjunctions); Commercial CA and STM companies	• Civil: NASA - for U.S. and international mission partner robotic and crewed spacecraft. • Military: DoD - Currently provided by DoD to all space operators. • Private Sector: SSA and STM providers currently receive support through DoD SSA sharing agreements. • Academia: Evaluation and refinement of predictive tools; algorithm development. Academia currently receive support through DoD SSA sharing agreements. • International: Data consumers.

Environmental Data: includes Space Weather (thermospheric for CA, ionospheric for communication), micrometeoroid forecast, Timing and Earth Orientation parameters, space debris population modeling, encounter risk frequency, etc.

- Space Weather (thermospheric for CA, ionospheric for communications), Timing and Earth orientation parameters, space radiation data and warnings for human space flight, micrometeoroid forecasts and warnings, anomaly resolution caused by the natural space environment.
- The key space weather data includes the 10.7 cm Solar Flux (often referred to as F10.7) and the Geomagnetic Index (Kp), both received from NOAA's Space Weather Prediction Center.

Environmental Data	
Key U.S. Federal Organizations & their Roles	**Other Key Stakeholders and their Roles**
Current: NOAA (DOC), DoD, NASA **Future:** NOAA (DOC), DoD, NASA	• Civil: NASA: model and algorithm development & data source. NOAA: Data source. • Private Sector: Earth Observation companies providing value added advanced services • Academia: University of Colorado Boulder's Space Weather Technology, Research, and Education Center (SWx TREC). • International: International space weather organizations such as ground sites, other spacecraft, including data & analysis from ESA Space Weather Office, UK Met Office and Australian Bureau of Meteorology.

Orbital Debris Management

Orbital Debris Management includes development, implementation, and enforcement of policy, procedures, and best practices to mitigate the impact of existing debris on space activities, and to minimize unnecessary creation of additional debris. It Includes activities in the unlikely event of a collision.

Debris Protection and Mitigation: Protection includes the assessment of the risk presented by orbital debris to operating spacecraft, and development of new materials and new designs for better protection. Mitigation focuses on controlling the growth of the orbital debris population by improved satellite design requirements and operational procedures.

- Long term environmental risk assessment, debris prevention and curtailment, satellite design, satellite operational procedures. It includes debris field tracking in the unlikely event of a collision.

<table>
<tr><th colspan="2">Orbital Debris Management</th></tr>
<tr><th>Key U.S. Federal Organizations & their Roles</th><th>Other Key Stakeholders and their Roles</th></tr>
<tr><td><u>Current:</u>
NASA, FCC, DoD, FAA (DOT) (for rocket bodies); NOAA (DOC) for Commercial Remote Sensing (CRS)

<u>Future:</u>
NASA, FCC, DoD, FAA (rocket bodies); DOC for CRS, U.S. Civil Government Agency</td><td><u>Civil: </u>NOAA and USGS apply NASA standards during acquisition phase.
<u>Military:</u> DoD (for its own assets).
<u>Private Sector:</u> provides deep analytics and predictive algorithms to inform the applications/licensing and STM process; flight safety systems (Space Data Association).
<u>Academia:</u> Research and Development.
<u>International:</u> IADC, ISO and others for design standards; diplomatic agreements to prevent debris generating Anti-Satellite (ASAT) activities by governments are needed.</td></tr>
<tr><td colspan="2">Policy, Regulations, and Standards Regime:
Policy & Regulations: FAA - debris mitigation of launch vehicles and upper stages (the most massive objects on orbit). FCC - Rules of 2004 and NPRM 2020.
Standards, Best Practices and Guidelines: DOC chairs Interagency Working Group on Orbital Debris Mitigation Requirements for Industry. International agreements between commercial sector and government. International standards development via codification of commercial debris mitigation best practices (Space Safety Coalition).</td></tr>
</table>

Debris Modeling and Measurements: Describe and characterize the current and future debris environment; conducting ground-based and space-based observations of the orbital debris environment.

- Impact testing; debris environment observation, characterization and prediction; work with industry to incorporate the most current and accurate debris models.

Debris Modeling and Measurements	
Key U.S. Federal Organizations & their Roles	**Other Key Stakeholders and their Roles**
Current: NASA **Future:** NASA	• Civil: FCC. • Private Sector: Industry assembles debris and fragmentation/breakup models and applies deep analytics and predictive algorithms to inform the applications/licensing, mission design, mitigation requirements and STCM process. • Academia: Basic and applied research. • International: IADC and ESA.

Space Traffic Operations Coordination & Management

Activities performed by space operators and SSA/STM organizations to prevent and mitigate unwanted orbital conjunctions in orbit. This is informed by, and dependent on other capabilities, such as SSA, Space Technology, Notifications and others. It includes the following components:

Space Traffic Coordination and Safety: Space traffic coordination and safety includes setting the conditions for effective data exchange and ongoing interaction between space operating stakeholders to promote a safe, stable and sustainable space operating environment. It primarily involves coordination of space activities to ensure safety by sharing information and synchronizing operations—the government needs to facilitate and promote operator synchronization and coordination, such as by creating and maintaining Operator Forums.

Space Traffic Coordination and Safety	
Key U.S. Federal Organizations & their Roles	**Other Key Stakeholders and their Roles**
Current: DoD **Future:** U.S. Civil Government Agency Lead	• Military: DoD. • Private Sector: Private sector companies as both consumers and providers; Space Safety Coalition • Academia: Standards Development. • International: Establishing data Standards and rules of the road; ISO, Inter-Agency Space Debris Coordination Committee (IADC), American Society for Testing and Materials (ASTM) International.
Policy, Regulations, and Standards Regime: • Regulatory environment & licensing (future). • Standards and best practices as key mechanisms.	

Collision Avoidance Risk Assessment: Collision risk assessment and management; anomaly resolution.

- Risk Assessment and Management, including collision likelihood assessments, collision consequence assessments, and data actionability, including collision likelihood assessments, collision consequence assessments, and data actionability; Anomaly resolution

Collision Avoidance Risk Assessment	
Key U.S. Federal Organizations & their Roles	**Other Key Stakeholders and their Roles**
Current: DoD, NASA **Future:** U.S. Civil Government Agency Lead, operators	• Civil: NOAA, USGS and EUMETSAT are participants. Separate NASA office performs assessments for ISS and human space flight. • Military: DoD, for DoD assets - performed for all national security space missions within a classified environment. • Private Sector: New commercial services - may be under contract to DoD or selling commercial analyses in the marketplace. • Academia: Research partner. • International: EUSST is focused on Risk Management; European Organisation for the Exploitation of Meteorological Satellites (EUMET SAT).

Collision Mitigation: Collision Avoidance, Synchronization, and Maneuver planning operations.

Collision Mitigation	
Key U.S. Federal Organizations & their Roles	**Other Key Stakeholders and their Roles**
Future: U.S. Civil Government Agency Lead	• Civil: NASA (for its own and NOAA assets). • Military: DoD (for its own assets). • Private Sector: Commercial services. • Academia: Science research, informing public policy. • International: EUSST, ESA.

Frequency Deconfliction: Coordinate and synchronize frequency spectrum traffic to prevent or mitigate interference.

Frequency Deconfliction	
Key U.S. Federal Organizations & their Roles	**Other Key Stakeholders and their Roles**
Current: FCC, NTIA (DOC) **Future:** FCC, NTIA (DOC)	• Civil: NASA (for its own and NOAA assets), NTIA. • Military: DoD (for its own assets), NTIA. • Academia: Assist tracking high-interest reentries. • International: International Telecommunications Union (ITU) - International Allocations and Operational Requirements.

Design and Launch

Design and launch include the necessary activities to promote a safe, stable, and sustainable space operational environment.

Satellite, Constellation & Orbit Design: includes performance guidelines and requirements, including orbital debris mitigation requirements (which are also addressed in Orbital Debris Management). It includes effective design actions by operators and innovation for satellite and constellation design.

- Providing performance guidelines and requirements for satellites and constellation design; ensure safety in the design to include hardware/software design and constellation design; orbit selection deconfliction.

<table>
<tr><th colspan="2">Satellite, Constellation & Orbit Design</th></tr>
<tr><th>Key U.S. Federal Organizations & their Roles</th><th>Other Key Stakeholders and their Roles</th></tr>
<tr><td><u>Current:</u>
FCC, FAA (DOT), NOAA (DOC)

<u>Future:</u>
Current: FCC, FAA (DOT), NOAA (DOC)</td><td>• <u>Civil:</u> FCC, DOC's CRSRA licenses commercial remote sensing, State, and NASA (NPDs, NPRs, S&MA regulations). NOAA and USGS apply NASA standards during design.
• <u>Military:</u> DoD through CSpOC and USSTRATCOM (USSPACECOM) and OSD Policy.
• <u>Private Sector:</u> Manufacturers, Operators, Commercial insurance underwriters.
• <u>Academia:</u> Academia builds and launches payloads.
• <u>International:</u> International design and test standards organization.</td></tr>
<tr><td colspan="2">Policy, Regulations, and Standards Regime:
• Policy & Regulations: NASA - NASA Policy Directives (NPDs), NASA Procedural Requirements (NPRs), Safety & Mission Assurance (S&MA) regulations.</td></tr>
</table>

Pre-Launch and Launch Support: Activities include pre-launch coordination and post-launch early orbit determination, including conjunction assessments and mitigation. Registration is coordinated in the same way that payload reviews are coordinated for U.S. based launches (FAA-led coordination with all space-related interagency) and then forwarded to State Department for final determination and transmittal to the UN. Unless exempt, the FAA requires a payload determination for launch license—a payload review is conducted to make the determination.[58]

- Range safety certification, launch manifesting, launch commit criteria development; predicted tracking, pre-launch coordination, post-launch early orbit determination; Collision Avoidance, pre-launch vetting and safety, including predicted conjunctions during launch windows, launches, and initial spacecraft orbit spatial allocation

[58] U.S. Code of Federal Regulations, Title 15, Chapter 3. Subchapter C. 415-3. https://ecfr.federalregister.gov/current/title-14/chapter-III/subchapter-C/part-415

<table>
<tr><th colspan="2">Pre-Launch and Launch Support</th></tr>
<tr><th>Key U.S. Federal Organizations & their Roles</th><th>Other Key Stakeholders and their Roles</th></tr>
<tr><td><u>Current:</u>
FAA (DOT), NASA, DoD, NOAA (DOC), USGS (DOI)

<u>Future:</u>
FAA (DOT), NASA, DoD, NOAA (DOC), USGS (DOI)</td><td>• <u>Civil:</u> FAA (commercial launch); NASA or DoD (USG launches), State (UN Registry) and EPA – National Environmental Policy Act (NEPA).
• <u>Military:</u> DoD.
• <u>Private Sector:</u> Launch companies and manufacturers, satellite companies and manufacturers, launch and LCOLA service providers, operators, insurance and underwriters.
• <u>International:</u> Handled by countries as Launching States.</td></tr>
<tr><td colspan="2">Policy, Regulations, and Standards Regime:
• FAA - The FAA requires a license or permit from any U.S. Citizen or entities seeking to conduct or operate vehicle launch/reentry in the U.S. A payload review is included as part of its U.S commercial launch authorization, unless it is exempt.
• NASA or DoD are responsible for U.S. government launches.
• Department of State is responsible for UN Registry updates.</td></tr>
</table>

Spectrum Management and Use: it includes Spectrum Allocation and Licensing and developing policies for spectrum use. It involves innovative design by satellite operators to mitigate impact and enable efficient use of spectrum.

- Licensing and Regulation (Remote Sensing, Export Control etc.); improve policies, processes, and technologies for spectrum use (including allocations and licensing)

Spectrum Management and Use	
Key U.S. Federal Organizations & their Roles	**Other Key Stakeholders and their Roles**
Current: FCC, NTIA (DOC), BIS (DOC), NOAA (DOC), State **Future:** FCC, NTIA (DOC), BIS (DOC), NOAA (DOC), State	• Civil: FCC - Commercial Spectrum Allocation, Licensing, Operational Requirements; NTIA (DOC)—allocations and assignments; Department of State. • Private Sector: Radio Frequency Interference (RFI) and Equiv. Power Flux Density (EPFD) modeling tools, used by ITU and the space industry. • International: ITU - International Allocations and Operational Requirements.
Policy, Regulations, and Standards Regime: • FCC - Spectrum allocation and licensing; NTIA (DOC) – Government allocations and assignment.	

Early Orbit: Management of transit orbits to on-station positions.

Early Orbit	
Key U.S. Federal Organizations & their Roles	**Other Key Stakeholders and their Roles**
Current: FAA (DOT) **Future:** FAA (DOT)	• Civil: NASA • Military: DoD – early orbit CA • Private Sector: Commercial SSA service providers (initial object association, refined orbits, launch performance assessment, spacecraft maneuver calibrations); Industry-formed associations (CONFERS) and SSC
Policy, Regulations, and Standards Regime: • FAA – clearing airspace	

Disposal and Reentry

Disposal and Reentry involves safing and repositioning of expended space capabilities to prevent interference with existing and future space activities.[59] It includes reentry predictions and assessments and post-mission disposal by satellite operators and debris removal.

Safing, Repositioning, De-Orbit/Reentry includes reentry predictions and assessments and effective operator planning. It includes operational procedures for compliance, ground traces and tracking confirmations, debris assessment and survival and determining graveyard parking orbits.

<table>
<tr><th colspan="2">Safing, Repositioning, De-Orbit/Reentry</th></tr>
<tr><th>Key U.S. Federal Organizations & their Roles</th><th>Other Key Stakeholders and their Roles</th></tr>
<tr><td><u>Current:</u>
FAA (DOT), FCC, DoD, NOAA/OSC (DOC) for Commercial Remote Sensing (CRS)

<u>Future:</u>
U.S. Civil Government Agency, FAA (DOT), DoD, FCC, NOAA/OSC (DOC) for CRS</td><td><u>Civil:</u> Department of State - for reentries outside of U.S. territory classified as "high-interest" uncontrolled reentries); DOE for reentries involving radioactive power generators (high-interest by definition);[60] FAA (AST) – Reentry.
<u>Military:</u> DoD (reentry).
<u>Private Sector:</u> Commercial SSA service providers, On-Orbit Servicers.
<u>International:</u> Assist tracking high-interest reentries.</td></tr>
<tr><td colspan="2">Policy, Regulations, and Standards Regime:
FAA (reentry licensing). The FAA and DoD provide support for reentries. This includes reentry predictions, safety analysis, and ground, maritime, and aviation safety and notices as well as orbital collision avoidance from orbit to reentry. FAA AST has responsibility for reentry - Commercial space is authorized for global responsibility under Title 51.</td></tr>
</table>

Disposal and Debris Removal: includes primarily post-mission disposal by satellite operators and debris removal. It includes End-of-Life support and guidelines, advise on disposal orbits and related maneuvers, and legal adjudication of debris ownership/removal authority. Advanced Services include but are not limited to active debris removal.

<table>
<tr><th colspan="2">Disposal and Debris Removal</th></tr>
<tr><th>Key U.S. Federal Organizations & their Roles</th><th>Other Key Stakeholders and their Roles</th></tr>
<tr><td><u>Current:</u>
FAA (DOT), DoD

<u>Future:</u>
FAA (DOT), U.S. Civil Government Agency Lead</td><td><u>Civil:</u> FAA (end-of-mission planning, as part of licensing process).
<u>Military:</u> DoD.
<u>Private Sector:</u> Debris Mitigation and Remediation (removal) companies.</td></tr>
<tr><td colspan="2">Policy, Regulations, and Standards Regime:
Establish standards and guidelines.</td></tr>
</table>

3.2 Departmental Capacity and Support

The analysis of the capabilities points to the breadth and depth of expertise required to successfully execute on the SSA and STM missions. As described earlier, an organization does not need to possess all of the required capabilities and can successfully partner with other stakeholders. However, if it has access to these capabilities within its host department, it is a much easier proposition than trying to establish partnerships with external agencies, and other external stakeholders. As a result, two primary organizational aspects become important: intra-departmental capacity and intra-departmental support.

Departmental capacity refers to the combined expertise a department can bring to the table as a force multiplier. It includes not only the relevant, transferable technical expertise and experience but also the diversity of such experience. As an example, a core objective is to grow the space commercial marketplace—as such, to grow a market sector, an organization needs expertise in economic development, commerce and trade domain knowledge, building consensus in the industry, enabling marketplace innovation and other attributes. An organization that can leverage its departmental capacity in these areas will have a significant advantage.

The criticality assigned to evidence of departmental senior leadership support—including both political appointees and career senior executives—cannot be overstated.[61] Departmental leadership support complements overall departmental capacity. First, leadership and management mission clarity and support can provide significant advantage since executive vision and leadership is a vital factor for success. The level of support from organizational management and leadership toward the new mission requirements, as observed vis-a vis their other priorities, can determine if organizational management and leadership will be an asset in achieving the mission.

Building on its leadership and management support, an organization must be able to leverage the capacity that exists—either through formal or informal agreements. Although formal agreements are more sustainable and can increase the probability of success, they can also decrease the reliance on personal relationships (an important factor) to incentivize departmental collaboration.

Finally, a critical enabling factor is the organizational culture that can support the agency in meeting its adaptive challenges and collaborating internally. The importance of a dynamic and collaborative agency culture cannot be emphasized enough. While it is intangible and hard to measure, it can effectively help, or serve as an obstacle, in an organization's efforts in being able to successfully leverage the departmental capacity and support.

[61] Senior leadership includes political appointee-level employees, career SES-level employees, and GS-15 level employees.

3.3 Capabilities in Decision-making

The capabilities assessment and evaluation of departmental capacity and support provide an enterprise view of the fundamental functional capabilities required to successfully meet the SSA/STM mission requirements and objectives. SSA/STM functions require a breadth and depth of capabilities which are expected to evolve given the dynamic and evolving SSA and STM landscape. This analysis of the enabling capabilities highlights the role that the lead civil agency will play to effectively:

1. Partner with other federal agencies;

2. Engage and incentivize the private sector to promote cooperation among industry partners and advance space technology;

3. Engage and work with the international community to facilitate and establish international consensus norms, standards, and guidelines for safe space operations;

4. Leverage the expertise of the research and academic community; and

5. Develop a supporting network of policies, regulations, and standards.

STM Operational Model

The Panel's analytical considerations now turn to more specific features of an operating model that will perform in this unique, rapidly changing environment. To be successful, the new civil STM organization needs to adapt to the speed of innovation, drawing from commercially available goods and services where possible to advance national needs.[62] Further, it must recognize the new players in the commercial environment and serve as an industry advocate within the Executive Branch.[63] Finally, the new civil STM organization must draw from design principles that guide the development of a network-based governance system.[64] Such a decentralized approach is necessary in order to foster the following six mission objectives:

- **Foster Collaboration across the Space Economy:** The STM agency should be a network-based organization that connects the public and commercial actors across the space economy through a shared interest in safety and sustainable use of orbital space.
- **Foster Public-Private Collaboration for Research and Standards:** The STM agency must foster platforms for collaboration where commercial and research and development activities may thrive. To advance the non-military commercial and research

[62] 51 USC 50702 (d) (4).
[63] See for example: Keith Carlisle and Rebecca L. Gruby, "Polycentric Systems of Governance: A Theoretical Model for the Commons," *Policy Studies Journal*, Volume 47, Issue 4, November 2019, Pages 927-952.
[64] Sources informing the development of these six objectives include Stilwell, Morin, and Panel research.

uses of space, the STM agency must work collaboratively with public agencies, private industry, academia, and other actors engaged in this domain. It must place a high priority on serving as a convener, coordinator, and trusted leader among and within the larger domestic and international community.

- **Create a Shared Platform for SSA:** The STM agency should foster a joint effort among government, industry, and academia to create a robust system that allows for inputs of SSA data from multiple sources. This effort can be coordinated through work defining an open architecture for sharing SSA data.
- **Market-Driven Data Management:** The STM agency will seek to tap commercial and other sources of SSA data to improve basic SSA services—such as conjunction assessment and warnings—without displacing private services. At the same time, it will seek to enable innovation of more advanced services to meet diverse and evolving operational needs, including attribution and maneuver optimization.
- **Encourage Responsible Industry Leadership:** The creation of the standards and best practices should be developed in consultation with industry. Industry, particularly the New Space operators themselves, have the capability (as well as the responsibility) to create new methods of mitigating risk connected with their activities in space. However, such action may not evolve spontaneously, given the extant incentives facing private actors. The STM agency should take the lead in establishing the framework within which competing firms can compete, innovate, and sustain the orbital commons
- **Foster International Cooperation**: The STM agency will foster international agreements on standards of behavior for the purpose of collision avoidance. It will consult with commercial space actors, international partners, and relevant organizations (e.g., CONFERS) in developing data-sharing protocols, standards and norms for operating in orbit and mitigating debris.

Based on these principles, the agency selected for STM must have an operating vision to remain relatively small as an organization, focused on enhancing its capabilities and market service reach via engaging creatively with force multipliers. These can be gleaned from its active approach to collaboration with stakeholders both within and external to government.

The focus of this agency's work must be integrally connected to data management first and foremost to be effective. To that end, the agency should establish commercial and international relationships that will help it procure high quality SSA data from trusted sources. The agency's objective is not to accumulate data in volume, but rather curate data with utility to enhance industry growth.

In addition, an important function is to fuse these data and provide outputs that are useful to the community at large. In many respects, an agency given to the STM task should operate with flexibility and creativity when acquiring and processing data, placing a maximum focus to enhance acuity of all "eyes in the sky." In so doing, the aim is to enhance the utility and veracity of conjunction notices so that these can maximally support safe and rapid growth of the commercial space industry, thus enhancing its commercial viability.

With respect to STM, the agency should approach its work with the aim to initially establish its reputation serving as a *space traffic facilitato*r. As data sets improve, and their utility grows for the space community, the agency can move forward to serving more of a *space traffic coordination* role. In time, in consultation with space actors, the agency will have an opportunity to perform more of a *space traffic management* role. In short, there is a crescendo of expectations best embraced by this operator that moves progressively from facilitation to coordination, and finally nearing "management." Management is not the first step, but rather logically more of a later development, as the agency's trusted role as a convener and data manager matures.

3.4 A Vision for an SSA/STM Agency

The outlined set of capabilities required, as well as the broader set of principles that should guide its operations, create the mosaic of an agency charged to integrate and coordinate a whole of government solution.

Envisioned is an entity that harnesses the capacity and depth of agencies/departments which gather the data and situation awareness for their core mission purposes and engages that collective capacity in a more organized, coordinated, and efficient manner. By encouraging public-private partnerships, the agency can fully engage in devising the most efficacious model to provide public services and formulate a market dynamic.

Most importantly, the forgoing analysis suggests the role of an integrator, coordinator, and process manager; what is not called for is an operational role to provide SSA or conduct STM on a transaction basis. Instead, this vision set forth here puts the lead agency in the role of prompting the collective public capabilities to orchestrate a sum-of-the-parts outcome that is greater than the simple arithmetic value. By framing the market for space safety, where commercial success is predicated on innovation, service, and stewardship of common pool resources, the agency will encourage commercial customers introduce cost and service efficiencies.

A Scenario for 2025

The features described in the previous paragraphs provide an outline of how the STM agency lead should work. To better grasp these points, the following narrative offers a more animated view on how it should operate in the coming years.

By the year 2025—with the continued growth of the space commercial industry–close to 2,000 satellites will be launched each year. Several types of objects will be whirling in orbit, starting with manned and unmanned space vehicles, active and inactive satellites. With advances in technology and capabilities, there should be advanced capabilities to identify a more granular array of space objects, including many of those present in 2020 but not currently trackable. Based on current estimates, there will be an estimated 2,500,000 space objects in 2025—both human-generated and otherwise.

In addition, there is the prospect of the Kessler Syndrome coming true in its projection: Due to the growing density of space debris and objects in the low Earth orbits, the probability of collisions and the amplified debris that such collisions will generate, will have significantly increased over the years. As a result, in this look forward, the availability of open orbital slots in LEO will be increasingly quite limited and governed by an updated Outer Space Treaty, that is likely needed to be modified to include a commitment for state actors to minimize debris in space.

For this imagined scenario for 2025, the Panel introduces a hypothetical commercial entrant into the space domain. Called SmallSpaceFirm (SSF, not a real company), it is a relatively budding U.S-based entrant into the market seeking to launch a constellation of 150 satellites into space in order to set up an advanced communications network. To do so, SSF must submit an application to AST (true in 2020 and assumed to remain true in 2025) as part of the payload review process. While AST is the agency that receives launch applications, the application (as it does now) triggers an inter-agency approval process involving the Lead STM Agency, DOC, NASA, DOD, FCC, State and others. As part of the launch regulations, the U.S. government requires the following:

(a) Subscription to an approved SSA basic data service, required and enforced by the Lead STM Agency, in order to have high quality SSA data that allow for precise analytics that lead to actionable conjunction warnings (STM)
(b) Agreement to international standards and best practices on debris mitigation and proper disposal, according to what might be an approved future International Debris Management Standards, as certified by an approved federal certifying authority.
(c) Insurance and liability coverage that will require launch and satellite companies to purchase Advanced STM services through the Space Technology Platform.
(d) Perhaps additional licenses, as currently or in future will be required from FCC, FAA, and DOC (NOAA), as needed.

Oversight of space orbital operations in the U.S. in 2025 should be the responsibility of the Lead STM Agency. That Agency should play a facilitator/coordinator role of civilian space operations. To foster collaboration across the space economy, the Lead STM Agency will foster a connected network of the different actors across the space economy. In addition, it will facilitate a number of international agreements on standards of behavior for the purpose of collision avoidance. All of these actions led by the Lead STM Agency should occur with close collaboration with federal partners, which will include DOD, NASA, AST, FCC, State and others, as appropriate. The work will be planned within an all-of-government tent, with responsibility to effectively collaborate and convene by the Lead STM Agency.

The Lead STM Agency will have established a shared technology platform that allows consumers and providers to connect, share resources, and sell products and services. These products and services are built on curated data from multiple space situational data sources, that is overseen and managed and by the Lead STM Agency.

In addition to commercial companies, the platform should include space entrepreneurs, innovators, the academic and research community, and international governments and companies. The goal is to foster a trusted environment where all parties have a forum in which to work together in a thriving and rapidly changing commercial marketplace to ensure safe, sustainable operations. All of platform actors have access to the curated SSA dataset, provisioned by the Lead STM Agency.

At this point, the narrative advances forward: after approval of the SSF's launch application in the year 2025, and after it has launched its satellites into operation, the company receives an urgent, escalated message from its Advanced Services Provider of a potential conjunction warning to one of its satellites to that of one of its bigger competitors, which will be named BigSpaceFirm (BSF). This message includes a short summary, risk assessment, and suggested maneuver planning. The warning is delivered promptly because both companies are part of the networked ecosystem, where they have worked together on and agreed to standard guidelines, and where these guidelines have been established and led by the industry consortium and facilitated by the Lead STM Agency. At the same time, SSF is alerted by its research partner of the potential conjunction. Unlike SSF, the research partner has signed onto the Lead STM Agency's basic services and thus has access to necessary and relevant basic information. It uses this information to improve its conjunction predictive algorithms.

From here, efforts to resolve a potential conjunction proceed quickly and most of the interactions are between the two satellite operator firms. According to established standards and guidelines ("rules of the road") which the Lead STM Agency facilitated development and adoption of by 2025, there is more clarity surrounding what maneuvering actions are recommended for BSF to avoid the conjunction. Similar to its other partners, the satellite companies will keep the Lead STM Agency informed of all subsequent activities following the conjunction assessment warnings. Presuming a maneuver is successfully executed, a brief summary report, including data and lessons learned from the incident are shared on the platform.

Chapter 4: Data, Financial, and Regulatory Components of Agency Space Traffic Management Operations

This chapter provides insights into three important elements that will enable the agency selected to implement the civilian-commercial STM mission. These three include improving capabilities for integrating, processing, and sharing SSA data; putting in place enabling statutory authorities and regulations; and planning budget requests sufficient to build STM capabilities over time. This chapter is divided into three sections to cover each element.

4.1 Establishing an Open, Networked Approach to SSA Data Management: Opportunities and Challenges

This section is organized into five segments:

1. New developments creating an imperative to improve SSA services
2. The importance of establishing an a more open, networked approach to SSA data management
3. Ensuring data integrity and national security
4. Major challenges to establishing an open, networked approach to data management
5. The advantages of using a third-party cloud service provider

New Developments Creating an Imperative for Improved SSA Services

There is broad agreement among stakeholders that the conjunction warnings currently provided by DoD are not sufficiently accurate or timely. Evidence of dissatisfaction with DoD's SSA services is provided by the emergence of private sector service providers catering to both federal government and commercial satellite operators.

Two recent developments are generally recognized as creating an imperative to improve SSA services in the near-term and over the longer term:[65]

- The move toward launching large constellations of satellites in LEO puts many more objects in an already crowded orbital regime.

[65] Glenn Peterson, Marlon Sorge, and William Ailor, *Space Traffic Management in the Age of New Space, The Aerospace Corporation*, April 2018.

- The modernization of DoD's Space Fence, which allows for detection of much smaller space objects than before.

Together these two developments create the potential for a great increase in potential "false alarms," that is, conjunction warnings that are insufficiently accurate. These developments force satellite operators to spend significant resources on additional risk assessment, expensive maneuvers or to ignore warnings. The latter choice has the potential to imperil not only their assets, but also the future viability of the orbital path in the event of a collision that generates significant debris.

At the same time, two trends promise to enable the production of more actionable conjunction warnings. First is the proliferation of sensor capabilities, including multiple types of sensors (radar, optical, passive RF and laser) from independent sources across the world available from governments and commercial providers. One of the most promising is the development of active RF transponders on new satellites that will allow very high accuracy tracking that can enable close-proximity maneuvers. However, this technology is still in the prototype stage. The second trend is the improvement of software/algorithms for processing the sensor data to enable more accurate conjunction warnings and other more advanced SSA/STM services, such as attribution and maneuver optimization.[66]

The Importance of Establishing an Open, Networked Approach to SSA Data Management

DoD is not well positioned to take advantage of these new developments and strategies because it relies on a legacy system that is tied to a sensor network with software geared toward the system's original purpose of providing early warning of nuclear missile attack not providing persistent tracking and guidance for collision avoidance. While DoD observational data might be sufficient in many cases, algorithms for orbit determination are not. Relatedly, the DoD system is not scalable to meet the demands of a growing number of detectable objects in space and to deal with an increasing number of space operators. The limitations of DoD's software/algorithms hinder its ability to rely on automation; a significant number of staff must be devoted to validating conjunction assessments.

DoD has made some progress in integrating various non-DoD sources of data via the Unified Data Library (UDL). However, the UDL is hindered by a prescriptive approach to accepting SSA data from non-DoD sources. Data providers must submit data in specific formats that meet the requirements of the DoD internal system architecture. Not only is this process inefficient and burdensome for data providers, but also important information can be lost in the translation thereby limiting the contribution of this data to more accurate conjunction warnings.

There is a general consensus among stakeholders that a more open, networked approach to SSA data management is needed to enable not only more accurate and timely conjunction warnings in

[66] *Global Trends in Space Situational Awareness and Space Traffic Management*, 2018.

the near term, but to enable the innovation of more advanced SSA and STM services to meet the diverse and evolving operational needs of the emerging space economy. Recognition of the limitations of the DOD's closed, internal system is reflected in the call for an Open Architecture Data Repository (OADR) in SPD-3. However, it is important to recognize that an OADR is an essential piece, but not the only piece, of on open, networked approach to data management, as discussed in Chapter 3.

One additional element, as suggested by the above discussion of the limitations of DoD's UDL, is the need for a more flexible, dynamic capability to take in SSA data from different sensor types and a proliferating set of data providers in a way that is more efficient and preserves information needed for more accurate conjunction warnings and other more advanced services. Format-neutral, extensible approaches to data ingestion have been demonstrated in the private sector.

With regard to the repository itself, in applying the open architecture concept, it is useful to think in terms of different "layers." These include the data layer where SSA data from diverse sources is normalized and integrated or "fused" together to provide an increasingly robust basis for generating conjunction warnings and other more advanced services. There is the business process layer where the software (e.g., algorithms) resides for translating observations data from different sources into orbital determinations that are the foundation of conjunction warnings and other services. Also, within the open-architecture repository would be a secure space for experimenting with available data to develop potential new products and services (sometimes referred to as an R&D sandbox).

It is important to note that the "repository" is not a single physical location, but a framework governing how data are managed and shared across potentially many locations. Not all data must reside in a single location but may be shared according to agreed-upon protocols across data bases maintained by various providers.

Primary advantages of an "open," or non-proprietary architecture approach include:

- Interoperability among components;
- Ease of modernization and upgrading components to take advantage of, and remain current with, innovations;
- Ease of data sharing; data integration from various sources and multiple organizations; and
- Enabling competition/avoiding vendor lock-in because requirements for vendors are written in terms of outcomes to be achieved and the standards to which the product must be developed to make it consistent with the architecture used.

Ensuring National Security and Data Integrity

An important consideration for DoD and any civilian agency taking on the civil/commercial SSA mission is how to provide the reliable warnings of possible conjunctions with military and other classified assets without disclosing information about those assets that would threaten national security. To address this issue in the context of its own SSA services to civil/commercial customers, DOD has limited itself to providing the warning while disclosing limited information on the objects themselves or the methodology used in assessing the conjunction. This "black box" approach has contributed to mistrust among some operators about the credibility of conjunction warnings.[67] The concern about disclosing sensitive information about the location of military assets is likely to be rendered moot over time, if it has not been already, as more and better commercial sources of SSA data become available globally that allow the surveillance and tracking of objects independent of the DoD's sensor network.

Concerns about data integrity in the context of an open, networked approach to data management include ensuring the quality and accuracy of the data taken in and the security of data against cyber-attacks. Neither presents a notable technical challenge. It is generally acknowledged that the best way to ensure data integrity and protect against cyber-security threats is a multi-pronged, or layered approach. Such an approach includes encryption of data in transit from providers and in storage; collection of data from multiple types of sensors (e.g., radar, optical, passive RF, laser), locations and provider systems; and high-fidelity calibration to enable automated rejection of bad data. This approach has an established track record of success in the private sector.

Major Challenges to the Successful Establishment of an Open, Networked Approach to SSA Data Management

The major challenges to the successful establishment of open, networked approach to data management have less to do with technical obstacles than with difficulties in reaching agreement on issues such as the conditions under which data will be shared and how they will be paid for. In interviews with stakeholders, two major considerations were identified. These considerations are:

1. What will be produced by the government versus purchased from commercial providers and provided by the government?
2. What types of data will be provided, with whom will they be shared, and under what conditions will these data be shared?

There is little controversy over whether the federal government should provide a basic service for no charge. However, there is concern about what is produced by the government versus what is purchased from commercial providers to be included in the basic service. The core concern is that direct government production will substitute for private sector production, threaten to limit private sector innovation, both of which are keys to meeting evolving operational needs.

Thinking ahead to the provision of more advanced services related to meeting the evolving demands of space traffic management, a major issue relates to the level or granularity of

[67] *Global Trends in Space Situational Awareness and Space Traffic Management*, 2018.

information shared by operators. In addition to near-term imperative of avoiding collision between satellites, three areas include:

- Spectrum warning, sufficient to provide continuous radio frequency interference avoidance;
- Cyber warnings, sufficient to provide real-time cyber alerting; and
- Debris identification and avoidance, sufficient to provide real-time debris avoidance.

In all cases, more detailed information will be needed from operators to enable useful warnings. However, this will require operators to share information often considered to be proprietary.

There is precedent for successfully addressing this information sharing challenge. One example is the National Information Exchange Model (NIEM) in the airline industry. NIEM sets standards, has stakeholder representation, governance, long-term commitment from participants, a documented architecture, and increasing levels of trust between participants. This information sharing program has enabled extensive sharing of information about operations while protecting the anonymity of operators.

Advantages of Using a Third-Party Provider of Cloud Services

Good practice research clearly indicates that an OADR should be hosted by a third-party cloud services provider. Successful precedents can be found in the private sector and in the NOAA Big Data Program. The use of a third-party provider of cloud services offers many advantages compared to developing and maintaining an internal system that are important to meeting the challenges of the emerging mission environment. These include:

- Scalability;
- Redundancy;
- Speed;
- Ability to stay on the cutting edge of technology;
- Flexibility; and
- Reputational incentive of external provider to ensure security of data.

Contracting with a third-party provider of cloud services (or "infrastructure-as-a-service") allows an agency to take advantage of greater computational and back-up capacity. Relying on a third-party cloud service provider obviates the need for data to travel through agency firewalls, enabling greater speed and therefore more timely service to stakeholders. A private sector cloud service provider is better positioned to attract and retain top talent and make investments in new technology. In keeping with an open architecture approach employed by cloud providers, agencies can avoid the common pitfall of becoming locked into a proprietary system. Finally, the established cloud services providers have a clear reputational incentive to prevent cyber-attacks.

It is important to emphasize that the federal government generally has a poor track record in procuring IT systems and services, compared with the private sector. While the choice to procure infrastructure-as-a-service avoids many of the challenges of procuring the development of an internal system it is still a non-trivial task. Careful and sustained attention will be needed on developing and carrying out a requirements process to inform the procurement that balances meeting specific needs while leaving open opportunities to evolve technologies and capabilities in response to a rapidly changing technical and market environment.

4.2 Establishing Regulations and Authorities

This section provides an assessment of what statutory and regulatory changes might be needed to enable a successful transfer of the civilian-commercial STM mission to civilian agency. The assessment is guided by the understanding that any agency selected will need to coordinate effectively across other federal agencies with authorities and capabilities pertinent to the successful performance of the civilian-commercial STM mission, across the life cycle of space objects—from launch to de-orbiting/disposal—as described in Chapter 3. This discussion focuses on two of the four candidate agencies: DOT's Office of Commercial Space Transportation (AST) and DOC's Office of Space Commerce (OSC). While there may likely to be some similarities between these two and NASA and DoD, this report does not examine all four in detail due to time and other constraints.

The Department of Transportation

Public Law 89-670 finds that the establishment of DOT is necessary to "assure the coordinated, effective administration of transportation programs of the Federal Government." AST was established by the Commercial Space Launch Act of 1984, as amended and re-codified at 51 U.S.C. 50901 – 50923) as part of the Office of the Secretary of Transportation within the DOT. In November 1995, Commercial Space Transportation was transferred to FAA as the FAA's only space-related line of business. AST was established to:

- Regulate the U.S. commercial space transportation industry, to ensure compliance with international obligations of the U.S., and to protect the public health and safety, safety of property, and national security and foreign policy interests of the U.S.;
- Encourage, facilitate, and promote commercial space launches and reentries by the private sector;
- Recommend appropriate changes in Federal statutes, treaties, regulations, policies, plans, and procedures; and
- Facilitate the strengthening and expansion of the United States space transportation infrastructure.

With the rapid growth of the space economy, and in response to directives in SPD-2, AST is seeking to develop new performance-based regulations for launch and reentry operations. In his letter from April 3, 2020, Wayne Monteith, the Associate Administrator of AST noted the principal challenge facing his agency:

> "Since 2012, licensed activities increased 1,000 percent and AST's budget and staffing increased roughly 40 percent. Moreover, we are now looking at another potential increase of 100-500 percent in commercial launch activity by 2021 while our staff may only increase about 20 percent. Making this period even more interesting is the significant uptick in the complexity and variability of proposed launch and reentry vehicles. We also expect a commercially viable human spaceflight participant landscape involving space tourism that could lead to 100+ flights per year."[68]

AST licenses commercial launches. As such, the agency has authority to control access to orbital space and can stipulate the safety characteristics and other parameters of space launch vehicles and the reentry of objects from space through the atmosphere. It is important to note that the mandate of AST, and the DOT more generally, does not extend into outer space.

Existing legal authority allows all civilian agencies to share government-owned data, variously through Cooperative Research and Development Agreements; through the Paperwork Reduction Act 44 U.S.C.A. § 3506 (d); and/or through the provisions of the Evidence Act.

Department of Commerce

The mission of DOC is to promote job creation, economic growth, sustainable development, and improved living standards for all Americans by working in partnership with businesses, universities, communities, and workers. The department was originally created as the United States Department of Commerce and Labor on February 14, 1903. It was subsequently renamed the Department of Commerce on March 4, 1913, as the bureaus and agencies specializing in labor were transferred to the new Department of Labor.

The OSC is the principal unit for space commerce policy activities within NOAA within DOC. Its stated mission is to foster the conditions for the economic growth and technological advancement of the U.S. commercial space industry. According to OSC's website, the Office focuses on various sectors of the space commerce industry, including satellite navigation (GPS), commercial remote sensing, space transportation, and entrepreneurial activities. The Office participates in government-wide discussions of space policy issues as well as internal efforts to increase NOAA's use of commercial space solutions.

U.S. Code Title 51, Chapter 50702 (c) establishes the OSC as a legal entity. It calls on OSC to be the principal unit for the coordination of space-related issues, programs, and initiatives within DOC, including:

[68] Wayne Monteith, April 3, 2020 letter.

a. to foster the conditions for the economic growth and technological advancement of the U.S. space commerce industry;

b. to coordinate space commerce policy issues and actions within DOC;

c. to represent DOC in the development of U.S. policies and in negotiations with foreign countries to promote U.S. space commerce;

d. to promote the advancement of U.S. geospatial technologies related to space commerce, in cooperation with relevant interagency working groups; and

e. to provide support to Federal Government organizations working on Space- Based Positioning Navigation, and Timing policy, including the National Coordination Office for Space-Based Position, Navigation, and Timing.

In addition, 51 U.S. Code Section 50702 (d) vests the OSC director with carrying out the functions of the Office to include—

a. promoting commercial provider investment in space activities by collecting, analyzing, and disseminating information on space markets, and conducting workshops and seminars to increase awareness of commercial space opportunities;

b. assisting United States commercial providers in the efforts of those providers to conduct business with the United States Government;

c. acting as an industry advocate within the executive branch of the Federal Government to ensure that the Federal Government meets the space-related requirements of the Federal Government, to the fullest extent feasible, using commercially available space goods and services;

d. ensuring that the United States Government does not compete with United States commercial providers in the provision of space hardware and services otherwise available from United States commercial providers;

e. promoting the export of space-related goods and services;

f. representing the Department of Commerce in the development of United States policies and in negotiations with foreign countries to ensure free and fair trade internationally in the area of space commerce; and

g. seeking the removal of legal, policy, and institutional impediments to space commerce.

Given these roles, most authorities that OSC might need to serve as the lead civilian agency for SSA/STM are already in place. In addition to the authorities available to all civilian agencies with regards the sharing of government-owned data, OSC asserts the authority to provide basic messaging through its authorized function to "to foster the conditions for the economic growth and technological advancement of the United States space commerce industry (51 U.S.C. 50702(c)(1)) and to seek "the removal of legal, policy, and institutional impediments to space commerce" through 51 U.S.C. 50702 (d)(7). It also asserts the authority to provide analytics related to space commerce through 51 U.S.C. 50702 (d) (1) - (3).

In addition, OSC needs bridge language amending 10 USC 2274 to acknowledge transition of SSA information to non-U.S. government entities from DoD to DOC. This would provide continuity, clarity, and comfort for DOD, the entire USG, industry, and the international community. OSC would also benefit from clear authority for coordinating actions of other agencies such as FAA (e.g., launch licensing) and FCC (regulation regarding debris mitigation) to help ensure an integrated approach across the life cycle of space objects.

4.3 Establishing a Budget and Fiscal Considerations

The issue of resources is a key factor when considering the transfer of STM. Without a doubt, adequate resources are required to carry out the job successfully. While lower than expected appropriated resources may not change an agency's mission toward STM, it will certainly constrain the speed at which the work is done. This is a critical aspect for market growth. A level of funding below the cost requirements would be problematic given the important task at hand.

During these times of budgetary uncertainty, agencies are vulnerable to the ebb and flow, and velocity of change, that takes place in budget policies and funding cycles. This is an added risk that must be managed effectively. Ensuring that funding is committed to on a short and long-term basis is the proper mitigation to employ. It further emphasizes why the need to procure adequate resources based on appropriate funding models is even more critical.

There is a general sense that the U.S. is in a critical race against time and can lose ground in space commercial leadership if actions regarding the funding of a lead agency for STM are further delayed. Given these observations, there is agreement across academia, the commercial sector, public/private partners, and government that Congress must authorize appropriate funding. This report recommends where these funds should be appropriated.

Funding Models

This report establishes that the agency selected to serve as the Executive Branch advocate and coordinator for U.S. leadership in space commerce will not operate as a status quo organization. The fluidity and elasticity of the space industry as a whole is on an accelerated path. This requires an agile organization apprising many interconnecting segments and that must approach its task with finesse and innovation to meet the challenge of the current crisis as well as maximize the opportunities.

An organization of this magnitude demands committed resources that will fuel the burgeoning enterprise. There are multiple options to consider for funding this enterprise over a sustained period. It may require a hybrid approach or one that leverages the strongest funding model that leads to cost and service efficiencies.

Stakeholders are interested in looking across potential models (e.g., partnerships with industry and/or academia, and regulatory approaches) to execute the SSA and STM missions without creating a large expansion of government roles and resource needs.

As an entrepreneurial, start-up organization, financing this operation could incorporate a hybrid of component pillars: fee for service and appropriations.

Fee for Service and Appropriations

Within an entrepreneurial start-up, there are often reasonable concerns pertaining to the sustained financing of an STM enterprise without adding a burden to taxpayers. To address this issue, a public finance model that could alleviate this concern would consider two pillars: Fee for Service and Appropriations. It is urgent that the STM lead agency develop a model that would leverage multiple avenues for financing to support an agile organization, imposing minimal burden upon the Treasury, and shifting funding needs as the organization matures and grows with the market.

Fee for Service

As the STM agency grows and expands over time, it might envision future additional fee-based activities beyond basic services. Coupled with a Revolving Fund and Working Capital Fund, some government services are financed via dedicated taxes or an Industrial Fund. Likewise, commercial users would be charged fees tied directly to that service.

Examples include the federal gasoline tax which supports interstate highway construction and maintenance and the aviation excise tax which supports construction and safety improvements at airports, and technological upgrades to the air traffic control system.[69] This same structure might be adapted for some SSA and STM functions, thus supporting robust, government-provided services. If created properly under authorities enacted by the Congress, a revenue stream is created independent of the SSA and STM services. However, the Panel notes that any operator can pass the fees on to their customers. If this commercial data provides an acceptable level of coverage, then there would be no need for the U.S. government to pay for commercial data and pass it on to the industry. Fees would only be charged to cover other essential costs of maintaining an STM operation and other government entities (including foreign government entities) that consume these data in the process of delivering public goods and services. That said, a fee-for-service financing mechanism ought not inhibit public interest uses of SSA data. Finally, a fee-for-service financing regime must consider the effect on access to SSA data. Fees (subject to legislative authority being enacted) would be deposited into a fund that has the authority to retain and expend the fees without regard to fiscal year limitation.

[69] FAA, "Airport and Airway Trust Fund Overview," June 2020. https://www.faa.gov/about/budget/aatf/

Appropriations

The COVID-19 pandemic has impacted day to day living. Without a doubt, the safety and well-being of U.S. citizens are first and foremost. Having the government, public private partnerships, and the community as a whole working together to resolve this pandemic has not fallen short of inspiration. But imagine not having the ability to communicate with one another while in quarantine either through social media, networking platforms, mobile communications, GPS, and even videos. It is through this connectivity where citizens are able to reach out and make the best of an extremely challenging situation.

Satellites are launched into orbit with the intent to capture, synthesize, and analyze valuable data that are packaged and presented for consumption by the general public. These data and information make lives of citizens easier. Data that are interpreted to deliver accurate weather predictions and forecasts, through commercial services such as the Weather Channel, that help farmers plan for and produce a food source are critical in supporting communities across the country during the pandemic. When communities cannot fully access their local grocers, they also look to farmers and markets to fill the gap in the food supply chain to maintain healthy communities. Utilizing weather forecasts built on data captured by satellites is a key element of planned food production to help mitigate global risks. But that data resource is constantly being threatened.

The United States relies on two satellite systems for weather forecasts and observations: (1) polar-orbiting satellites that provide a global perspective every morning and afternoon and (2) geostationary satellites that maintain a fixed view of the nation. NOAA is responsible for the polar satellite program that crosses the equator every afternoon, and for the geostationary satellite program. DoD is responsible for the polar satellite program that crosses the equator in the early morning orbit. These agencies are planning or executing major satellite acquisition programs to replace existing polar and geostationary satellites that are nearing the end of, or are beyond, their expected life spans.[70]

Any gap in satellite data would result in less accurate and less timely weather forecasts and warnings of extreme events—such as hurricanes and floods. Given the criticality of satellite data to weather forecasts, the likelihood of significant gaps in weather satellite data, and the potential impact of such gaps on the health and safety of the U.S. population and economy, the GAO concluded that the potential gap in weather satellite data was a high-risk area and added it to the High-Risk List in 2013.[71]

More recently, in recognition of NOAA's progress, the GAO removed the geostationary satellite segment from the high-risk area in 2017. However, NOAA continues to experiment with other data sources and assimilate these data into its weather models. Balancing the use of proprietary commercial data and serving the public good, the agency also continues to invest millions of dollars in data acquisition from the commercial sector; ingesting that commercial data into

[70] GAO 2019 High Risk Report.
[71] GAO 2019 High Risk Report.

numerical models to help gauge a precise state of the conditions for weather predictions—further mitigating the risk of a weather gap.

The space industry is on an accelerated path for unprecedented growth. Unfortunately, the more satellite launches there are, the greater the risk for collision. This is the threat and uncertainty that space debris presents. Without proper coordination and oversight, these collisions can potentially disrupt the very networks that keep citizens connected during challenging times, such as a pandemic. For the fraction of the cost of weather satellites, the gap of uncertainty regarding the impact of collision on daily activities, directly or indirectly, can be reduced.

Many estimates of the global and international space economy currently exist from various private and government organizations. The space economy has been estimated somewhere between $414 billion up to $1.5 trillion, with commercial space revenues representing 79 percent of total space activity according to advocacy organizations, such as the Space Foundation. The OECD (2014) found commercial revenue in the global space economy was dominated by consumer services (58 percent), followed by space manufacturing and launch services (33 percent), and satellite operator services (9 percent) in 2013. The Canada Space Agency (2018) reported Canada's space sector generated revenues of $5.6 billion (CAD) in 2017, spearheaded by satellite communications. Likewise, the German space industry generated an estimated $3.1 billion in sales in 2013, driven by satellite manufacturing.[72]

Under an appropriations funding model, the operational costs for the lead STM agency, as suggested by authoritative agency projections, would range between $15 million in a start-up year to an average of $45 million a year in outyears. Furthermore, the space commerce STM agency operations are projected to cost a small fraction of the current $5 billion NOAA budget as a whole.

However, if desired, annual appropriations would provide for the "public good" portion of the overall cost of STM operations (such as assisting non-profit institutions), while fees generated from the for-profit industry could cover the other portion.

Activities and Costs

Efforts to establish a civil agency to serve the STM task is built on a strong legacy of space leadership by the U.S. Receiving the task of STM from DoD means that a civil agency must estimate the cost for doing the work. At what price would this transfer be to the beneficiary agency? What are the funding implications of a transfer, including infrastructure and personnel costs? What are the cost drivers?

During the course of this study, the study team received pre-decisional, confidential, cost projections from various agency documents. Based on content reviewed, there is no major distinction in the cost projections that would influence a decision toward one agency over another,

[72] Highfill, Georgi, and Dubria, 2019.

and thus provide a distinctive conclusion as to which agency should lead STM based solely on estimated cost projections.

Infrastructure and Personnel Costs

The projected infrastructure and personnel costs represent funding to support a market-driven approach to STM. The infrastructure and personnel costs for STM excludes the classified parts of DoD tasks. The remaining tasks are mapped to an estimate of cost ranges. This required ruling out the classified portions of the DoD budget that would not apply to the civilian agency responsibilities under SPD-3.

The classified DoD tasks exempt from cost estimates are:

- Space Surveillance Network
- Operations and Management
- All Classified Infrastructure- people, SCIF costs, secure communications
- Recapitalization of mission systems

Implementation of STM tasks successfully requires funding several core operational and development activities: staff, FFRDC and contractors, OADR and Cloud Infrastructure, Interagency Agreements, and Commercial SSA Data Buys. Funding plans anticipate a five-year phased approach to upstarting the STM work.

It is estimated that the costs for executing the requirements for providing STM over a five-year period (FY2020-FY2024) range from a total of $153.0 Million to $218.6 Million (See Table 4-1) with an inflation rate of 2 percent per year. In FY2025, it is anticipated that the STM task will be in a steady state of funding.

When assessing the cost estimation dollars as a percent of total agency operations and development, Commercial Data Buys represent the lions-share of the costs followed by staffing. Both commercial Data Buys and Staffing are also the cost drivers over the next fiscal years for FY2021-FY2024.

Table 4-1. Projected STM Cost Estimates (in millions)

	FY20	FY21	FY22	FY23	FY24	Total
Staff (Benefits, Facilities, Travel and Support)	$2.0	$5.3	$8.8-$10.8	$9.1 - $13.7	$9.3 - $14.4	**$34.4- $46.1**
FFRDC and Contractors (Technical and Ops Center)	$1.4	$4.5	$9.6-$12.0	$9.9 - $12.9	$8.4 - $11.4	**$33.8 - $42.2**
OADR and Cloud Infrastructure	$0.0	$1.9	$4.6 - $12.1	$6.0 - $16.5	$6.0 -$18.5	**$18.5 - $49.0**
Interagency Agreements	$0.7	$0.9	$1.7	$2.7	$2.8	**$8.9**
Subtotal - Agency Development and Operations	**$4.1**	**$12.6**	**$24.7-$36.6**	**$27.7-$45.8**	**$26.4-$47.1**	**$95.6 - $146.2**
Commercial SSA Data Buy	$0.0	$2.4	$15.0 - $20.0	$20.0 - $25.0	$20.0 - $25.0	$57.4 - $72.4
Grand Total with Commercial Data Buy	**$4.1**	**$15.0**	**$39.7 - $56.6**	**$47.7 - $70.8**	**$46.4 - $72.1**	**$153.0 - $218.6**

Source: DOC Position Paper May 2020

Infrastructure Costs

The OADR and Cloud infrastructure costs support an expanded market-driven approach to STM and can range from an estimated total of $18.5 million to $49.0 million over five years. Initially, the ramp-up phase of the STM work in FY2020 does not include any new money for OADR or Commercial SSA Data Buys, but the activities are focused on active experimentations by leveraging existing assets (e.g., NOAA Big Data Program Cloud Service Providers for OADR).

Personnel Costs

The overall projected costs just for staff ranges between $34.4 million to $46.1 million. The staff estimates represent a strong investment in people and an expected growth in federal full-time equivalents (FTEs). Stakeholders have emphasized the importance of having access to technical expertise.

The cost projections reflect the growth investment in highly skilled technical personnel. Expertise is essential and a pool of candidates can be trained through academic pipelines by partnering with universities to fill critical positions.

Key Cost Drivers

Some requirements will drive the funding costs over time. The key cost drivers based on the highest dollar estimate includes, by rank (1) Commercial Data Buys, followed by (2) Staff (3)

Research and Development (costs of services provided by FFRDCs) (4) OADR and Cloud Infrastructure, and (5) Interagency Agreements.

Future of Funding

There is a consensus across industry, academia, government, and the commercial sector that Congress must appropriate adequate funding for STM. The expectation is that investments and costs associated with carrying out this work should reflect specific outcomes: a safer space orbit, accountability for behaviors, and less risk.

The market that supports this outcome should be enterprising, accessible, and affordable. Space commerce is a dynamic field. What it is today is not what it will be tomorrow and flexibilities regarding assuring appropriate funding requirements must also be fluid. The accelerated growth is at an aggressive pace as more actors enter into industry. The funding aspects for the civil agency to take a leading role in STM are just as critical.

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Chapter 5: Final Space Traffic Management Agency Evaluation

This chapter provides an assessment of the suitability of selected agencies is assessed to perform the STM task. The final evaluation is based upon the criteria outlined in this report with respect to key capabilities, departmental support, and concept of operations. Four agency candidates are given a thorough review based on these criteria. The chapter concludes with a recommendation for which agency should be legislatively mandated to perform the STM task.

As described in Chapter 3, the STM landscape is a complex, networked ecosystem. This complexity is due to a number of factors: the evolutionary and dynamic nature of the enabling capabilities; the inter-dependency between and among capabilities; the multitude of actors required to achieve successful mission objectives; and the balance of policy, regulatory, standards, and best practices that are needed to ensure safety of space operations, catalyze innovation and spur commercial growth. Such a dynamic landscape requires an operating model with certain key characteristics (as described in Chapter 4) and a STM agency that is a coordinator and a catalyst—a network-based organization that connects the different actors across the space economy through a shared interest in safety and sustainable use of orbital space. It needs to monitor and track the evolution of the enabling capabilities and foster innovation in the ecosystem. To be successful, the STM agency needs to have an enterprise view of the dynamic and evolving STM landscape.

5.1 Methodology of Agency Evaluation

In support of the assessment, and as a starting point, an initial analysis of the landscape helped to determine agencies that are currently, and/or in the past, have been involved in SSA and STM activities. Building on this analysis, the study team validated the list of agencies with inputs from more than 100 stakeholder interviews and identified four possible leading candidates: OSC, AST, NASA, and DoD. As seen from Figure 5-1, each candidate's current level of SSA and STM activity is mapped to the capabilities.

The Federal Communications Commission (FCC) is not included as a potential candidate because of its narrower role in the SSA and STM mission. It adopted comprehensive rules on orbital debris mitigation in 2004 which require disclosure of an applicant's debris mitigation plans as part of the technical information submitted to the Commission.[73] It has since issued proposed rules that state that unless the FCC has already authorized a satellite system, the satellite system must submit a description of the design and operational strategies it will use to mitigate orbital debris.[74] FCC was not included as a leading candidate given that the focus of the agency is on one specific

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[73] Federal Communications Commission, *Mitigation of Orbital Debris*, *Second Report and Order*, 19 FCC Rcd 11567 (2004) (*2004 Orbital Debris Order*).

[74] FCC, *Mitigation of Orbital Debris in the New Space Age*, *Report and Order and Further Notice of Proposed Rulemaking*, IB Docket No. 18-313.

area of the STM mission: Orbital Debris Mitigation. In comparison, the four leading candidates have multiple STM mission-related activities or authorities.

The Panel identified a few important considerations as context for the assessment:

First, it is not possible to accurately evaluate agencies based on their current SSA and STM activities since some candidates have the legal authority to work on a number of mission activities, while other agencies do not. As an example, OSC has been named as the lead agency in SPD-3 while DoD and NASA have been continuing to provide SSA and STM services.[75] However, due to the lack of specific authority in other STM mission activities, AST is focused in areas of its current authorities: pre-launch, launch, and reentry.

Second, rather than evaluating and comparing candidate approaches against each other, the focus of the evaluation must be on the approach and its alignment with the ideal operational model, as described in detail in Section 3-4 in Chapter 3. The approach must enable a network-based ecosystem, foster public-private collaboration, create a shared platform to enable market-driven data management, leverage industry leadership and foster international cooperation. It is important to evaluate the approach on its relevance to the dynamic environment and its probability of success to meet mission objectives.

Third, it should account for what factors can be changed compared to those factors that may be harder to change. As an example, a candidate's lack of resources at this point may easily be offset if it is identified as the lead agency and it is able to secure sufficient congressional appropriations.

[75] While OSC was identified as the lead agency for STM, it is noted that Congress has not allocated necessary budgetary resources to OSC in order for it to fulfill all of its preparatory tasks.

Figure 5-1. Key Federal Entity Role Mapping to Capabilities

Current Federal Entity Capabilities and Components

	Notifications		**Space Technology**		**Space Situational Awareness**			**Orbital Debris Management**	
Entity	Notification Database and Channels	Notification Dissemination	Open Network and Data Architecture	Research and Development	Surveillance and Tracking	Conjunction Assessment Screenings and Catalog Maintenance	Environmental Data	Debris Modeling and Measurements	Debris Protection and Mitigation
DoD	•	•		•	•	•	•		•
NASA				•		•	•	•	•
DOC				•			•		•
FAA									•

	Space Traffic Operations Coordination and Management				**Design and Launch**			**Disposal and Reentry**		
Entity	Space Traffic Coordination and Safety	Collision Avoidance Risk Assessment	Collision Mitigation	Frequency Deconfliction	Satellite and Constellation Design	Pre-Launch and Launch Support	Spectrum Management and Use	Early Orbit	Safing, Repositioning, De-Orbit/Reentry	Disposal and Debris Removal
DoD	•	•				•			•	•
NASA		•				•				
DOC				•	•	•	•		•	
FAA						•		•	•	•

Source: National Academy of Public Administration

Evaluation Factors

The evaluation uses four primary factors to ensure a sound assessment of each candidate, the factors not only assess the technical approach and organizational capacity, but also the necessary non-technical skills (coordination, building partnerships, culture etc.). In the following section, a description of each factor, along with its sub factors, is included.

1. Functional and Technical Competency
2. Organizational Leadership and Capacity
3. Partnerships
4. Stakeholders and Customers

In the evaluation, a potential fifth factor, financial and legislative issues, has not been included, in large part because these factors can change, largely by congressional action. With the appropriate legislative action by Congress, an agency that lacks the required appropriations or legislative authority may be granted those to assist in successfully fulfilling the mission objectives. Research with respect to this set of issues does not reveal a distinctive difference between candidate agencies. In contrast, the four primary factors are more characteristic of the agency and cannot be readily enhanced by congressional action in the same manner as financial and legislative factors.

For each factor and sub factor, an evaluation scale, with rankings of 0, 1, 2, and 3, is used to consider suitability of each agency. The evaluation scale is connected with each factor and sub factor.

Functional and Technical Competency

The factor of functional and technical competency assesses the candidate's ability to establish and grow its functional and technical competency. It includes two sub factors:

> **Technical Approach:** How effective is the candidate's technical approach to meet primary mission objectives? How well does the approach address the dynamic landscape? What is the probability of success of the approach?
>
> The technical approach, is guided by the following questions:
>
> - How sound is the overall technical approach with included performance metrics and risk management principles.
> - As technology evolves, how well does the approach scale?
> - What is the long-term technical relevance of the approach?

Technical Approach Evaluation Scale	
0	Approach does not map well to the primary mission objectives. Probability of success is low.
1	Approach will help to accomplish a few primary mission objectives. Probability of success is low-medium.
2	Approach will help accomplish many of the mission objectives. Probability of success is medium-high.
3	Approach will help accomplish most or all primary mission objectives. Probability of success is medium-high,

Organization's Capability Competency: How effective will the candidate be in each capability? How will the approach aid or hinder each capability?

Capabilities include: Notifications, Space Technology, Space Situational Awareness, Orbital Debris Management, Space Traffic Operations, Coordination & Management, Design and Launch, Disposal and Reentry.

- How is the organization looking to address each capability?
- What is the organization's competency for each capability?

Capability Competency Evaluation Scale	
0	Candidate will find it hard to grow, procure or partner to build the necessary capabilities.
1	Candidate will be able successful in a few capabilities. Probability of success is low-medium.
2	Candidate will be able to establish many of the required capabilities. Probability of success is medium-high.
3	Candidate will accomplish most, or all required capabilities. Probability of success is medium-high

Organizational Leadership & Capacity

This factor provides an assessment of organizational leadership and management support, department-wide support, and organizational culture. It includes the following subfactors:

Leadership and Management: How supportive is the organizational leadership and management toward the new mission requirements compared to their other priorities? How effective is the management structure?

- What is the leadership vision? How does the expertise and experience of the management team align with organizational needs?

Leadership and Management Evaluation Scale	
0	Leadership and management support will be low or minimal; multiple competing priorities.
1	Leadership and management support are expected to be somewhat supportive.
2	Leadership and management support are expected to be quite supportive. The new mission will rank as one of the top priorities.
3	Leadership and management support are expected to be very high. The new mission is one of the topmost priorities for the organization.

Organizational Capacity, Including Support: What resources and capacity does the candidate have as support within its parent organization? While it does not have to be current, how effective is its support?

- What capacity does it have to operate and scale a "start-up" Federal Office?
- What support does it have within the department and/or agency to support its mission? Are there specific examples of working together?
- What does the support structure look like within the Department or Agency?
- How has the organization performed historically and how does it respond to management challenges?

Organizational Capacity Evaluation Scale	
0	Little support exists/is expected within the organization.
1	Low or minimal support exists/is expected within the organization.
2	Some support exists/is expected within the organization. Some evidence or clarity on the degree of support.
3	Good support exists/is expected within the organization; evidence of the type and nature of support from related or comparable efforts.

Organizational Culture and Collaboration: How will the organizational culture support the organization in meeting its adaptive challenges and collaborating internally?

- What is the organization's ability to foster and manage organizational change as needed?

Organizational Culture and Collaboration Evaluation Scale	
0	Organizational culture can run counter to mission needs and objectives, including suggested approach.
1	Few parts of the organizational culture can be helpful with the new mission needs and objectives. Probability of organizational culture being helpful is low.
2	Much of the organizational culture will help the candidate be successful in meeting its mission objectives. Probability of organizational culture being helpful is low-medium.
3	The organizational culture is well aligned and will make the candidate be successful in meeting its mission objectives. Probability of culture being helpful is high.

Partnerships

This factor examines the ability of the candidate to build, sustain and grow key partnerships.

- How effective will the candidate be in developing partnerships with other federal government agencies, commercial players, academia and international actors?

Partnerships Evaluation Scale	
0	Ability to partner or collaborate with external/internal stakeholders is low or minimal.
1	Organization can establish key partnerships with a couple/few of external/internal stakeholders. No data or clarity exists from current or comparable efforts.
2	Organization can establish key partnerships with a couple/few external/internal stakeholders. Some data or clarity exists from other or comparable efforts.
3	Organization is expected to be successful at building relationships and partnerships with all external/internal stakeholders. Data or clarity exists from other or comparable efforts.

Stakeholder or Customer View

This factor provides their perception of the organization's ability to be successful in meeting the mission objectives. While some of the evaluation and insights on the other factors do come from stakeholders and customers, this factor really focuses on the getting the stakeholder/customer centric point of view, perception and (any) experience with each candidate.

- What do external stakeholders think of the candidate's approach? How do external stakeholders perceive the candidate's ability to partner?

- How well does the organization work with external stakeholders? How effective is the stakeholder engagement process?

Stakeholder or Customer View Evaluation Scale	
0	Stakeholders & Customers view organization as hard to work with - perception is unfavorable.
1	Stakeholders & Customers view on organization is neutral.
2	Stakeholders & Customers view organization as positive - few examples cited.
3	Stakeholders & Customers view organization as positive - many examples cited.

Finally, each factor and its sub factor are assigned weights, which are shown in Table 5-1. The weights are based on the key attributes as described in the ideal operating model and are further described below in Table 5-2.

5.2 Final Candidates and Evaluation

This section provides summary observations of each of the four leading candidates on each key factor: functional and technical competency; organizational leadership and capacity; partnerships; and stakeholders and customers. It includes observations for each agency that are incorporated to make a final determination of each candidate.

Department of Defense (DoD)

For an overview of DoD and its mission, please refer to Section 2.5 in Chapter 2. With respect to viewing a snapshot of the DoD's current role in SSA/STM activities, please refer to Figure 5-1 above: Key Federal Entity Role Mapping to Capabilities.

Functional and Technical Competency

- As the space economy expands and new pressures confront the orbital environment, DoD is facing challenges in providing up-to-date surveillance and warning services for the non-national security-related sector. That sector requires much more precise information than the DoD system was designed for. Also, the DoD system is not scalable to meet the demands of a growing number of objects in space and to deal with an increasing number of space operators. After several years of efforts, DoD has not yet successfully upgraded the computer systems that underpin its own monitoring and analysis capabilities. There have been multiple failed acquisition programs over the last two decades to try and replace those systems at significant expense.[76]

[76] Brian Weeden, "Space Situational Awareness: Examining Key Issues and Changing Landscape," Testimony before the Subcommittee on Space and Aeronautics, U.S. House of Representatives, February 11, 2020.

- Commercial operators increasingly view today's DoD surveillance and warning system as inadequate to achieve safe operations in today's commercial space environment. It is a legacy system that is tied to sensor network with software geared toward the system's original national security purpose of providing early warning of nuclear missile attack. Nonetheless, it supports limited persistent tracking and guidance for collision avoidance.

Organizational Leadership and Capacity

- DoD has a number of competing missions in the space arena. In addition, with the growth of offensive challenges to U.S. space assets from a few other nations, DoD seeks to focus on its core national security mission. For these reasons, DoD is seeking to exit its role in supporting the civilian space sector. The SSA/STM mission supporting commercial space is a diversion from the core mission of DoD, which is national security.
- As described in Chapter 3, the lead civil agency role requires agility and flexibility, and requires extensive collaboration with stakeholders, including international governments and other actors. DoD's mission and culture pose some inherent challenges to meet the above objectives for the commercial sphere.
- DoD continues to face challenges in its efforts to upgrade software for its space systems.[77] Cost and schedule overruns are attributed in large part to a lack of user engagement. GAO notes that this problem is more general to DoD software development, citing a recent Defense Acquisition Board report that describes DoD's current approach to software development as broken and a leading source of risk.

Partnerships

- In its current role, DoD has built effective partnerships with a number of stakeholders, including those in government, the private sector, academia, and in the international arena. However, there is some concern on DoD's ability to grow international partnerships given its core national security mission.

Stakeholders and Customers

- Most stakeholders agree that the commercial-facing STM function should be moved away from DoD while some stakeholders have also raised the concern that international partners may find DoD less favorable to work with because of its national security mission.

National Aeronautics and Space Administration (NASA)

For an overview of NASA and its mission, please refer to Section 2.5 in Chapter 2. For its current role in SSA/STM activities, please refer to Figure 5-1 above: Key Federal Entity Role Mapping to Capabilities.

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[77] GAO, *Space Acquisitions: DOD Faces Significant Challenges as it Seeks to Address Threats and Accelerate Space Programs, GAO-19-482T*, pp. 15-16.

Functional and Technical Competency

- Conjunction Assessment (CA) and other SSA-related activities are managed separately for the Human Spaceflight program and for its robotic missions. NASA has dedicated personnel co-located with DoD personnel who perform CA screenings for NASA missions and provide the predicted close approach data back to the risk assessment analysts at JSC and CARA.
- NASA is the only agency, aside from DoD, with an established SSA/STM operation. It is well regarded but is limited to providing conjunction analytics and warnings for NOAA and vis-à-vis its own assets.[78]

Organizational Leadership and Capacity

- NASA has multiple competing research and development missions and has faced a few challenges in meeting cost and program schedule objectives. According to the GAO, its portfolio of major projects continued to experience significant cost and schedule growth this year and the performance is expected to worsen,[79] and NASA acquisition continues to be on the GAO High Risk List.[80] As a result, its organizational research competency, while highly respected, may not align well with a new and expansive STM operational role as foreseen in this context since the lead civil agency in serving as a notifications provider in a commercial marketplace is expected to play an important coordination and facilitation operating role.

Partnerships

- NASA is well respected in the international community and is therefore well positioned to establish and sustain relationships with other international civilian government actors given its apolitical posture as a science agency. NASA has very strong partnerships with academia and the larger research community as well and has also established strong partnerships and technical interfaces with all space-focused U.S. government agencies—in addition to international actors.[81]

Stakeholders and Customers

- Most stakeholders reinforce the need for NASA to continue its research role which is a critical enabler for a successful SSA/STM mission. As a widely and highly respected organization, stakeholders wish that NASA will continue to build on its core competency of providing technical expertise and research to improve an SSA/STM mission.

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[78] NASA has performed CA for 30 years. Initial USSTRATCOM capability and high-accuracy catalogue (ASW) developed with NASA. [NASA Conjunction Assessment Risk Analysis (CARA) Overview].
[79] NASA Assessments of Major Projects, GAO-20-405: Published: Apr 29, 2020. Publicly Released: April 29, 2020.
[80] GAO, High Risk List – NASA Acquisition Management, https://www.gao.gov/highrisk/nasa/why_did_study
[81] NASA Conjunction Assessment Risk Analysis Updated Requirements Architecture

Federal Aviation Administration (FAA) Office of Commercial Space Transportation (AST)

For an overview of AST and its mission, please refer to Section 2.5 in Chapter 2. For its current role in SSA/STM activities, please refer to Figure 5-1: Key Federal Entity Role Mapping to Capabilities.

Functional and Technical Competency

- AST's approach to SSA is based on open architecture that is focused on a "safety-first" approach. While there is some discussion of working with stakeholders on developing standards and guidelines, AST's approach has been described as more of a command-and-control approach, akin to how FAA operates the air traffic control system, and also similar to DoD. As a result, its approach will have some limitations with flexibility and scalability in meeting the evolving needs of the marketplace, as outlined in Chapter 3. In addition, the agency's technical approach on the importance of safety and a regulatory mindset, while important to this task, may lead to undue regulatory burdens on a nascent, growing industry, and thus may impede the growth of a vibrant commercial marketplace.
- As discussed in Chapter 3, AST has its current competency and congressionally directed activity connected with Orbital Debris Management, Launch & Design, and Disposal and Reentry activities. For Orbital Debris Mitigation, AST handles debris mitigation for launch vehicles. As part of launch operations, the agency has consolidated all commercial and civil registration information for registration at the United Nations since 2018. FAA leads space inter-agency coordination of registration and payload reviews. The FAA provides support for reentries which includes reentry predictions, safety analysis, and ground, maritime, and aviation safety and notices as well as orbital collision avoidance from orbit to reentry. AST is consistently described as competent and experienced in performing these prescribed functions.

Organizational Leadership and Capacity

- AST's organizational capacity and the culture to support a dynamic mission environment may be limited. Its parent organization (FAA), and other DOT organizations, are focused on the transportation mission, which is clearly understood by the Department's Mission Statement: "Our mission is to plan, deliver, operate and maintain a transportation system that is safe, enables easy movement of people and goods, enhances the economy and improves our quality of life." As a result, AST has a principal focus on safe transportation in order to be consistent with the Department's mission. However, STM is much larger than pre-launch, launch and reentry areas which are the core focus of AST, focused on the transportation mission.
- In the past, during the Obama Administration, AST was deemed a leading contender to perform the STM task. However, several interviews with knowledgeable sources indicate that there was substantial skepticism and opposition to AST taking on the STM task from within FAA and Department, and even resistance in some cases. The lack of high-level

FAA and Departmental support prompted further consideration, and later a decision of the National Space Council, to look elsewhere for an Agency to fulfill this role.

- Furthermore, the projected exponential increase in launches may serve to distract AST from what would be a new and rapidly expanding SSA/STM mission that will require a coordinator role in a complex networked ecosystem. AST continues to face challenges in its current missions. For example, a recent GAO report (GAO-19-437) highlighted that AST has not effectively planned or projected for future workforce growth in its planning.[82]

Partnerships

- Based on AST's experience with the air traffic environment, AST seems positioned to establish robust partnerships with key stakeholders, including international partners. In addition, based on its previous efforts in STM, the agency has engaged industry.[83]

Stakeholders or Customers

- Many stakeholders and potential customers have a respectful view of AST and its team that works in its pre-launch, launch, and reentry role. However, when given a choice between OSC and AST, stakeholders overwhelmingly favor OSC to serve in the STM task. Most commercial stakeholders view AST unfavorably as compared to OSC to lead the STM mission and views of commercial partners and AST seem to differ on whether safety should be the pivotal factor in the context of space operations. In addition, U.S. Government agency stakeholders made their preferences known through the SPD-3 coordination process. A few key stakeholders question the overall effectiveness of AST's philosophy, mindset, and likely approach toward potentially managing STM function.

Department of Commerce (DOC) Office of Space Commerce (OSC)

For an overview of OSC and its mission, please refer to Section 2.5 in Chapter. For its current role in SSA/STM activities, please refer to Figure 5-1: Key Federal Entity Role Mapping to Capabilities.

Functional and Technical Competency

- OSC's technical approach is forward-looking, relying on the commercial marketplace to leverage industry capabilities. In addition, OSC's approach relies on due consideration of safety and the importance of risk management for commercial market development. OSC's approach aligns well with the Panel's ideal operational model to spur commercial activity.

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[82] GAO, *Commercial Space Transportation: Improvements to FAA's Workforce Planning Needed to Prepare for the Industry's Anticipated Growth, GAO-19-437*, May 2019.
[83] FAA, Office of Commercial Space Transportation, "*Towards a Civil Space Traffic Management System,*" https://www.faa.gov/about/office_org/headquarters_offices/ast/media/6_space_traffic_management_plans.pdf.

- Since being named as the lead agency in SPD-3 more than two years ago, OSC has managed to grow its competency in a number of capabilities, such as Space Technology, Orbital Debris Management, Notifications and others. It is involved in regulatory policy for Commercial Remote Sensing (CRS) and chairs an inter-agency working group on orbital debris. More importantly, through the various bureaus of Commerce, OSC has significant expertise and experience in most of the capabilities. This diversity of experience in most areas can be a significant advantage. For example, OSC is uniquely positioned to leverage the experience from the NOAA Big Data Project. Finally, OSC is also looking to extend its technical expertise by proactively increased engaging and partnering with the private sector.

Organizational Leadership and Capacity

- While OSC supports the Commercial Remote Sensing mission, it is clearly complementary to the SSA and STM mission and its current approach supports the future operating model provided in Chapter 3. In particular, OSC aids in developing government policies "affecting the industry, voicing the industry's interests within interagency policy discussions, and representing U.S. commercial interests in international negotiations."[84]
- OSC has demonstrated the available support capacity via the multiple bureaus and components within its department that are providing support already to the OSC. Many of DOC's bureaus, such as Bureau of Industry and Security (BIS), National Oceanic and Atmospheric Administration (NOAA)/National Weather Service (NWS) Space Weather Prediction Center (SWPC), National Telecommunications and Information Administration (NTIA), National Institute of Standards and Technology (NIST), and others, bring relevant and cutting-edge expertise. This diversity of mission expertise and experience in DOC is transferrable to the SSA/STM mission and can enhance prospects for mission success. The Department offers the successful NOAA Big Data Program as evidence for successful creation of an open architecture data repository, in addition to the National Weather Service (NWS) which performs a comparable function of aggregating data from multiple data sources and fusing the data together to provide weather data to its customers and the larger community. DOC has some open GAO priority recommendations in IT management and workforce planning.[85]

Partnerships

- There is clear evidence that OSC has been proactive in building partnerships both internally and externally. The Agency has built on its SPD-3 mandate to establish partnerships with all stakeholders—civil government, military, private sector, academia and international (particularly France, Japan, the United Kingdom, Germany, and the United Arab Emirates). It already has an established and broad network in the space industry community, both domestically and internationally, and has relationships to

[84] Department of Commerce, Office of Space Commerce, "Archive for Commercial Remote Sensing," https://www.space.commerce.gov/category/remote-sensing/
[85] Department of Commerce, *GAO-20-497*, April 20, 2020.

commercial entities that will be necessary for this industry to grow safely and at a pace that will ensure U.S. primacy.

Stakeholders or Customers

- Stakeholders/experts are almost unanimous in favoring OSC as the lead agency to provide STM services given the Agency's mission and culture, which is more conducive to promoting and enabling space commerce. A minority of them express concerns about the Department's lack of regulatory experience and its ability to balance regulatory (safety) and business promotion.

5.3 Final Candidate Evaluation Scores

The following section includes an evaluation of each candidate based on the above technical factors with their associated key guiding questions. Table 5-1 provides a summary evaluation; Table 5-2 provides the detailed evaluation that includes both the raw and the weighted scores for each candidate.

Summary Candidate Agency Evaluation

To interpret the scores, the guide below is included, with summary observations, derived from Section 5.1, which includes detailed observations.

- Scoring Range (0-1): Candidate has significant limitations to perform the role of the lead civil agency.
- Scoring Range (1-2): Candidate has a number of key limitations to perform the role of the lead civil agency.
- Scoring Range (2-3): Candidate has very few or minor limitations to perform the role of the lead civil agency.

Table 5-1. Evaluation Summary[86]

Factors	Weights	OSC	AST	DoD	NASA	Comments
Functional and Technical Competency	**20%**	0.5	0.5	0.3	0.5	DoD scores low in this factor given the limitations with its current approach of using its legacy system built for another purpose.
Organizational Leadership & Capacity	**35%**	1.05	0.8	0.7	0.9	Due to its focus on the important priorities of its national security mission, DoD's organizational support to the STM mission is expected to be a lower priority. OSC scores high in this factor given the depth and breadth of expertise and experience its departmental bureaus can bring to the STM mission.
Partnerships	**25%**	0.75	0.75	0.5	0.75	DoD scores low in this factor due to its limitations in building effective partnerships with international governments and commercial actors.
Customers & Stakeholders	**20%**	0.6	0.2	0.2	0.4	Most commercial stakeholders and academia view OSC favorably to lead the STM Coordinator role. Other stakeholders, such as other U.S. Government agencies and international actors, are neutral.
TOTAL	**100%**	**2.9**	**2.25**	**1.7**	**2.55**	

[86] Table 5-1 highlights key summary observations for a candidate's score that is well below or above the other candidates' scores. For detailed observations, please refer to Section 5.2.

Table 5-2. Final Evaluation Scores - Detailed

Factor	Sub Factor	Weights	Weighted Scores				Raw Scores			
			OSC	AST	DoD	NASA	OSC	AST	DoD	NASA
Functional and Technical Competency	Technical Approach	10%	0.3	0.3	0.1	0.3	3	3	1	3
	Organization's capability competency	10%	0.2	0.2	0.2	0.2	2	2	2	2
Organizational Leadership & Capacity	Leadership and Management	10%	0.3	0.3	0.2	0.3	3	3	2	3
	Organizational & Departmental capacity, including support	15%	0.45	0.3	0.3	0.3	3	2	2	2
	Organizational culture and collaboration	10%	0.3	0.2	0.2	0.3	3	2	2	3
Partnerships		25%	0.75	0.75	0.5	0.75	3	3	2	3
Customer & Stakeholder View		20%	0.6	0.2	0.2	0.4	3	1	1	2
TOTAL			2.9	2.25	1.7	2.55				

As the space domain is increasingly congested, and national security issues connected with space expand, DoD's focus on its core missions of security and defense will crowd out the requisite focus and resources required to work with the non-military commercial space community. In addition, due to the classified nature of its principal work, DoD is somewhat constrained to build effective external partnerships, in particular with non-military international actors. That said, DoD's continued involvement in providing catalog and SSA data will be critical going forward. But this work is best performed in a supporting role, rather than as a core responsibility. Thus, it will be important for the STM agency to collaborate closely with DoD.

Given its technical expertise and experience of supporting the STM mission over the years, and its experience in building effective partnerships with the academic and research community, NASA is considered a strong candidate to perform this function since it continues to be an invaluable technical resource to the entire SSA/STM community. As such, NASA should continue in its current role as a technical and research partner but adding the role of coordinator of the STM enterprise may serve to distract it from its core competency. Furthermore, NASA enjoys relatively strong bipartisan congressional support. Such support might be threatened as STM functions are likely to mature into more toward a regulatory role over a period of years.

AST is a strong potential candidate for performing the STM mission. As shown in Chapter 3, it has its current competency and activity connected with Orbital Debris Management, Launch and Design, and Disposal and Reentry activities. AST ably leads space inter-agency coordination of registration and payload reviews, and provides support for reentries which includes reentry predictions, safety analysis, and ground, maritime, and aviation safety and notices as well as orbital collision avoidance from orbit to reentry. However, AST may be limited in terms of departmental capacity and support, which focuses resources on a transportation mission. In this respect STM can be seen as an additional task that does not squarely fall into the transportation mission, albeit that space objects are in flight. In addition, most commercial stakeholders view AST unfavorably when compared to OSC to lead the STM mission. It is important to note that U.S Government agencies made their preferences known through the SPD-3 coordination process and unanimously selected OSC as the lead agency. According to the Panel's research, the SPD-3 process is described as an extensive interagency process involving both career professionals and political leadership.

5.4 Recommendation

Based on a rigorous evaluation of the several dimensions of this evaluation, the Panel determines that OSC is best suited to perform non-military SSA and STM tasks. OSC's concept of operations, as well as its skills and capabilities identified in research, fall most closely in line with the optimal model outlined in Chapter 3. OSC's concept of operations reflects the idea that OSC should serve as a guiding force to help bring about a safer operating environment in the space domain. To that end, the Panel sees OSC as best suited to approach the STM work with the following six prominent objectives to guide its start-up and continued operations:

1. Foster collaboration across the space economy.
2. Foster public-private collaboration for research, standards.
3. Create a shared platform for SSA.
4. Expand market-driven data management.
5. Draw on industry leadership.
6. Foster international cooperation.

Furthermore, clear departmental support to OSC to take on this task and on-going similar missions (e.g. space weather and earth weather missions) involving data management and commercial engagement strongly support this recommendation.

The changes to advance SSA/STM that should be introduced over time are not clearly seen today, nor can they be. This is an enormously dynamic environment in which to operate, and it will be virtually a death knell to an innovative commercial space industry if this agency approaches its task with a command and control philosophy. Even the word "management" in STM is perhaps a misnomer. As noted earlier, this agency, at least at the outset, must serve as a convener, staffed with requisite technical skills and experience in its staffing, that can bring actors together and, collaboratively drive them to find common objectives and coalesce to enhance safety and precision in space. This agency must evolve with the technological and industry changes that are occurring quickly and profoundly. Over time, as space becomes increasingly congested and this agency establishes a reputation respected among stakeholders, this agency should be prepared to lead domestic and international efforts to collaboratively formulate "rules of the road" that can serve to advance a safer operating environment for the diverse universe of space actors.

In this analysis, the Panel identifies AST and NASA as strong candidates to perform the STM function. Indeed, there are many important features and contributions to the commercial space environment provided by AST, including its proven track record of regulating pre-launch and re-entry of private sector space vehicles. It is critical that AST maintain its able leadership in the sphere of regulating launch and reentry. Similarly, NASA should continue in its important role in research and development. Thus, the Panel recognizes the important roles that AST and NASA play in the space domain and stresses the criticality of a continued close collaboration between OSC and these agencies going forward.

The role of DoD remains critical to mission success in STM. OSC must find ways to leverage the DoD data and capabilities to produce them in order to advance this important mission. DoD and other national security agencies' capabilities are classified and must remain so, but there is opportunity for OSC to use these to benefit the commercial space sector appropriately.

OSC must actively engage with the Department of State, FCC, and all other agencies with important roles to ensure there is a close collaboration that enhances confidence in U.S. Government leadership across all actors, friend and even foe.

Given these findings, the Panel makes the following recommendations:

First, the Panel requests the Congress to enact authorizing legislation without delay ensuring that OSC has the requisite on-orbit authority allowing it to promulgate STM regulation(s), when appropriate, for orbital operations that fall outside the current licensing and continuing supervision framework. The Congress should also promptly act to provide DOC with the correct mix of appropriated funds and the authority to assess and utilize fees so that OSC can build this critical capability with the requisite personnel, office infrastructure, and authorities, as needed. With respect to transition of SSA information to non-U.S. Governmental entities from DoD and

DOC, OSC already has the authority to collect, share, analyze and disseminate data. That said, the Panel calls on the Congress to make this existing authority (embedded in 10 USC 2274) even clearer in statute in order to benefit the entire space sector.

Second, recognizing the dynamic and evolving nature of the STM function, the Panel recommends that OSC should continue on a path to adopt the operating model outlined in this report. This model should guide how OSC develops its organization and operating concept in order to enhance its work, not only within the federal government, but also within the broader constellation of stakeholders active in building the commercial space industry.

Finally, should the Secretary of Commerce deem it appropriate, the Panel would endorse and support a decision to elevate the OSC from its current place, as a part of NOAA, into the Office of the Secretary. Having the OSC as a direct report to the Secretary is an important signal of senior level Departmental support to the SSA and STM missions. It would also enhance OSC's ability to engage and leverage important external audiences, both domestic and international.

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Appendices

Appendix A: Panel Biographies and Study Team Members

Panel of Academy Fellows

Michael Dominguez,* *Panel Chair:* Director, Strategy, Forces and Resources Division, Institute for Defense Analyses. Former positions with the U.S. Department of Defense: Principal Deputy Under Secretary of Defense for Personnel and Readiness; Assistant Secretary of the Air Force for Manpower and Reserve Affairs, including service as Acting Secretary of the Air Force; Assistant Director for Space, Information Warfare, and Command and Control, Office of the Chief of Naval Operations. Military service in various assignments with the U.S. Army's Southern European Task Force.

Jane Fountain*: Distinguished University Professor of Political Science and Public Policy and an adjunct distinguished professor in the College of Information and Computer Sciences at the University of Massachusetts Amherst. She directs the National Center for Digital Government, a university research center. From 1989 to 2005 she served on the faculty of the Kennedy School of Government at Harvard University. Fountain was selected to the World's 100 Most Influential People in Digital Government and one of the 14 Most Influential Academics in Digital Government in 2018 and 2019 by apolitical. She was named a Federal 100 awardee in 2013.

Sean O'Keefe*: Member of the faculty at Syracuse University's Maxwell School as the Howard and Louise Phanstiel Chair in Strategic Management and Leadership. Professor O'Keefe previously served in both Bush Administrations including appointments as NASA Administrator, Secretary of the Navy, OMB Deputy Director, and Comptroller and CFO at DoD. Between public service assignments, O'Keefe held academic appointments at Syracuse, Penn State, and at LSU as Chancellor of the University. Before his current faculty service at Syracuse, he was Chairman and CEO of Airbus Group, Inc., the U.S. subsidiary of the global aerospace corporation. Selection as a Presidential Management Intern from graduate school led to his earliest public service on the staff of the U.S. Senate Committee on Appropriations.

Martin Faga*: Member of the Board of Thomson Reuters Special Services and of Inmarsat Government and a member of the Advisory Board of Hawkeye 360. Air Force junior officer from 1963 to 1968. After a serving as an engineer at MITRE Corporation in McLean, VA, Mr. Faga joined the CIA as a reconnaissance satellite systems engineer. In 1977, he joined the staff of the Intelligence Committee of the U.S. House of Representatives. In 1989, President Bush appointed Mr. Faga as Assistant Secretary of the Air Force for Space, and Director of the National Reconnaissance Office, responsible for the nation's satellite reconnaissance program. In 1993, Mr. Faga became vice president at MITRE Corporation, an engineering firm, later serving as CEO from 2000 to 2006.

* ***Academy Fellow***

Patrick Kennedy*: Confirmed by the U.S. Senate as Under Secretary for Management on November 6, 2007 and served in that position until January 27, 2017. In that position he was responsible for the people, resources, finances, facilities, technology, consular affairs and security of the Department of State, both domestically and overseas, and served concurrently as the Department's Chief Financial Officer. From September 2001 to May 2005, he was U.S. Representative to the United Nations for Management and Reform with the Rank of Ambassador. In 1993 he became Assistant Secretary of State for Administration and served in that post until 2001. From 1973, when he joined the Foreign Service, to 1993, he served in a number of positions in Washington and overseas, including as Management Counselor at the U.S. Embassy in Cairo, Egypt and as Executive Director and Deputy Executive Secretary of the Department's Executive Secretariat.

Study Team

Brenna Isman, *Director of Studies:* Ms. Isman has worked for the Academy since 2008 and provides oversight across the Academy's studies. She recently served as the Project Director for the Academy's project that assisted a national regulatory and oversight board in developing and implementing its strategic plan. She also recently directed the Academy's statutorily required assessments of the NASA's use of its Advisory Council and the Environmental Protection Agency's practices for determining the affordability of regulatory mandates, as well as the Academy's organizational assessments of the U.S. State Department's Office of Inspector General and the Amtrak Office of the Inspector General. Ms. Isman has served as a Senior Advisor on strategic plan development for the Postal Regulatory Commission (PRC) and Social Security Administration (SSA), and organizational change consulting support for the Coast Guard. Her prior consulting experience includes both public and private sector clients in the areas of communication strategy, performance management, and organizational development. Prior to joining the Academy, Ms. Isman was a Senior Consultant for the Ambit Group and a Consultant with Mercer Human Resource Consulting facilitating effective organizational change and process improvement. She holds an MBA from American University and a Bachelor of Science in Human Resource Management from the University of Delaware.

Roger Kodat, *Senior Project Director:* Mr. Kodat has led more than thirty projects at the Academy. These include the Academy's recent Congressionally directed study of the science and technology policy advisory capabilities needed by the Congress. Mr. Kodat was appointed and served as Deputy Assistant Secretary of the Treasury, responsible for Federal Financial Policy, from 2001 to 2007. His responsibilities at Treasury included leading reforms of the U.S. Postal Service and oversight of the Federal Finance Bank. Prior to joining government, Mr. Kodat had an extensive career in commercial finance and investment banking, including serving as Senior Country Officer for both Chase Manhattan Bank and Manufacturers Hanover Trust in Eastern Europe. He holds a B.S. from Northwestern University and both an MBA in Finance and M.A. in Political Science from Indiana University, Bloomington.

Karen Hardy, *Senior Advisor:* Dr. Hardy is Chief Executive Officer of Strategic Leadership Advisors LLC and an Adjunct Professor at George Mason University's School of Business.

* ***Academy Fellow***

Previously, she was the Deputy Chief Risk Officer and Director Risk Management at the Department of Commerce. In this role she was an Executive Member of the DOC IT Review Board and the DOC Acquisition Review Board. She served as a Senior Advisor to the U.S. Controller at the Office of Management and Budget, Washington, DC for risk management policy development and implementation. Previously, she was a Senior Management Analyst at the National Institutes of Health and served on the U.S. Technical Advisory Group for the ISO 31000 International Standard for Risk Management. Dr. Hardy is a published scholar of the IBM Center for the Business of Government. She is the author of the first award winning textbook on Enterprise Risk Management in government and is a founding Board member of the Association for Federal Enterprise Risk Management (AFERM). She holds an Ed.D in Organizational Leadership and Human Resources Development from Nova Southeastern University, an MBA and is a RIMS Certified Risk Management Professional.

Sujai Shivakumar, *Senior Advisor:* Dr. Shivakumar is an expert in American technology and innovation policy, with nearly two decades of experience in directing studies, convening high-level dialogue, and preparing reports at the National Academies of Sciences, Engineering, and Medicine. He has extensive experience in the assessment of public-private technology partnerships, analyses of policies supporting advanced manufacturing and the technical workforce, and comparative reviews of international innovation policies and their impact on the U.S. innovation system. Dr. Shivakumar directed the Academies' study of National Innovation Programs for Flexible Electronics and its flagship study of The Supply Chain for Middle-Skill Jobs, He also directed the Academies' Innovation Policy Forum, a focal point for a national and international dialogue on innovation policy. In addition, he directed the assessment of the Small Business Innovation Research (SBIR) Program and was the lead researcher on the Academies' review of the U.S. Manufacturing Extension Partnership. He is a recipient of the National Academies Distinguished Individual Service Award. Dr. Shivakumar holds a doctorate in economics from George Mason University and was an Earhart Foundation scholar at the Ostrom Workshop in Political Theory and Policy Analysis at Indiana University-Bloomington. He is the author of The Constitution of Development (Macmillan, 2005) and co-author with Nobel Laureate Elinor Ostrom of The Samaritan's Dilemma, The Political Economy of Development Aid (Oxford UP, 2005). He has served as an advisor to the United Nations Development Programme, Sida, ActionAid, and the Gates Foundation, among other organizations on crafting rules and networks to foster development.

Sukumar Rao, *Senior Advisor:* Mr. Rao is President of the Parnin Group and has specialized in cross-agency program implementation, performance improvement, IT strategy, digital transformation, and information architecture and data management. Previously, he was a Principal at SRA International. He served as the project manager for a number of OMB-led cross-agency initiatives to evaluate the performance of operations and service delivery of the 24 CFO ACT agencies, including mission areas, IT and mission-support/administrative operations. He brings a depth of IT strategy experience that includes evaluation of government-wide high risk IT projects, assessment of cloud computing and shared services, and design and implementation of digital transformation initiatives. He also served as Program Manager for a Homeland Security Science and Technology Program, leading and managing the strategic planning process to design a $30 million R&D program to improve a nationwide emergency alert system. Mr. Rao has an MBA from Columbia University and Master of Science and Bachelor of Engineering degrees in Telecommunications. He is a Project Management Professional (PMP) and Certified Technology Business Management Executive (CTBME).

Jonathan Tucker, *Senior Advisor:* Dr. Tucker joined the Academy's staff in 2004 and has extensive expertise in policy analysis, program evaluation, organizational design, management assessment, and strategic planning. He recently served as Project Director for the Academy's organizational assessment of the R&D area of the U.S. Forest Service and the Academy's assessment of the Department of Transportation's proposed reorganization of its research entities. He also recently served as a Senior Advisor on the Academy's statutorily required study of the project partnership agreement (PPA) procedures utilized by the Army Corps of Engineers and supported the Academy's recent studies of the NASA Advisory Council and the procurement strategies of the Transportation Security Administration (TSA). He holds a Ph.D. in Public Policy from George Mason University, an M.S. in Science and Technology from Rensselaer Polytechnic Institute and a B.A. in Public Policy from New College of the University of South Florida.

Richard Pezzella, *Senior Research Associate:* Mr. Pezzella is currently supporting the Academy's assessment of the organizational climate and employee engagement at the U.S. Secret Service. He recently worked on the Academy's Blue Ribbon Panel study of building renovation options for the Architect of the Capitol, and a study providing guidance on the design and implementation of an innovative personnel system for the U.S. Agency for International Development (USAID). He previously supported the Academy's study of the organization of the research components of the Department of Transportation, and a two-study series with the National Coalition of STD Directors on addressing the epidemic of sexually transmitted infections in the United States. His areas of interest include infrastructure, public health, international relations, technology, and space policy. He holds a B.A. in Anthropology and International Relations from the State University of New York at New Paltz.

Elise Johnson, *Research Associate:* Ms. Johnson joined the Academy as a Research Associate in June 2019. She is currently working on a year-long, independent assessment of the U.S. Office of Personnel Management. Ms. Johnson has also supported projects for the Bureau of Transportation Statistics (DOT), the National Oceanic and Atmospheric Administration (DOC), the State Chamber of Oklahoma Research Foundation, and the National Coalition of STD Directors. Ms. Johnson graduated in May 2019 from the University of Maryland, earning a B.A. in Public Policy and a B.A. in Government and Politics.

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Appendix C: Individuals and Organizations Interviewed

<u>Office of the Director of National Intelligence</u>

- **John Paul Parker**, Intelligence Community Space Executive, Office of the Director of National Intelligence

<u>National Space Council</u>

- **Colonel Curtis Hernandez, USAF,** Director of National Security for Space Policy
- **John Giles, Colonel, USAF (Ret)**, Former Senior Policy Advisor
- **Dr. Scott Pace**, Executive Secretary

<u>United States Department of Commerce</u>

- **Wilbur Ross,** Secretary of the Department of Commerce

Office of the Secretary

- **Karen Dunn Kelley**, Deputy Secretary

National Institute for Standards and Technology

- **Dr. Walter Copan,** Under Secretary of Commerce for Standards and Technology; Director, NIST

National Oceanic and Atmospheric Administration

- **Dr. Neil Jacobs,** Assistant Secretary of Commerce for Environmental Observation and Prediction, performing the duties of Under Secretary of Commerce for Oceans and Atmosphere (NOAA Administrator)
- **Scott Leonard,** Mission Operations Division Manager, National Environmental Satellite, Data, and Information Services (NESDIS)
- **William Murtagh**, Program Coordinator, Space Weather Prediction Center
- **Dr. Louis Uccellini,** Assistant Administrator for Weather Services, Director, National Weather Service

Office of Space Commerce

- **Kevin O'Connell,** Director
- **Brian Bates,** DoD/National Geospatial-Intelligence Agency Rotational Fellow
- **Doug Brauer,** NOAA Rotational Fellow
- **Mary Cull,** Special Assistant
- **Mark Daley,** Deputy for Operations

- **Marina Hague,** Management and Program Analyst
- **Dr. Diane Howard,** Chief Counsel
- **Jason Kim,** Senior Policy Analyst
- **Dr. Jinni Meehan,** Space Weather Awareness Analyst
- **Mark Mulholland,** Contractor
- **Chelsey Neuhaus,** O/S Liaison

United States Department of Defense

Office of the Secretary of Defense

- **Yu-Han (Hugh) Chen**, Space Policy Lead, Cost Estimation and Program Evaluation Program

Office of the Under Secretary of Defense for Policy

- **Stephen Kitay,** (outgoing) Deputy Assistant Secretary of Defense for Space Policy
- **Justin Johnson,** Deputy Chief of Staff to the Secretary of Defense; (incoming) Acting Deputy Assistant Secretary of Defense for Space Policy
- **John Hill,** Principal Director

United States Space Force

- **Major General John Shaw, USAF,** Combined Force Space Component Commander, U.S. Space Command; Commander, Space Operations Command, U.S. Space Force
- **Major General Stephen Whiting, USAF,** Deputy Commander, Headquarters
- **Colonel Jason Baker, USAF,** Individual Mobilization Augmentee to the United States Space Command Chief of Staff
- **Colonel Marc Brock**, **USAF,** Chief, Programs Division
- **Gordon Kordyak, Colonel, USAF, (Ret),** Executive Agent for Space Domain Awareness
- **Colonel Mafwa Kuvibidila, USAF,** Space Force Operations and Communications
- **Colonel Dennis Wiley, USAF,** Liaison Officer

United States Strategic Command

- **Robert Rego, Major General, USAF, (Ret),** Strategic Missions Advisor to the Commander

<u>United States Department of State</u>

Bureau of Arms Control, Verification & Compliance (AVC)

- **Eric Desautels**, Acting Deputy Assistant Secretary of State for Defense Policy, Emerging Threats, and Outreach
- **Richard Buenneke**, Senior Advisor, National Security Space Policy, Office of Emerging Security Challenges
- **Lt. Colonel Stephen Hobbs, USAF,** Military Advisor, Office of Emerging Security Challenges
- **Major Robert Wray, USAF,** Military Advisor, Office of Emerging Security Challenges
- **Amber Charlesworth,** Foreign Affairs Officer, Office of Space and Advanced Technology, Bureau of Oceans and International Environmental and Scientific Affairs

Bureau of Oceans and International Environmental and Scientific Affairs

- **Dr. Ryan Guglietta**, Foreign Affairs Officer, Office of Space and Advanced Technology
- **Robert Theodorsian**, Foreign Affairs Officer, Office of Space and Advanced Technology
- **Neevy P. Van Laningham,** Foreign Affairs Officer, Office of Space and Advanced Technology

<u>Federal Aviation Administration</u>

- **Stephen Dickson,** Administrator
- **Wayne Monteith, Brigadier General, USAF (Ret),** Associate Administrator for Commercial Space, Office of Commercial Space Transportation
- **Kelvin Coleman**, Deputy Associate Administrator for Commercial Space, Office of Commercial Space Transportation
- **Stephen Earle, Lieutenant Colonel, USAF (Ret),** Space Traffic Program Lead, Office of Commercial Space Transportation
- **Dr. George Nield**, Former Associate Administrator for Commercial Space, Office of Commercial Space Transportation

<u>Federal Communications Commission</u>

- **Thomas Sullivan,** Chief, International Bureau
- **Jose Albuquerque,** Division Chief, Satellite Division, International Bureau
- **Jennifer Gilsenen**, Assistant Bureau Chief, International Bureau
- **Karl Kensinger,** Deputy Division Chief, Satellite Division, International Bureau
- **Troy Tanner,** Deputy Chief, International Bureau

<u>National Aeronautics and Space Administration</u>

- **Jim Bridenstine,** Administrator
- **James Morhard,** Deputy Administrator
- **Stephen Jurczyk,** Associate Administrator
- **Randy Cruz,** Senior Advisor to the Administrator
- **Mike Gold,** Acting Associate Administrator for Intergovernmental Affairs
- **Dr. Matt Hejduk,** Chief Engineer, NASA CARA, Astrorum Consulting LLC
- **Margaret Kieffer,** Director, Export Control and Interagency Liaison Division
- **Pamela Melroy, Col, USAF (Ret),** Former Astronaut, Space Shuttle Program; Former Senior Technical Advisor and Director of Field Operations, Office of Commercial Space Transportation, Federal Aviation Administration
- **Lauri Newman,** Conjunction Assessment Risk Analysis (CARA) Manager, NASA CARA Program

<u>United States Congress</u>

U.S. Senate

- **Alicia Brown,** Professional Staff Member, Subcommittee on Commerce, Justice, Science, and Related Agencies, Committee on Appropriations
- **Allen Cutler,** Professional Staff Member, Subcommittee on Commerce, Justice, Science, and Related Agencies, Committee on Appropriations
- **Joel Graham**, Professional Staff Member, Subcommittee on Aviation and Space, Committee on Commerce, Science, and Transportation
- **Mary Guenther,** Professional Staff Member, Subcommittee on Commerce, Justice, Science, and Related Agencies, Committee on Appropriations
- **Blaise Sheridan,** Professional Staff Member, Subcommittee on Commerce, Justice, Science, and Related Agencies, Committee on Appropriations
- **Jean Toal Eisen,** Clerk, Subcommittee on Commerce, Justice, Science, and Related Agencies, Committee on Appropriations
- **Matt Womble,** Professional Staff Member, Subcommittee on Commerce, Justice, Science, and Related Agencies, Committee on Appropriations

U.S. House of Representatives

- **Asha Balakrishnan,** ASME Congressional Fellow, Subcommittee on Space and Aeronautics, Committee on Science, Space, and Technology

- **Stephanie Gadbois,** Clerk, Subcommittee on Commerce, Justice, Science, and Related Agencies, Committee on Appropriations
- **Tom Hammond,** Professional Staff Member, Subcommittee on Space and Aeronautics, Committee on Science, Space, and Technology
- **TJ Lowdermilk,** Professional Staff Member, Subcommittee on Commerce, Justice, Science, and Related Agencies, Committee on Appropriations
- **Pamela Whitney**, Professional Staff Member, Subcommittee on Space and Aeronautics, Committee on Science, Space, and Technology
- **Ashlee Wilkins**, Professional Staff Member, Subcommittee on Space and Aeronautics, Committee on Science, Space, and Technology

Non-Profit, Academia, and Advocacy

- **Dr. William Ailor,** Aerospace Fellow for SSA/STM, The Aerospace Corporation
- **Patrick Bauer,** Senior Project Engineer, The Aerospace Corporation
- **Ronald Birk,** Associate Principal Director for Civil Systems Group, The Aerospace Corporation
- **Richard Coleman,** President, Space Transportation Association
- **Dr. Mary Lynne Dittmar**, Executive Director, Coalition for Deep Space Exploration
- **Dean Fulmer,** Commercial Space Transportation Lead, MITRE
- **Mike French**, Director for Space, Aerospace Industries Association
- **Mick Gleason,** National Security Senior Project Engineer, The Aerospace Corporation
- **Ali Hale,** Vice President, Space Transportation Association
- **Dr. Henry Hertzfeld,** Professor of Space Policy and International Affairs, Space Policy Institute, George Washington University
- **Julian Hoffman,** Government Relations Representative, MITRE
- **Jeff Isaacson,** President, Universities Space Research Association
- **Dr. Moriba Jah,** Associate Professor and Director of ASTRIAGraph, Department of Aerospace Engineering and Engineering Mechanics, University of Texas at Austin
- **Therese Jones,** Senior Director for Policy, Satellite Industry Association
- **Dr. Scott Kordella,** Director, Space Systems, MITRE
- **Dr. Bhavya Lal,** Lead, Space Portfolio, Science and Technology Policy Institute, Institute for Defense Analyses

- **Miles Lifson,** PhD Candidate, Department of Aeronautics and Astronautics, Massachusetts Institute of Technology
- **Richard Linares,** Charles Stark Draper Professor; Co-Director, Space Systems Lab, Department of Aeronautics and Astronautics, Massachusetts Institute of Technology
- **Erin Miller,** Vice President of Operations for Space, Space Information Sharing and Analysis Center (Space ISAC)
- **Dr. Jamie Morin,** Vice President, Defense System Operations, The Aerospace Corporation
- **Ted Muelhaupt,** Principal Director, Center for Orbital and Reentry Debris Studies (CORDS), The Aerospace Corporation
- **Jim Muncy,** Commercial Spaceflight Federation
- **Marlon Sorge,** Principal Engineer, Space Innovation Directorate, The Aerospace Corporation
- **Eric Stallmer,** CEO, Commercial Spaceflight Federation
- **Dr. Ruth Stilwell,** Executive Director, Aerospace Policy Solutions LLC
- **Tom Stroup,** President, Satellite Industry Association
- **Kevin Toner,** Portfolio Director, MITRE
- **Quentin Verspieren**, PhD Student, University of Tokyo
- **Dr. Brian Weeden,** Director of Program Planning, Secure World Foundation
- **Christian Zur,** Director of Space Systems, U.S. Chamber of Commerce

Commercial Organizations

- **Chad Anderson,** CEO, Space Angels
- **Jim Armor,** Director, Government Relations, Northrup Grumman
- **Frank Backes,** Senior Vice President, Kratos Defense & Security Solutions
- **Mark Bolden,** Senior Scientist, Trusted Space
- **Todd Brost,** Director of Special Programs, SSA Team, Numerica
- **Dr. Dan Ceperly,** CEO, LEO Labs
- **Clint Clark,** Vice President of Sales and Business, ExoAnalytic Solutions
- **Jim Cooper,** Senior Systems Engineer, Analytical Graphics Inc.
- **Patricia Cooper,** Vice President of Satellite Government Affairs, SpaceX
- **Phil Cunio,** Senior Systems Engineer, ExoAnalytic Solutions

- **Andrew D'Uva,** President/Founder, Providence Access Company
- **Alan DeClerck,** Business Development and Strategy, LEO Labs
- **Jeff DeTroye,** Director, Missions Operations at Intel Operations and Maintenance, Global Intelligence Solutions, Raytheon
- **Doug Engelhardt,** Technical Fellow, Satellite Navigation Systems, Maxar
- **Weston Faber,** Research Scientist, L3Harris
- **Brien Flewelling,** Chief Space Situational Awareness Architect, ExoAnalytic Solutions
- **Barbara Golf,** Ops Trainer and Crew Evaluator, National Space Defense Center, United States Air Force; Centauri Corporation.
- **Paul Graziani,** CEO, Analytical Graphics Inc.
- **Seth Harvey,** CEO, Bluestaq LLC
- **Doug Hendrix,** CEO, ExoAnalytic Solutions
- **Matt Jones,** Assistant Director, Boeing
- **Dr. T.S. Kelso,** Technical Program Manager, AGI Center for Space Standards and Innovation
- **Tom Kubancik,** Chief Revenue Officer, Trusted Space
- **Travis Langster,** Vice President, Analytical Graphics Inc.
- **John Macdonald,** International Strategy & Business Development Manager, L3Harris
- **Mike Manor,** Senior Strategic Director for Government Affairs, Sierra Nevada Corporation
- **Peter Marquez,** Space Policy, Strategy, Operations, and Acquisition Expert, Andart Global
- **Ty McCoy,** Chairman, Space Transportation Association
- **Charlie McGillis,** Director, Customer Engagement and Strategy, Slingshot Aerospace
- **Dr. Darren McKnight,** Technical Director, Centauri Corporation
- **Dan Oltrogge,** Director, AGI Center for Space Standards and Innovation
- **Chirag Parik,** Azure Space Lead, Microsoft Corporation
- **Jillianne Pierce,** Project Administrator, Space Florida
- **Tami Plofchan,** Director, Government Affairs, Lockheed Martin
- **Jared Stout,** Policy Advisor, Venable LLP; formerly, Deputy Executive Secretary and Chief of Staff, National Space Council

- **Melanie Stricklan,** CSO, Slingshot Aerospace
- **John Wagner,** Vice President for National Security and Space, Sierra Nevada Corporation
- **Jennifer Warren,** Vice President, Technology Policy and Regulation, Lockheed Martin
- **Waqar Zaidi,** Lead System Engineer, Space Domain Awareness, L3Harris
- **Ann Zulkosky,** Director of NASA Programs, Lockheed Martin

<u>**International Stakeholders**</u>

- **Francois LaPorte**, CAESAR System Manager, National Centre for Space Studies (France) *(Centre national d'études spatiales, CNES)*
- **Monique Moury**, Head of Operational Flight Dynamics, National Centre for Space Studies (France) *(Centre national d'études spatiales, CNES)*

Appendix D: Department of Commerce and Department of Transportation Organizational Overviews

Department of Commerce

The Department of Commerce was created in 1903 as the Department of Commerce and Labor.[87] Ten years later, it was renamed the Department of Commerce when the bureaus specializing in labor were transferred to the new Department of Labor. The Department of Commerce (DOC) was created to promote job creation and economic growth.[88] DOC provides U.S. companies with programs such as the National Weather Service, Foreign Commercial Service, and NOAA Fisheries. It helps negotiate trade agreements and create a level playing field for American businesses and workers. Since 2017, Wilbur Ross has been the Secretary of Commerce. DOC is comprised of 13 bureaus and 15 offices.[89]

Bureau of Economic Analysis (BEA)

The Bureau of Economic Analysis (BEA) creates economic indicators such as the gross domestic product (GDP) and the trade balance, which directly impact the decisions of business leaders, policy makers, and the American people.[90] BEA is currently run by Acting Director and Deputy Director, Mary Bohman.

Bureau of Industry and Security (BIS)

The Bureau of Industry and Security (BIS) maintains and strengthens efficient export controls and treaty compliance systems to advance U.S. leadership in strategic technologies.[91] BIS is led by Acting Undersecretary for Industry and Security, Cordell A. Hull.

United States Census Bureau

The U.S. Census Bureau collects and disseminates information regarding the nation's economy, society, and institutions to facilitate informed policy decisions.[92] It is led by Director Dr. Steven Dillingham.

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[87] "History," Department of Commerce, July 9, 2020. https://www.commerce.gov/about/history
[88] "About Commerce," DOC, July 9, 2020. https://www.commerce.gov/about
[89] "Bureaus and offices," DOC, July 9, 2020. https://www.commerce.gov/bureaus-and-offices
[90] "Bureau of Economic Analysis," DOC, July 9, 2020. https://www.commerce.gov/bureaus-and-offices/bea
[91] "Bureau of Industry and Security," DOC, July 9, 2020. https://www.commerce.gov/bureaus-and-offices/bis
[92] "U.S. Census Bureau," DOC, July 9, 2020. https://www.commerce.gov/bureaus-and-offices/census

Economic Development Administration (EDA)

The Economic Development Administration (EDA) leads the federal economic development agenda by promoting innovation and competitiveness through investments.[93] Dana Gartzke currently performs the delegated duties of the Assistant Secretary of Commerce for Economic Development.

Office of the Under Secretary for Economic Affairs

The Office of the Under Secretary for Economic Affairs (OUS/EA) manages the U.S. Census Bureau, BEA, and the Office of the Chief Economist (OCE).[94] OUS/EA uses the data collected and analyzed by these groups to write in-depth reports, fact sheets, and briefings about economic policy issues and economic events. Karen Dunn Kelley is the current Deputy Secretary of Commerce.

International Trade Administration (ITA)

The International Trade Administration (ITA) promotes trade and investment and ensures compliance with trade agreements and fair trade.[95] Joseph C. Semsar is the Deputy Under Secretary for International Trade and is performing the non-exclusive functions and duties of this position. Diane Farrell is the Acting Deputy Under Secretary for International Trade.

Minority Business Development Agency (MDA)

The Minority Business Development Agency (MBDA) promotes the growth of minority-owned businesses through business assistance services and the advancement of public and private sector programs.[96] David J. Byrd has just been announced as the MBDA's new National Director, after joining MBDA last year as the National Deputy Director.[97]

National Institute of Standards and Technology (NIST)

The National Institute of Standards and Technology (NIST) works on developing technology and determining how new technologies will fit into the regulatory network of the country.[98] Dr. Walter

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[93] "Economic Development Administration," DOC, July 9, 2020. https://www.commerce.gov/bureaus-and-offices/eda
[94] "Office of the Under Secretary for Economic Affairs," DOC, July 9, 2020. https://www.commerce.gov/bureaus-and-offices/ous/ea
[95] "International Trade Administration," DOC, July 9, 2020. https://www.commerce.gov/bureaus-and-offices/ita
[96] "Minority Business Development Agency," DOC, July 9, 2020. https://www.commerce.gov/bureaus-and-offices/mbda
[97] "Department of Commerce Announces New National Director of Minority Business Development Agency," Minority Business Development Agency, June 17, 2020. https://www.mbda.gov/news/press-releases/2020/06/department-commerce-announces-new-national-director-minority-business
[98] "National Institute of Standards and Technology," DOC, July 10, 2020. https://www.commerce.gov/bureaus-and-offices/nist

Copan leads NIST, acting as the Under Secretary for Standards and Technology as well as the NIST Director.

National Oceanic and Atmospheric Administration (NOAA)

The National Oceanic and Atmospheric Administration (NOAA) provides weather forecasts, storm warnings, and climate monitoring for fisheries and coastal restoration systems.[99] NOAA has high-tech instrumentation and scientific research to provide policy makers, businesses, and the American public with reliable information. Dr. Neil Jacobs leads NOAA as the Assistant Secretary of Commerce for Environmental Observation and Prediction, while also performing the duties of the Under Secretary of Commerce for Oceans and Atmosphere.

National Technical Information Service (NTIS)

The National Technical Information Service (NTIS) provides innovative data services to federal agencies through partnerships with the private sector to promote economic growth and advance federal data priorities.[100] The National Technical Information Service Director is Avi Bender.

National Telecommunications and Information Administration (NTIA)

The National Telecommunications and Information Administration (NTIA) advises the President on telecommunications and information policy issues, emphasizes expanding broadband Internet access, and promotes ensuring the Internet continues to fuel innovation and economic growth.[101] Adam Candeub leads NTIA as the Acting Assistant Secretary of Commerce for Communications and Information.[102]

United States Patent and Trade Office (USPTO)

The U.S. Patent and Trademark Office (USPTO) provides high quality and timely examinations of patent and trademark applications, delivers intellectual property (IP) information worldwide, and guides American and foreign IP policy.[103] Andrei Iancu acts as the Under Secretary of Commerce for Intellectual Property and as the USPTO Director.

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[99] "National Oceanic and Atmospheric Administration," DOC, July 10, 2020. https://www.commerce.gov/bureaus-and-offices/noaa

[100] "National Technical Information Service," DOC, July 10, 2020. https://www.commerce.gov/bureaus-and-offices/ntis

[101] "National Telecommunications and Information Administration," DOC, July 10, 2020. https://www.commerce.gov/bureaus-and-offices/ntia

[102] "Adam Candeub." NTIA, August 19, 2020. https://www.ntia.doc.gov/page/adam-candeub

[103] "U.S. Patent and Trademark Office," DOC, July 10, 2020. https://www.commerce.gov/bureaus-and-offices/uspto

Office of the Secretary

The Office of the Secretary is the general management side of DOC and provides support to the Secretary, Wilbur Ross.[104] The office assists the Secretary in formulating policy, provides advice to the President, and supervises the operating units of DOC.

104 "Office of the Secretary," DOC, July 10, 2020. https://www.commerce.gov/bureaus-and-offices/office-secretary

Department of Transportation[105]

Congress established the Department of Transportation (DOT) in 1966 with the mission of ensuring U.S. transportation systems were safe and efficient. It also tries to ensure that transportation is used to improve the quality of life of all Americans and increase the productivity of American workers. DOT employs around 55,000 people through its 11 operating administrations. The Secretary of Transportation is Elaine L. Chao.

Office of the Secretary of Transportation (OST)

The Office of the Secretary (OST) assists the Secretary of Transportation in leading the DOT and in advising the President on federal transportation programs. OST also oversees the creation of national transportation policy and encourages the use of intermodal transportation. The Office also enforces transportation legislation and regulations and helps negotiate international transportation agreements. The Office's Chief of Staff is Todd Inman.

Federal Aviation Administration (FAA)

The Federal Aviation Administration (FAA) oversees the safety of civil aviation by issuing and enforcing regulations and standards for the manufacture, operation, certification, and maintenance of aircrafts. It also operates airport towers, air route traffic control centers, and flight service stations, as well as develops air traffic rules to meet national defense standards. The FAA also licenses commercial space launch facilities and private sector launches. Steve Dickson is the FAA Administrator.

Federal Highway Administration (FHWA)

The Federal Highway Administration (FHWA) runs highway transportation programs that ensure the safety and accessibility of roads and highways nation-wide. FHWA provides funding to states to construct and improve the National Highway System, bridges, and roads. It also plans and supervises the building of roads to national parks and Indian reservations. Nicole R. Nason is the FHWA Administrator.

Federal Motor Carrier Safety Administration (FMCSA)

The Federal Motor Carrier Safety Administration ensures safety in motor carrier operations by enforcing safety regulations and improving safety information systems. The Administration works closely with law enforcement, the motor carrier industry, and labor safety interest groups

[105] "About DOT", U.S. Department of Transportation, July 10, 2020.
https://www.transportation.gov/about
"Our Administrations", U.S. Department of Transportation, July 10, 2020.
https://www.transportation.gov/administrations
"Meet Key Officials", U.S. Department of Transportation, July 10, 2020.
https://www.transportation.gov/mission/meet-key-officials

to achieve its mission. Jim Mullen is the Acting Administrator for the Federal Motor Carrier Safety Administration.

Federal Railroad Administration (FRA)

The Federal Railroad Administration (FRA) promotes railroad safety through federally mandated safety standards, operating practices, and safety inspections. The FRA also conducts research to try to improve safety measures and to enhance the usefulness of the railroad system. The FRA Administrator is Ronald Batory.

Federal Transit Administration (FTA)

The Federal Transit Administration (FTA) provides grants to cities and communities to help plan and build transit systems that are convenient, cost-effective, and accessible. The FTA offers both leadership and resources to assist cities in the creation of technologically advanced transit systems. The FTA upkeeps the National Transit Library (NTL), which holds reports, documents, and data created by professionals in transit studies. K. Jane Williams is the Acting Administrator of the FTA.

Maritime Administration (MARAD)

The Maritime Administration (MARAD) encourages the maintenance of the U.S. merchant marine, ensuring that it can carry domestic commerce and a portion of its foreign commerce and that it is capable of aiding the Navy in times of war or emergency. MARAD also oversees U.S. shipbuilding and repair services, the ports, and intermodal water and land transportation systems. The MARAD Administrator is Mark H. Buzby.

National Highway Traffic Safety Administration (NHTSA)

The National Highway Traffic Safety Administration's (NHTSA) mission is to reduce deaths, injuries and economic losses from motor vehicle crashes. To achieve its mission, NHTSA provides grants to state and local governments to conduct highway safety programs as well as creates and enforces safety performance standards for motor vehicle use. In addition, NHTSA researches safety defects in motor vehicles, promotes the use of safety belts and air bags, and sets and enforces fuel economy standards. NHTSA also provides consumers with auto safety information via a hotline. James Owens is the current Acting Administrator of the NHTSA.

Pipeline and Hazardous Materials Safety Administration (PHMSA)

The Pipeline and Hazardous Materials Safety Administration (PHMSA) oversees the safety of over 800,000 shipments daily of hazardous materials in the United States and the transportation of energy through pipelines. PHMSA focuses on reducing the number of deaths and injuries related to the transportation of hazardous materials and energy in addition to promoting transportation solutions that help communities and protect the environment. The PHMSA Administrator is Howard "Skip" Elliot.

Saint Lawrence Seaway Development Corporation (SLSDC)

The Saint Lawrence Seaway Development Corporation (SLSDC) operates the waterway between the Great Lakes and the Atlantic Ocean to ensure safe, reliable, and efficient travels for commercial and noncommercial vessels. The SLSDC also works with the Saint Lawrence Seaway Authority of Canada to supervise operations safety, vessel inspections, and traffic control for the Great Lakes and the Saint Lawrence Seaway. In addition, the SLSDC encourages trade opportunities that benefit port communities, shippers, and receivers. Craig H. Middlebrook is the Deputy Administrator of SLSDC.

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