Orbital Traffic Management Study

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In reply to

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EXECUTIVE SUMMARY


“It is the sense of the Congress that an improved framework may be necessary for space traffic management of United States Government (USG) assets and United States private sector assets in outer space and orbital debris mitigation.”¹

Further, that law provides direction to make “recommendations related to the appropriate framework for the protection of the health, safety, and welfare of the public and economic vitality of the space industry.”

Directed assessments of relevant policy, regulations, international considerations, technology, and operations topics have been conducted. These assessments provided the foundation for developing, evaluating, and recommending alternate frameworks for the management of space traffic and orbital activities.

Orbiting spacecraft and the space environment in which those spacecraft operate are critically important. In this decade, a new focus has been appropriately made on the defense and protection of spacecraft to ensure the continued flow of information to and from space. Just as there is risk to spacecraft that must be mitigated through defense and protection, there is risk to spacecraft because of the possibility of unintended collisions and physical interference from space objects in intersecting orbits. The likelihood of such events is low, but the consequences can be high, especially in cases involving crewed spacecraft. Therefore, it is in the U.S. national strategic and economic interests to have an improved domestic space traffic safety governance framework (Framework) that specifically aims to mitigate and reduce the risk of possible space traffic safety incidents, while at the same protect the economic vitality of the space industry. Likewise it is important to enable the Department of Defense (DOD) to focus on its space protection and defense mission operationally, and allow its technical support systems to evolve based on protection and defense-centric requirements.

The current Framework does not provide a holistic approach by leading in the combined development of technically informed “rules of the road” and the provision of value-driven, safety-based products and services used during spacecraft operations. Such “rules of the road”, based on space traffic safety concerns, could lead to the maturation of international norms of behavior, which would greatly enhance the strategic stability of the space domain.

Objectives for any space traffic safety governance framework were created by the study team that focus on mitigating space traffic safety–related risks, protecting and enhancing national security interests, and ensuring the economic vitality of the space domain and industry. Five Frameworks were created for consideration. Each Framework exists at a distinct point on a continuous spectrum of space traffic safety governance options in which the USG’s prescriptive role ranges from low to high. The specific possible USG roles for consideration were the following:

- Developing and enforcing space traffic safety–related data sharing policies, best practices, guidelines, standards, and rules and regulations
- Providing space traffic safety products and services to private and foreign space operators

• Selecting, employing, and/or training space traffic safety SSA operators, certifying private spacecraft operators, and developing operational processes and procedures

After review and assessment of a range of Framework options, conclusions and recommendations are provided as follows.

A Framework that best balances the needs for safety, national security, and economic interest is a framework led by a civil agency. That civil agency will perform the following activities:

1. Facilitate privately led, technically informed development of codified best practices, guidelines, and standards. These documented processes include improved approaches to reduce the risk of space traffic safety incidents. These processes can inform future licensing requirements for payloads.²

2. Provide advisory products and services that enhance operational safety, such as a public space catalog and conjunctions data messages. The agency should become the trusted open source of SSA data.

3. Provide leadership in technical and operations matters related to space traffic safety in international fora and develop data-sharing relationships with international owner-operators and partners.

4. Balance the needs of space traffic safety with the interests of space commerce and the space industrial base and, therefore, encourage, facilitate, and promote the uninterrupted and free flow of commerce in orbital space.

5. Use a business approach for providing SSA products and services in a manner that is most cost-effective, enables innovation to occur on commercial technology development timescales, and is consistent with the required data security policies needed for national security.

6. Interface appropriately with all interagency partners to ensure a whole-USG approach to space traffic safety governance.

A civil agency should be provided with appropriate liability indemnification, and at this time it should not have authorities to dictate real-time operational decisions (e.g., mandating a collision avoidance maneuver). The civil agency will be required to develop strong interagency processes and procedures with other USG spacecraft owner-operators (i.e., Department of Defense [DOD], Intelligence Community [IC], and NASA). Strong consideration must be given to facility and personnel security requirements based on the requirements of these interagency interfaces.

This particular Framework is also the quickest and most affordable way to implement the civil-based options. It also offers the most flexibility by providing options to increase the role of the civil organization over time (and possibly transition to the more prescriptive Framework options) as is deemed appropriate.

² This implies that reviews related to orbital debris mitigation are most appropriately conducted by this civil agency. This may require the transfer and/or consolidation of these activities from the agencies that are currently responsible for such reviews (FCC, FAA, NOAA) to this civil agency. Because the FCC will continue to license radio-frequency use, this will result in the need for most commercial space activities to obtain two authorizations—one for radio frequency use and another for the other safety-focused aspects of its space operations.
Implementation of this Framework would require legislative authorities to be granted and appropriate funding to be provided. A time of transition will be required to ensure that expected flows of products and services, currently provided by the DOD, are uninterrupted.
1.0 INTRODUCTION


“It is the sense of the Congress that an improved framework may be necessary for space traffic management of United States Government assets and United States private sector assets in outer space and orbital debris mitigation.”

Further, that law provides direction to make “recommendations related to the appropriate framework for the protection of the health, safety, and welfare of the public and economic vitality of the space industry.”

The law directed assessments of relevant policy, regulations, international considerations, technology, and operations topics (see Appendices A–G). The assessments have been conducted and frameworks developed in accordance with the NASA Statement of Work (see Appendix J), which directly maps to the CSLCA requirements.

To inform the assessments, interviews were conducted with stakeholders across many U.S. Government (USG) agencies and departments, academia, federally funded research and development centers, university affiliated research centers, and industry (see Appendix L). These assessments provided the foundation for developing, evaluating, and recommending alternate frameworks for the management of space traffic and orbital activities. This report first provides definitions for important terms and an overview of the methodology used to address the directed tasks. Then the report establishes a risk-based context for the need for an improved framework for space traffic management. Next, specific framework objectives are identified, a generic framework conceptual model offered, and the alternate frameworks to meet those objectives are developed and evaluated. Finally, the framework that best meets the goals contained in the direction from Congress is recommended. Appendix K provides more detail on the overall study approach.

1.1 Definition of Terms

The phrases “orbital traffic management” and “space traffic management” have been used interchangeably in the literature, public discourse, and policy discussion to describe governance approaches for supporting the safety of orbiting spacecraft and debris mitigation. Past studies defined the term “space traffic management”; in these reports, there continues to be a lack of consistency and agreement in what the term means. Regardless, use of the phrase “space traffic management” is problematic, in that it implies a specific approach to the overall orbital safety problem. To many,
“management” implies centralized command and control. Also, “space traffic management” creates a direct analog to “air traffic management”; that is one possible framework to approach orbital safety issues. To avoid potential bias and/or confusion, the following generalized phrases and terms will be used in this report to discuss the central issue of orbital safety:

**Framework**: an outline of interlinked items that support a particular approach to a set of specific and constrained objectives. An established strategy to execute policy through technical and operational means.

**Orbital Space**: the region of the space domain used by Earth-orbiting spacecraft.

**Space Situational Awareness (SSA)**: the requisite decision-making knowledge to deter, predict, avoid, operate through, recover from, or attribute cause to the loss, disruption, or degradation of space services, capabilities, or activities, including space traffic safety hazards.

**Space Traffic**: space objects residing in or transiting through orbital space.

**Space Traffic Safety**: freedom from those conditions in orbital space that may lead to incidents resulting in harm (death or injury to astronauts and spaceflight participants, damage to public welfare, damage or loss of spacecraft, interference to spacecraft). Incidents of specific concern are collisions or orbital breakups.

**Space Traffic Safety Incident**: 1) a collision, which is the result of two space objects unintentionally contacting one another in orbital space or 2) an orbital breakup, which is an explosion or disassembly of a space object that generates orbital debris.

**Space Traffic Safety Governance**: the establishment of policies, requisite authorities, interagency relationships; development of subordinate regulations and rules; and implementation of technical, organizational, and operational solutions to enhance Space Traffic Safety.


Distinct nomenclature is used to describe objects and their location in orbital space:

**Orbital Debris**: any object placed in space by humans that remains in orbit and no longer serves any useful function. Objects range from spacecraft to spent launch vehicle stages to components and also include materials, trash, refuse, fragments, and other objects that are overtly or inadvertently cast off or generated.

**Orbit Types**: orbits defined by altitudes or periods of rotation around the Earth. These include Low Earth Orbit (LEO), Medium Earth Orbit (MEO), and Geosynchronous Orbit (GEO).

**Orbit Zones**: a notional concept of generally more specific orbits that are subclasses of orbit types. Zones can be delineated by their mission utility to one or more spacecraft and hence overall value. Examples of specific orbits that could be designated as orbital zones include the International Space Station (ISS) orbit, a variety of sun-synchronous orbits (e.g. the NASA A-Train orbit) and the Global Positioning System (GPS).

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8 The European Space Agency has created the phrase “Space Surveillance and Tracking”, which they define as the ability to detect and predict the movement of space debris in orbit around the Earth. This term could be utilized in place of “SSA” throughout this report when “SSA” is used in the context of providing safety focused products and services.

9 NASA NPR 8715.6A, Appendix A.
orbits. Geostationary Earth orbit is a specific zone within GEO commonly used for global telecommunications.

**Spacecraft**: a functional system in orbital space conducting or capable of conducting a variety of missions and further distinguished by those systems carrying humans (crewed spacecraft), and those systems not carrying humans (robotic spacecraft). To clarify, once a spacecraft is no longer functional or capable of being commanded, it is considered in this report to be orbital debris.

**Space Object**: orbital debris or spacecraft.

### 1.2 Methodology

The alternate Frameworks were developed using the steps that follow.

1. Identify and describe the Space Traffic Safety risks driving the need for an improved Space Traffic Safety Governance Framework.
2. Identify the top-level Space Traffic Safety Governance objectives, assumptions, and constraints for management of USG assets and U.S. private\(^{10}\) sector assets in outer space and orbital debris mitigation.\(^ {11}\)
3. Construct a conceptual model that describes basic elements and interfaces of a generic Framework.
4. Create a pragmatic, useful set of distinct and feasible alternate Frameworks in the context of the risk-informed objectives.
5. Evaluate the ability of alternative Frameworks to meet the objectives and satisfy constraints.
6. Provide Framework implementation recommendations based on the evaluations.

### 1.3 Risks: Driving the Need for an Improved Space Traffic Safety Governance Framework

The basic premise driving the need for an improved Space Traffic Safety Governance Framework is based on an awareness and perception of increased risk for space traffic. It is expected that an improved Framework can mitigate those risks. Given a set of scenarios leading to a Space Traffic Safety Incident, the risk is a combination of incident likelihood and incident consequence.

What follows is not meant to be a definitive space traffic risk assessment. It is rather a discussion of two topics:

1. Important contributions to and characteristics of Spacecraft Traffic Safety related risks.
2. Feasible mitigation steps that can lead to a risk-informed approach to the development of objectives and constraints of possible Frameworks.

#### 1.3.1 Consequences of Space Traffic Safety Incidents

The consequences of Space Traffic Safety incidents could be catastrophic, including the immediate effects of a loss of life (e.g., onboard ISS) or loss of very important space-based services. Generation of orbital debris would lead to additional future collision risk and possibly interfere with current or yet to be launched spacecraft.

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\(^ {10}\) “Private” is all domestic non-USG, including both domestic commercial and domestic academic.

\(^ {11}\) Pub.L. 114-90, Nov. 25, 2015, Section 109.
The recent National Academy of Sciences “National Security Space Defense and Protection” report details the overall importance of space systems to the nation and world:

“Space systems—systems with one or more components resident on Earth-orbiting satellites—are integral parts of the national and global information infrastructure. Some of these systems are essential parts of that infrastructure in that their functions either cannot be performed solely by terrestrial systems or can only be performed poorly and/or with great difficulty and expense by land, sea, or air-based substitutes. In the abstract, were all of the space systems suddenly to shut down, the global information infrastructure would cease to function as the world has come to expect; were the use of space to be denied in perpetuity, current information capabilities would be nearly impossible to reconstruct.”

Likewise, the satellite industry provides a significant direct contribution to both the U.S. and global economy. The 2016 Satellite Industry Association (SIA) State of the Satellite Industry Report shows the global space industry is responsible for a total of $335.3B in 2015 annual revenues ($208.3B is from the global satellite industry, of which $89.2B is from the US satellite industry). For this industry to continue to innovate, grow, and thrive, it is vital that the Space Traffic Safety risks are minimized.

A range of consequences—from minor to catastrophic—are possible in the event of a Space Traffic Safety Incident. Real-world examples of incidents with a range of consequences include the following:

- The Iridium-33 spacecraft/Cosmos-2251 collision of February 2009. Both space objects were catastrophically destroyed in the collision and created more than 2,000 pieces of orbital debris.
- Most recently, the August 2016 collision of the European Space Agency’s Copernicus Sentinel-1A spacecraft with a small (about 1 centimeter [cm]) debris particle. Using onboard cameras, ground operators were able to determine a solar array had been struck by the particle. The spacecraft continues to function normally; in other words, there was little immediate consequence.

A variety of factors must be considered when estimating the possible consequence of Space Traffic Safety Incidents:

- The size of the space objects involved, the design/geometric details, and density of the objects. Larger and denser objects contain more kinetic energy and hence can cause more damage to another object (as demonstrated in the Iridium/Cosmos vs. Sentinel-1A example). Also, collisions involving larger space objects can result in larger amounts of orbital debris.
- The relative velocity of a collision. This is a function of the relative orbits of the space objects colliding. Orbits crossing at right angles will have higher relative velocities. Space objects in nearly the same orbits will have much lower relative velocities (e.g. two spacecraft conducting proximity operations, such as a visiting vehicle with the ISS). Note that even small objects (e.g. 1 cm size) at high relative velocities can still cause catastrophic damage to a spacecraft.

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http://www.esa.int/Our_Activities/Observing_the_Earth/Copernicus/Sentinel-1/Copernicus_Sentinel-1A_satellite_hit_by_space_particle. Latent consequences are possible (e.g., power issues).
• The physical location of the collision impact. For instance, a small piece of orbital debris could strike a spacecraft on a solar array with minimal mission consequence; however, a strike on a payload sensor could result in loss of mission capability.

• The crewed characteristics of the space objects involved (i.e., does the spacecraft carry humans). If crewed spacecraft are involved, assessments must account for possible loss of human life.

• The value of the spacecraft involved in the incident. Of most interest is the information-content value transferred by the spacecraft, not necessarily monetized (e.g., the information from a U.S. Department of Defense (DOD) or Intelligence Community (IC) satellite has enormous value, but it is difficult to value using a dollar metric).\(^\text{15}\)

• The value of the particular orbital zone(s) affected by a collision or orbital breakup. Examples of high-value orbital zones include the ISS orbital zone, polar/sun-synchronous orbital zones and, in particular, those used for science missions (e.g., NASA’s A-Train), and the geostationary orbital zone.

1.3.2 Likelihood of Space Traffic Safety Incidents

It is predicted that about one collision will occur per year between tracked non-maneuvering space objects and debris greater than 1 cm size in the LEO region.\(^\text{16}\) An orbital collision between two space objects occurs when: 1) the orbits (i.e., the paths they take around the Earth) of those two objects intersect or nearly intersect and 2) those two objects are at that point of intersection at or very close to the same time.\(^\text{17}\) Some spacecraft constellations are designed with intersecting orbits so that they may accomplish their missions (e.g., GPS). The timing of the spacecraft passing through these intersections is phased by design and controlled in operations to avoid a possible collision. Otherwise, for the most part, operators avoid placing their spacecraft into orbits that intersect with the orbits of other spacecraft.

However, these intersections do take place, because of a variety of external perturbations that result in orbits being changed. Examples of such perturbations include the non-spherical shape of the Earth; the gravity of the Moon, Sun, (and even Jupiter); atmospheric drag at lower orbits; and solar and Earth radiation pressure created by the reflection, absorption, and emission of energy.\(^\text{18}\) With such variables in place, there exist finite probabilities that any space objects in an orbit type will, over time, unintentionally come into contact with one another as their orbits are changed enough to intersect and the two objects happen to pass through that intersection simultaneously (or nearly so). These infinite possibilities require the continual update of space object positions and velocities in order to compute the most probable space object collision predictions; this is the basis for needing good SSA.

\(^{15}\) Spacecraft insurance policies do not explicitly exclude on-orbit collision, whether with a spacecraft or orbital debris, so a collision is generally covered under those policies.

\(^{16}\) Personal communications with Glen Peterson, Aerospace Corporation, November 3, 2016. “Non-maneuvering” space objects can include a spacecraft that is 1) Non-maneuverable (i.e. has no propulsion), or 2) Maneuverable but does not move to avoid collision because it is either unwarned or incorrectly determines moving is not necessary, or 3) No longer functional, i.e. has become orbital debris. Collision probabilities are lower in MEO and GEO, but estimates cannot be made as confidently as in LEO because SSA capabilities are not as good in those higher altitude orbits.

\(^{17}\) The intersection and timing needs to occur close enough such that any physical parts of the bodies touch one another.

\(^{18}\) Atmospheeric drag is a function of solar activity. As such, atmospheric drag perturbation effects on space objects are constantly changing, sometimes daily and even hourly.
Common factors that influence the likelihood of a hazardous scenario resulting in a collision include the following:

- The size of the space objects potentially involved in the collision. For instance, the probability that the ISS will be struck by a CubeSat in a nearby orbit is much higher than the probability two CubeSats in nearby orbits will strike one another.

- The local density of space objects. More objects in the same region means a higher overall likelihood that two objects in that region will collide at some point in time. (An analogy is the increased risk of collisions between two vehicles on a congested highway versus a country road).

- The total amount of time spent in an orbit with a given density of space objects. More time presents more opportunities to collide. For example, a piece of orbital debris taking 20 years to decay from a given LEO altitude to an atmospheric re-entry will have a higher probability of colliding with another space object in LEO compared to an identical piece of orbital debris taking five years to decay from the same orbit altitude.

As previously stated, given data and models of spacecraft and orbital debris (both known and predicted) distributions in orbital space, it is predicted that about one collision will occur per year between tracked non-maneuvering space objects and debris greater than 1 cm size in the LEO region. A variety of other similar studies have been more recently synthesized by the Interagency Space Debris Coordination Committee. The results of the studies predict catastrophic collisions (like Iridium/Cosmos) to occur in LEO once every five to nine years. Once again, the models used in these studies did not consider spacecraft maneuvering to avoid collisions, although the predicted collision could occur between previously maneuverable spacecraft that have since become inactive, i.e. orbital debris. New, large constellations (with total number of spacecraft numbering in the hundreds to thousands) are being considered that, if launched, would increase local LEO population numbers; but, the near-term assessment is that the likelihood of increased collisions is not appreciably increased, as long as maneuvers for collision avoidance are performed for spacecraft both during normal operations and controlled disposals (if that disposal method is available). Over longer periods of time—decades to centuries—failed satellites in these constellations would create the likelihood of about one to two additional collisions per year.

Historical data compiled in 2009 show that at that time there had been eight total documented orbital collisions since the launch of Sputnik (including Iridium/Cosmos). Only three of these collision involved spacecraft. Since that time, four additional spacecraft-orbital debris collisions are suspected to have occurred (not including the recent Sentinel-1A incident).

A list of the top 10 worst debris producing events has been compiled; the Iridium/Cosmos collision is the only debris-producing incident on the list known to be caused by an unintentional collision. The China anti-satellite (ASAT) test of 2007 ranks as the event causing the largest number of pieces of debris. Six of

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19 Personal communications with Glen Peterson, Aerospace Corporation, November 3, 2016.
23 The accounting approach for the list counts the Iridium/Cosmos collision twice, once for each space object.
the remaining seven events on this list were the result of orbital breakup (explosions), and in the remaining incident, the cause is unknown.24

The likelihood of orbital breakup is very much a function of the spacecraft design features and the physical behavior of the satellite’s systems that contain energy (propellant tanks, pressurant tanks, batteries, and momentum wheels). The recent orbital breakups of three DOD Defense Meteorological Satellite Program (DMSP) satellites caused by battery-associated events are a good example of such debris generating events (this satellite series was designed and approved before orbital debris mitigation requirements were established in the United States).25 A recent example of an orbital breakup that was somewhat unusual is Japan’s Hitomi X-ray observatory. Because of a design error, this satellite literally spun itself out of control with such a rate of rotation that it came apart.26

1.3.3 Assessing Risk and Applying Risk Mitigation Strategies

The primary role of any Space Traffic Safety Governance Framework must be to mitigate the risks of Space Traffic Safety incidents. Mitigation approaches for these adverse events should use a combination of procedural, technical, and operational options that aim to reduce the consequence and likelihood of the events:

- Reducing consequences of Space Traffic Safety Incidents is a rather constrained approach that, for the most part, would impose requirements and/or restrictions on spacecraft designs or operational orbits. The ISS is designed to withstand collisions with smaller orbital debris (to date it has experienced about 300 total micro-meteoroid and orbital debris strikes), but this added survivability comes at a high cost because of the addition of mass for protection. Selection of operational orbits is typically a critical element of the system design. However, there exist spacecraft — such as experimental CubeSats — for which the mission performance is not highly dependent on the precise orbit. For such spacecraft, creating consequence mitigation strategies based on orbit selection is an area that could be explored further (e.g. identification of specific orbit keep-out-zones for Cubesat experimentation).

- Reducing the likelihood of Space Traffic Safety Incidents is a strategy currently practiced and is rich in options for the future. Current orbital debris mitigation guidelines focus on design practices to limit the probability of accidental explosions or other hazardous releases of energy, as well as providing operational practices that limit the amount of time spent in LEO and GEO as debris (i.e., the 25-year and GEO+300km decommissioning guidelines). Mission design practices in the future could be, at a minimum, encouraged to consider the likelihood of collision over the lifetime of the particular system. Such practices are especially important for future large constellations. During spacecraft operations, active collision avoidance serves as the primary and most effective method to reduce incident likelihood. Collision avoidance practices are best implemented through a combination of procedures, tools, and expert organizations.

1.3.4 Issues for Consideration in Risk Mitigation Efforts

The ability of a Framework to effectively mitigate risk of Space Traffic Safety Incidents is limited. Also, risk mitigation strategies in any Framework must consider a variety of contexts to avoid unintended
consequences related to policy, law, national security, economics, or other concerns. Key issues, therefore, must be considered in the development of Framework assumptions, constraints, objectives, and solutions, including the following:

1. The Outer Space Treaty of 1967 (to which the United States is a State Party) provides that States Parties bear international responsibility for ensuring that national activities are carried out in conformity with the Outer Space Treaty, and that the activities of non-governmental entities in outer space require authorization and continuing supervision by the appropriate State Party; however, the Outer Space Treaty provides no authority for a State Party to regulate the outer space activities of any entities not affiliated with that State Party.

2. Current space object basic characteristics data further show the limitations of Space Traffic Safety risk mitigation strategies based on operational controls. Table 1 provides a breakdown of current space objects in the space catalog maintained by the U.S. Air Force with a breakout showing the number of U.S. private and non-U.S. private spacecraft. This table does not include the estimated 500,000 pieces of orbital debris about 1 cm in size or the 1 million pieces of orbital debris about 5 mm or smaller in size.

<table>
<thead>
<tr>
<th>Cataloged Space Objects</th>
<th>Spacecraft</th>
<th>(U.S.) Private Spacecraft</th>
<th>USG+Foreign Spacecraft</th>
</tr>
</thead>
<tbody>
<tr>
<td>23,000²⁷</td>
<td>1,400²⁸</td>
<td>400²⁹</td>
<td>1,000³⁰</td>
</tr>
</tbody>
</table>

From this data, the following observations can be made:³¹

a. The overwhelming majority of trackable space objects are categorized as orbital debris. Of the approximately 23,000 cataloged space objects (all greater in size than 10 cm), only about six percent are (operational) spacecraft.

b. A little more than about one quarter of all (operational) spacecraft are U.S. private owned and operated. This is two percent of all cataloged space objects. Not all of the (U.S.) private spacecraft can be maneuvered propulsively (especially CubeSats).

Therefore, the ability of an improved domestically-focused Framework to mitigate risk of Space Traffic Safety Incidents through operational controls has limitations. This is especially true in the construct of risk mitigation schemes aimed to reduce collision risk through an active collision

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²⁷ Personal communications with the 18th Space Control Squadron, 1 November 2016. About 17,000 space objects are provided in the public catalog, available on the Space-Track.org web-based service. The remaining approximate 6,000 space objects fall into a category of space objects that cannot be associated to a known launch or cannot be reliably tracked with the confidence that the resulting orbit predictions can be used for public purposes.

²⁸ Personal communications with the 18th Space Control Squadron, 1 November 2016.

²⁹ Personal communications with the 18th Space Control Squadron, 1 November 2016. This figure developed by identifying all U.S. private owner-operators and summing numbers of their spacecraft that are known to be operational. This number includes approximately 150 private CubeSats. Numbers of U.S. national security (DOD and IC) spacecraft are not publicly available.

³⁰ This number is derived by subtracting U.S Private Spacecraft from the total number of operational spacecraft. This figure represents a combination of USG and foreign owned and operated spacecraft.

³¹These data must be considered in the context of the following facts. 1) A large number of spacecraft operate in stratified regions of orbital space. 2) Larger objects are more likely to collide with another object. 3) The number of domestic private spacecraft could surge with the development of new large small satellite constellations.
avoidance process. At the domestic level, it is assumed that DOD, IC, NASA/National Oceanic and Atmospheric Administration (NOAA) will remain responsible for the Space Traffic Safety of their own spacecraft. Therefore, any Framework must be an all-of-nation endeavor that requires partnerships across agencies and the private sector. Ultimately, to be most effective in mitigating Space Traffic Safety risks, an international approach will be required. Also, “one-size-fits-all” best practices, guidelines, standards, and rules are difficult to create and implement. Instead, such approaches must consider operational capabilities, limitations, and attributes.

3. Operational decision-making processes, specifically those associated with collision avoidance, are unlike any encountered in the other domains. The physics of orbital spaceflight is complex and most often non-intuitive. Space object observations are made using a variety of telescopes and radars to estimate orbits. Other techniques can be used by spacecraft owner-operators to determine their own orbits (e.g., using onboard GPS or radio ranging methods). Both measurement approaches have some degree of error associated with them. Mathematical models using probability and statistics are then used to reconstruct the prior orbits based on observations and to predict future orbits (days to weeks in advance) based on the models.\textsuperscript{32} The models used in both reconstruction and prediction are imprecise, because they make somewhat crude assumptions of physical parameters (e.g., spacecraft geometry) or they lack precise and up-to-date physical data (e.g., atmospheric density profiles needed to predict drag forces). This leads to uncertainty in the prediction of future orbits and uncertainty in assessing the potential of future collisions. The result is that the risk mitigation approach of maneuvering a spacecraft out of the way of another space object has the following attributes and considerations;

a. The collision warning and avoidance process begins about 4 to 7 days before a possible close approach might take place, based on the ability to somewhat confidently predict future orbits. Such a close approach (close is a predefined distance), where there is heightened risk of collision, is called a “conjunction.”

b. The collision avoidance decision-making process ultimately based on the probability of collision.\textsuperscript{33} This becomes a key metric in the risk-based decision of whether to maneuver and, if so, when and by how much. However, a general one-size-fits-all rule to maneuver based on pre-defined probability of collision threshold is challenging to implement without being counterproductive and ill-informed. It is important to understand the role uncertainties of orbits play in computing the probability of collision between two space objects in a conjunction. Intuitively (and correctly), the smaller the combined sizes of the space objects and the further apart their estimated point of closest approach, the lower the probability of collision. But, changes in the uncertainty of the combined orbits also change the probability of collision. Somewhat counter-intuitively, a higher combined uncertainty of orbits of two space objects will artificially create a lower probability of collision.\textsuperscript{34} In other words; bad knowledge can result in a false perception of safety. In the conjunction assessment process, this knowledge is improved by taking newer and focused measurements, which will drive the probability of collision to some maximum


\textsuperscript{33} Some missions rely on an estimated miss-distance, vice probability of collision, to make collision avoidance maneuver decisions.

number. Eventually, as orbit knowledge is improved and the time to conjunction approaches, there is an improved understanding of risk as the probability of collision will stabilize at some value (including zero). Better SSA data quality can improve this risk control endeavor, but also important is an understanding of the “uncertainty of the uncertainty.” A lack of clarity and full transparency in the uncertainty in measurements will result in a lack of confidence in probability of collision estimates. In summary, unless SSA and spacecraft operators are fully aware of SSA system capabilities and limitations, poor decisions can result.

c. Decisions must ultimately take into account the cost and benefit of potential maneuver, assuming that maneuver is possible. Operational contexts must be considered: will a maneuver impact current operations, for example? Even for the ISS, where human safety is the concern, debris avoidance maneuvers (DAMs) are not automatically conducted based on a probability of collision threshold, but rather consider current mission contexts.35 Operators must account for the impact a decision to maneuver will have on precious propellant inventories. Collision avoidance maneuvers actually require small amounts of thrusting and often can be conducted as part of a normal station-keeping process required to maintain an operational orbit. But, overly conservative conjunction warning processes combined with poor knowledge of space object orbits can result in false alarms that, if acted upon without regard to cost, could be economically and operationally detrimental over time.

4. The critical element in the Space Traffic Safety risk mitigation process is people. As stated in the NASA Risk Management Handbook, “In the face of complex decision making involving multiple competing objectives, the cumulative judgment provided by experienced personnel is an essential element for effectively integrating technical and nontechnical factors to produce sound decisions.”36 Such experienced personnel must understand the complexities of spaceflight and astrodynamics, the capabilities and limitations of the spacecraft involved, the SSA systems being used, and the costs of safety-based decisions. For the most part, such personnel are the spacecraft operators themselves.

5. Also key to the decision-making process is time; decisions must be made in a time-constrained environment. The establishment of organizations in any Framework devoted to risk mitigation must take into account the temporal flow of data and information used for decision-making throughout the organizations. In other words, adding extra layers of staff into an already complex time-sensitive process will be highly detrimental to effective and efficient safety decision-making.

1.4 Framework Development Assumptions

The following assumptions were used in the development of alternate Space Traffic Safety Governance Frameworks:

1. Space Traffic Safety encompasses the following activities and topics:
   a. The Launch Phase, post transit of the U.S. national air space.
   b. Spacecraft on-orbit operations, including end-of-life de-orbit operations.
   c. The Re-entry Phase (both controlled and uncontrolled) down to the U.S. national air space
   d. Orbital debris mitigation.

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See also Appendix A and E.
e. SSA activities necessary for Space Traffic Safety.

f. Space weather activities necessary Space Traffic Safety.

2. Spectrum management and mitigation of radio-frequency interference (RFI) are not considered in the development of alternative Frameworks.

3. Current DOD and NASA Space Traffic Safety processes are effective and well-practiced. Changes to Space Traffic Safety Governance processes, including existing agreements involving DOD and NASA for crewed spacecraft or DOD and NASA/NOAA for robotic spaceflight are not considered in the development of alternative Frameworks. Operations involving the 18th Space Control Squadron, Johnson Spaceflight Center Mission Operations, and the NASA Conjunction Assessment Risk Analysis (CARA) group remain unchanged. However, future modifications of joint agreements and operations processes are not precluded in any Framework as deemed appropriate by NASA and DOD. DOD partnerships with private owner-operators, such as the Commercial Integration Cell, should remain unaffected by future Framework choices. It is especially important to realize that such partnerships are in the interests of national security and aid in maintaining a resilient space enterprise.

4. Three of the Frameworks assessed for this report recommend delegation of certain authorities and responsibilities to a civil agency. Such delegation is assumed to be of value for two reasons. First, a civil agency can be granted the regulatory authorities required to execute the particular policy approach. Second, a civil agency can most effectively “demonstrate U.S. leadership in space-related fora and activities to reassure allies of U.S. commitments to collective self-defense; identify areas of mutual interest and benefit; and promote U.S. commercial space regulations and encourage interoperability with these regulations.”37 However, no assumptions or recommendations are made as to which specific civil agency could or should be designated, as such a recommendation was not specified by Congress as a report product.

5. Any Framework considered can require changes or modifications of domestic policy, rules, regulations, and associated authorities. Any new authorities necessary for a civil agency to implement a given Framework can be provided by necessary legislation.

6. Space Traffic Safety Governance Frameworks are domestic constructs. However, Space Traffic Safety–related products and services can be provided to foreign entities in the same way the DOD currently provides such Space Traffic Safety–related products and services.

7. The development, evaluation, and recommendation of Frameworks is independent of any other report findings required by the CSLCA.38

8. Frameworks do not include a mission assurance function. “Mission Assurance” here is defined as “providing increased confidence that applicable requirements, processes, and standards for the mission are being fulfilled.”39 That is, the Frameworks are not focused on reducing the risk of not satisfying mission requirements.

9. Changes to current United States Strategic Command (USSTRATCOM) SSA data-sharing agreements may or may not be required to implement a given Framework alternative. Renegotiation of USSTRATCOM SSA data-sharing agreements to enable Space Traffic Safety effectiveness and efficiency is not precluded.


38 A review of these reports shows that the findings and recommendations of those reports would not contradict the findings or recommendations of this report.

39 NASA NPR 8715.3C, Appendix B.
1.5 Framework Constraints

The following constraints were used in the development of candidate Space Traffic Safety Governance Frameworks:

1. All Frameworks shall be technically feasible (i.e., they use existing technologies, meaning research and development is not required).

2. All Frameworks shall not require modifications to existing international treaties or international law, nor do they require creation of new legally binding international instruments.

3. All Frameworks shall not require changes to DOD Title 10 and IC Title 50 authorities and responsibilities. Both organizations will continue to be responsible for the Space Traffic Safety Governance of their own spacecraft according to their current processes and procedures and using their own internal capabilities. Sharing of SSA resources between the organizations and any new civil agency responsible for Space Traffic Safety is not precluded.

1.6 Objectives of a Space Traffic Safety Governance Framework

Framework objectives, presented in Table 2, are based on those goals specified in Pub.L. 114-90, November 25, 2015, Section 109, Paragraph c(7), i.e., “the protection of the health, safety, and welfare of the public and economic vitality of the space industry”. These objectives establish well-defined criteria to evaluate Framework alternatives.

Table 2. Space Traffic Safety Governance Framework Objectives

<table>
<thead>
<tr>
<th>Objective</th>
<th>Considerations</th>
</tr>
</thead>
</table>
| I. Ensure and Enhance Safety of the Space Domain | ■ Protect workforce health (i.e., prevent death or injury of USG astronauts by reducing the risk of Space Traffic Safety Incidents involving crewed spacecraft)  
■ Protect public health (i.e., prevent death or injury of space flight participants by reducing the risk of Space Traffic Safety Incidents involving crewed spacecraft)  
■ Protect private and public orbital space assets by reducing the risk of Space Traffic Safety Incidents  
■ Ensure the long-term sustainability of the orbital space environment by limiting the creation and effects of orbital debris caused by Space Traffic Safety Incidents  
■ Protect the public general welfare by reducing the risk of Space Traffic Safety Incidents that could result in loss of vital space-based information services |
| II. Protect and Enhance National Security Space (NSS) Interests | ■ Enable and enhance the objectives of the National Space Policy, National Security Space (NSS) Strategy, and other derived NSS policies, strategies, and plans  
■ Develop transparency and confidence-building measures to encourage responsible actions in and the peaceful use of orbital space |
| III. Ensure Economic Vitality of the Space | ■ Encourage, facilitate, and promote the uninterrupted and free flow of commerce in orbital space |
1.7 Framework Conceptual Model

To meet the objectives specified in Table 2, this study offers a Framework conceptual model for Space Traffic Safety Governance. To effectively discuss options available in an overall Framework, a description of the Framework components and their relationships that make up the governance process should be visualized. Figure 1 shows these basic components and their hierarchical relationships using a stack model.

A basic Framework model consists of three stacks: the Policy Domain stack, Technology Domain stack, and Operations Domain stack. The Policy Domain stack displays the hierarchical relationship between high-level policies down to the direction of various subordinate, more detailed and less abstract standards, guidelines, and best practices (all together, these can be described as “Rules of the Road”). The Technology Domain stack describes the integrated elements that provide SSA and decision-making–related tools that provide the knowledge necessary to make informed assessments and mitigations of risks associated with Space Traffic Safety. The Operations Domain stack contains the human

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40 Spacecraft command and control systems can also be considered part of the Technology Domain. For simplicity, they are not shown. Also, active debris removal is another technology option for the future in the technology domain. It is not considered here.
operators and the specific operational instructions required to control and maintain the SSA tools and spacecraft. It is ultimately the human operators that will (should) make risk-based safety decisions.

Table 3 describes each stack element within the Framework model and provides relevant examples.

Table 3. Framework Stack Model Elements, Descriptions, and Examples

<table>
<thead>
<tr>
<th>Element</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Policy Domain</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Policies</td>
<td>High-level principles adopted or proposed by the USG.</td>
<td>• National Space Policy (e.g. SSA data will be used to support global space community)</td>
</tr>
<tr>
<td>Rules and Regulations</td>
<td>Specific rules and directives created to accomplish policy.</td>
<td>• Title 10 U.S. Code 2274—USSTRATCOM is responsible for the Commercial and Foreign Entities (CFE) program, renamed SSA Sharing program</td>
</tr>
</tbody>
</table>
| Standards           | A set of rules created and or adopted by committee. Standards are codified documentation describing requirements, specifications, or characteristics that can be used consistently to ensure that materials, products, processes, and services are fit for their purpose. Standards must be measureable and verifiable. | • ISO 24113, Space Systems: Space Debris Mitigation Requirements  
• The Consultative Committee for Space Data Systems (CCSDS) Space Data System Standard for Conjunction Data Messages (CDM) |
| Guidelines          | A codified set of recommendations or advice provided by one or more organizations. | • Interagency Space Debris Coordination Committee (IADC) Space Debris Mitigation Guidelines |
| Best Practices      | A technique or methodology that, through experience and research, has proven to reliably lead to a desired result. These can be written or unwritten. | • JFCC Space, *Spaceflight Safety Handbook for Satellite Operators*, Joint Space Operations Center, August 2016  
• JFCC Space, *JSpOC Recommendations for Optimal CubeSat Operations*  
• GEO operators notify others, through the Space Data Association, before they maneuver. |
| **Technology Domain** |                                                                             |                                                                                                |
| Functions           | Operational activities conducted to accomplish high-level objectives (policy, laws, and regulations) specified in the Policy Domain. | • SSA  
• Spaceflight safety |
| Products and Services | Tangible information exchanges and associated intangible support elements and mechanisms that are used for safety-related decision-making in space operations. | • Space object catalog  
• Launch and on-orbit collision avoidance (COLA)  
• Conjunction assessment (CA)  
• De-orbit and re-entry predictions |
| Applications        | Computer programs (software) used to analyze process data to create information products and services. | • Conjunction assessment software  
• Orbital data sharing software (e.g. Space-Track.org) |
### Element | Description | Example
---|---|---
**Computing Platforms** | Computers and associated networks that process, aggregate, segregate, store, and provide basic analysis on data received from sensors. | • Correlation, Analysis, and Verification of Ephemerides Network (CAVENet)
• Space Defense Operations Center (SPADOC)
• JSPoC Mission System (JMS)
• Cloud services (e.g., Amazon Web Services)

**Data Sensors** | Telescopes, radars, and other sensors used to detect, observe, and track space objects. Also, spacecraft communication and navigation systems used report spacecraft orbit data. | • Space Surveillance Network (SSN) sensors
• Spacecraft self-reported or self-determined ephemeris

### Operations Domain

**Operators** | Humans required to control and maintain systems, observe data products, and make final decisions in the context of space traffic safety. | • 18th Space Control Squadron
• NASA CARA staff
• JSC ISS Flight Operations staff
• Commercial spacecraft operators

**Processes and Procedures** | Steps, activities, and codified actions taken by operations staff in the conduct of SSA or spacecraft operations. | • ISS Debris Avoidance Flight Rules

### 2.0 PRESENTATION OF FRAMEWORK ALTERNATIVES

Five discrete Frameworks are offered for consideration. Each Framework exists at a distinct point on a continuous spectrum of Space Traffic Safety Governance options in which the USG’s prescriptive role ranges from low to high (Frameworks options 1 to 5, respectively). Those specific USG roles for consideration are the following:

- Developing and enforcing Space Traffic Safety–related data sharing policies, best practices, guidelines, standards, and rules and regulations (Policy Domain issue)
- Providing Space Traffic Safety products and services to private and foreign space operators (Technology Domain issue)
- Selecting, employing, and/or training Space Traffic Safety SSA operators, certifying private spacecraft operators, and developing operational processes and procedures (Operations Domain issue)

Each Framework represents a policy choice. Using the stack model presented, the policy will drive the way in which future Space Traffic Safety rules and regulations and lower-level guidelines and standards are created and possibly enforced. Likewise, the policy within a given Framework dictates the functions of
the Technology Domain approach and hence the products and services to be provided (and similarly for the Operations Domain model).\footnote{As noted, each Framework represents a discrete choice on what is a continuous spectrum of options. This approach has been used to illustrate distinct differences in possible alternatives. There exist, of course, options to use a hybrid blend of policy, technology, and/or operations approaches described in adjacent Framework alternatives.}

It is of critical importance that any policy adopted and any rules, regulations, standards, and operational requirements established are firmly based on physics, technical considerations, and operational limitations and timelines. The regimes that govern other domains of human activity – such as management of air traffic and naval operations – have been built over periods of centuries to millennia, and are technically based on lessons learned from a variety of accidents, mishaps, near-misses, and warfare.\footnote{It is interesting to note that, however, the maturity of safety related rules of the road in the maritime, land, and air domains for robotic vehicles is about on par with that of the space domain, for the most which is occupied by robotic vehicles! This is consistent with our observation that rules and regulations in the non-space domains, for the most part, are based on lessons learned from past mistakes.}

Ensuring the safety of space operations, however, cannot be similarly approached through long time periods of experience based on trial and error. The space domain has fundamentally different physics than others in that it is not inherently self-cleansing when an incident occurs. Once on orbit, spacecraft and space debris remain in orbit for many years (potentially tens of thousands), and can therefore create long-term hazards to the space environment. Fortunately, the likelihood of Space Traffic Safety Incidents currently is low, due to the physics of the environment and current space object densities. Unfortunately, Space Traffic Safety Incidents can be catastrophic and are likely to pose risk to other spacecraft. Policies and operational requirements that are not sufficiently based on informed physics and technical considerations will no doubt create economic consequences, while potentially not mitigating safety risks significantly. The Technology Domain is especially important in this regard: higher quality SSA data will lead to more informed and efficient decisions. The Technology Domain must focus on the development and distribution of trusted data.

It is important that any approach to Space Traffic Safety Governance be of a holistic nature, both within the USG as a whole, and between the USG and private operators. This is currently not the case. Nor is there a single entity both responsible and accountable for Space Traffic Safety, which practically guarantees a lack of progress. That said, the degree to which the USG exercises control as depicted in these options will most likely determine those functions that are “inherently governmental” as defined in Federal Procurement Law and Guidance.\footnote{Manuel, K., “Definitions of ‘Inherently Governmental Function’ in Federal Procurement Law and Guidance,” Congressional Research Service, December 23, 2014. See Appendix H.} The Frameworks options are provided below.

\begin{table}[h!]
\centering
\begin{tabular}{|l|}
\hline
\textbf{1. Private Space Traffic Safety Monitoring and Coordination} \\
\hline
\textit{Summary:} The overarching policy is to relieve the DOD of its role in private and non-USG Space Traffic Safety Governance and to advocate a self-monitoring approach for private of foreign owner-operators. No new authorities should be required to establish this approach. \\
\hline
\textit{Policy Domain Approach:} The USG plays a very informal shaping role in this Framework in the development of best practices, guidelines, and standards. A fully privatized, non-government funded ecosystem consisting of U.S. and international profit, not-for-profit, and academic organizations fund, develop, promote, and voluntarily comply with Space Traffic Safety best practices, guidelines, and \\
\hline
\end{tabular}
\end{table}
standards. It is assumed Space Traffic Safety functions do not meet the criteria to be judged an inherently governmental activity.

**Technology Domain Approach:** DOD ceases to provide Space Traffic Safety products and services (e.g., a private space catalog data, conjunction data messages) to private and foreign operators. The fully privatized ecosystem (i.e., commercially-owned/commercially operated [CO/CO]) develops and promulgates Space Traffic Safety products and services using a consortium-type or not-for-profit-led approach. Business models could include a fee-based approach for membership to this consortium. Space Traffic Safety products and services and a catalog could be derived from a combination of self-reported satellite ephemeris, potentially supplemented with commercial data sensor sources.

**Operations Domain Approach:** The operations staff members in this model would be commercial employees. The consortium members would determine intellectual property rights of processes and procedures.

**Analogs:** Space Data Association (SDA). This Framework in many ways resembles a private Space Traffic Safety Governance approach, much like an enhanced SDA model (see Appendix G for more information on the SDA). Organizations such as ASTM and ISO provide examples for this bottom-up approach.

### 2. DOD-Based Space Traffic Safety Monitoring and Data Sharing

**Summary:** The overarching policy is to continue with the status quo for Space Traffic Safety Governance.

**Policy Domain Approach:** The USG role is unchanged from today. USSTRATCOM is the lead for information-sharing approaches and dissemination, and as the focal point for USG interactions with owner-operators and foreign governments. Rules of the road continue to be developed in an ad hoc manner domestically. International efforts (e.g., International Organization of Standards (ISO), IADC) continue without change to USG approaches. No new authorities are required and the current approach regarding inherently governmental activities is unchanged.

**Technology Domain Approach:** The DOD continues to provide Space Traffic Safety products and services through Space-Track.org to private and other non-USG entities based on data-sharing arrangements and agreements. A single space catalog is produced and current data protection approaches are maintained.

**Operations Domain Approach:** Current DOD staff (civilian, military, and contractor) continue to provide operations support. USSTRATCOM and United States Air Force (USAF) processes and procedures continue to be employed.

**Analogs:** Status quo.
3. Civil-Based Space Traffic Safety Monitoring and Facilitation

**Summary:** The overarching policy is to establish the authorities for a USG civil agency to replicate the current DOD function of providing Space Traffic Safety products and services to private and foreign entities, facilitating information sharing among those owner-operators. The civil agency also facilitates the private development and evolution of Space Traffic Safety best practices, guidelines, and standards. This is a “bottom-up” approach.

**Policy Domain Approach:** The USG establishes authorities for a USG civil agency to be responsible for Space Traffic Safety Governance using a modest, bottom-up approach with the primary purpose of facilitating voluntary information sharing among owner-operators. The development of new USG rules and regulations pertaining to specific Space Traffic Safety matters are minimized and are limited to matters incorporated into the licensing and authorization processes. It is assumed Space Traffic Safety functions meet the criteria to be judged inherently governmental activities are primarily those associated with licensing, contracting, and international affairs.

The lead USG civil agency:
- Has no authorities to mandate communication or coordination among owner-operators or dictate operational decisions (e.g., to maneuver for collision avoidance).
- Establishes desired high-level goals and objectives for development, evolution, and sustainment of private Space Traffic Safety rules of the road. These best practices, guidelines, and standards focus on 1) spacecraft operations practices to reduce the risk of Space Traffic Safety Incidents, and 2) Data standards for the technology domain. This is done through facilitating the maturation and evolution of communities of interest (e.g., private CubeSat developers and operators, private GEO owner-operators) that eventually become formally allied through consortia that focus on creation and codification of best practices, guidelines, and standards. The USG does not formally provide an advisory role in development of these standards and practices (i.e., as specified by The Federal Advisory Committee Act, Pub.L. 92–463, 6 October 1972).
- Creates and manages USG interagency working groups and committees focused on Space Traffic Safety.
- Conducts continuous outreach with the consortia to understand product and service values, needs, expectations, and operational issues, risks, and concerns.
- Provides products and services free of user fees, in an advisory, non-directive role.
- Subscription to products and services provided by spacecraft owner-operators are highly desired but remain on a voluntarily basis.

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44 A clarifying example is with the conjunction warning process involving two spacecraft owner/operators. In this Framework, operationally, a civil agency would facilitate communication between those owner/operators, recommending that the space actors discuss a course of action for collision avoidance. Administratively, the civil agency would facilitate the development of working groups by asking spacecraft owner/operators to voluntarily come together to discuss the operational practices to be put into place during conjunction warning assessments.
**Technology Domain Approach:** The civil agency is given the authorities and funding to provide Space Traffic Safety products and services to private and other foreign entities. Specific technical architectures are flexible:

- Since this Framework replicates the current DOD function of providing Space Traffic Safety baseline products and services, the current DOD Technical Domain architecture could be fully shared or replicated, or a combination of both.
- Products and services replicate those offered by DOD today.
- A new, commercially driven architecture, using commercial sensors and computing platforms and applications could be prototyped, developed, and placed into operation. Such an approach offers several options in both the possible number of sources for each Technology Domain stack layer as well as the business models used to acquire and synthesize stack layers. For instance, several commercial sensor data sources could be purchased on a service-based contractual basis (i.e., data buys). Inclusion of DOD sensor data, if allowed, could possibly be accommodated. Then, the commercial and possible DOD data would be integrated into a computing platform, which could be USG-owned (i.e., acquired through conventional contracting means), or once again, purchased as a service. Likewise, applications could be USG-owned or purchased as a service. A systems integrator could be introduced. Finally, SSA and Space Traffic Safety operations and notifications could be conducted by the USG or contracted personnel (government-owned/government-operated [GO/GO] or government-owned/commercially operated [GO/CO]). Finally, a public-private partnership (PPP) approach could be employed to develop, operate, and acquire the entire SSA technical solution.

**Operations Domain Approach:** SSA operations staff in this approach could be a contractor or USG employee or an appropriate combination. Extending the consortia model to this domain, operations staff members could include employees of private spacecraft owner-operators acting in temporary assignments. In any contracted operations approach, contractor-developed processes and procedures data are at a minimum, USG purpose rights.

**Analogs:** The Institute for Nuclear Power Operations (INPO), NOAA/National Environmental Satellite Data and Information Service (NESDIS), and SDA practices provide good analogs for this approach. INPO, a not-for-profit established by the nuclear power industry, sets industry-wide performance objectives, criteria, and guidelines for nuclear power plant operations that are intended to promote operational excellence and improve the sharing of operational experience between nuclear power plants. INPO was established following congressional recommendations after the Three Mile Island reactor incident. While the Nuclear Regulatory Commission (NRC) maintains licensing authorities, INPO develops operations standards and performs safety inspections. Presidents/CEOs of the major power companies operating commercial nuclear plants sit on the INPO Board of Directors. NOAA/NESDIS models provide a relevant exemplar. First, the organization is focused on being a provider of trusted data in the weather domain with the inherent assumption that such data is a public good. Second, NOAA/NESDIS produces its own environmental information from NOAA spacecraft and it has recently established approaches to purchasing weather data from commercial sources, developing basic requirements for data types and formats that will provide it with the best environmental information.

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45 This analog is also useful in an international context, as NOAA weather data, products and services, and systems are developed in context of the goals, objectives, and standards of the World Meteorological Organization (WMO). The WMO is a specialized agency of the United Nations. This approach promotes international interoperability of weather data and information.
available. NOAA/NESDIS use these, the best data available, and thus is a trusted source to provide timely access to global environmental data to promote, protect, and enhance the nation’s economy, security, environment, and quality of life. Like Option 1, this option does create a product and services model very much like that of the SDA, in which owner-operators contribute to a space catalog. With those products and services now offered free of charge, greater membership should become possible.

### 4. Civil-Based Space Traffic Safety Monitoring and Coordination

**Summary:** The overarching policy is to establish authorities for a USG civil agency to be responsible for Space Traffic Safety Governance providing Space Traffic Safety baseline products and services to private and foreign entities, prescribing some level of coordination of information sharing among private owner-operators, while also expanding the leadership role of the USG in more proactively coordinating the development and evolution of best practices, guidelines, and standards for private spacecraft owner-operators. This “from-the-middle approach”, in which the USG plays a more proactive and prescriptive role than Option 3, still relies heavily on private-industry knowledge and practice to mature and eventually evolve USG rules and regulations. It is assumed Space Traffic Safety functions meet the criteria to be judged inherently governmental activities are those associated with licensing, contracting, development and management of advisory committees, and international affairs.

**Policy Domain Approach:** The USG establishes authorities for a USG civil agency to provide Space Traffic Safety baseline products and services to private and foreign entities, prescribing some level of coordination of information sharing among private owner-operators, and performing a formal advisory role in the development, evolution, and sustainment of private best practices, guidelines, and standards, with specific interest in formulating future Space Traffic Safety rules and regulations.

The lead USG civil agency:
- Has authority to mandate some level of communication and coordination among private owner-operators but does not have authority to dictate operational decisions (e.g., to maneuver for collision avoidance).
- Establishes Space Traffic Safety–focused working groups, engineering forums, and committees, including formal advisory boards and committees (established to represent specific communities of interest such as private CubeSat developers and operators, private GEO owner-operators) as specified by the Federal Advisory Committee Act, Pub.L. 92–463, 6 October 1972.
- Utilizes these advisory boards and committees to development, evolve, and sustain private Space Traffic Safety best practices, guidelines, and standards. These best practices, guidelines, and standards focus on 1) Spacecraft operations practices to reduce the risk of Space Traffic Safety Incidents, and 2) Data standards for the technology domain. Creates USG steering groups and interagency processes deemed necessary to coordinate Space Traffic Safety policy and technical issues between USG and non-USG spacecraft owner-operators.

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46 A clarifying example is, again, with the conjunction warning process involving two spacecraft owner/operators. In this Framework, operationally, a civil agency would coordinate communication between those owner/operators, requiring that the space actors discuss a course of action for collision avoidance and require them to inform/update the civil agency of these joint courses of action. Administratively, the civil agency would coordinate the development of committees used to develop codified operational guidelines and standards to be put into place during conjunction warning assessments. Owner/operator membership and proof the ability to comply with applicable standards would be a requirement in the civil agency’s licensing processes.
- Develops data specifications, performance standards and specifications, and interface control documents (ICDs) for use in Technical Domain solutions.
- Provides products and services free of user fees, in an advisory role.
- Subscription to products and services provided in the Technical Domain by private owner-operators are mandatory. This includes self-reporting of spacecraft ephemeris and operational status.

**Technology Domain Approach:** The civil agency is given the authorities and funding to provide Space Traffic Safety products and services to private and other foreign entities. The approach options are the same as in Option 3, although the solutions are required to conform to the product specifications discussed in the Policy Domain approach.

**Operations Domain Approach:** SSA operations staff in this approach could be contractor or USG employees or an appropriate combination. In any contracted operations approach, contractor-developed processes and procedures data are provided with unlimited rights.

**Analogs:** GPS provides a close analog to this Framework’s governance model in policy, organization, and technical approach. The GPS consists of a National Executive Committee for Space-based Positioning, Navigation, and Timing (PNT), which consists of civil and military departments and agencies that advise and coordinate among member department and agency requirements and provide resource allocation for maintaining and improving U.S. space-based PNT infrastructure. Under the National Executive Committee, GPS has an advisory board and several working groups, which allows USG and non-USG entities to provide input on GPS issues and policies. The National Space-based PNT Advisory Board enable GPS experts from outside the USG to provide independent advice related to policy, planning, program management, and funding. The Executive Steering Group—the GPS International Working Group—and the National Space-based PNT Systems Engineering Forum provide forums to elevate interagency issues, to meet and review the nation’s ongoing bilateral and multilateral cooperation activities and to conduct assessments and make recommendations on technical issues. The USG has more control over policies and standards, but non-USG organizations can provide input that will be taken seriously when issues arise.

### 5. Civil-Based Space Traffic Management

**Summary:** The overarching policy is to establish authorities for a USG civil agency to be responsible for Space Traffic Safety Governance using a top-down approach in which the USG plays a direct, prescriptive role in development and enforcement of Space Traffic Safety rules and regulations, including directing on-orbit activities.

**Policy Domain Approach:** The USG establishes authorities for a USG civil agency to develop and enforce prescriptive Space Traffic Safety rules and regulations. It is assumed a large number of the Space Traffic Safety functions will meet the criteria to be judged inherently governmental activities. The lead USG civil agency:

- Has authority to dictate private owner-operator operational decisions (e.g., to maneuver for collision avoidance) and mandate a high degree of communication and coordination between private owner-operators and the USG civil entity.

Rules and regulation development approaches could include the following:

- Establishment of Space Traffic Safety-related rules and rule-making procedures used to create mandatory compliance requirements in the domestic spacecraft system life cycle (design,
Operations, and decommissioning). Rules enforced during orbital activities would include requirements to conduct collision avoidance as directed.

- Safety certification requirements for ground and spacecraft systems of private operators.
- Training certification requirements for private spacecraft operators.
- A product certification requirement and data standard for Technical Domain elements (e.g., data sensors).

**Technology Domain Approach:** The civil agency is given the authorities and funding to provide Space Traffic Safety products and services to private and foreign entities. The approach uses the following:

- A GO/GO business model.
- Conventional acquisition processes to develop and purchase sensors, computing platforms, and applications.

**Operations Domain Approach:** A USG staff focused on 24/7 operational command and control of domestic non-USG spacecraft (i.e., “Space Traffic Controllers”) is used. This function could meet the interpretive criteria of “inherently governmental”, given the potential impact to private property.

**Analogs:** Federal Aviation Administration (FAA) air traffic and aviation safety approaches provide a model for this Framework. The FAA manages air traffic within the United States through all phases of flight, from departure clearance to landing clearance. It has full control of the air environment and created standards and systems that must be met to operate within the United States. One such system is the FAA System Operations Services, which is the focal point for stakeholder interaction through formal collaborative decision-making venues, and they serve as the FAA’s customer advocate. For operating standards, the FAA created the Safety Management System through a top-down approach that provides a systematic approach to achieving acceptable levels of safety risk by integrating modern safety risk management and safety assurance concepts into repeatable, proactive systems.

### 3.0 ASSESSMENT OF FRAMEWORK ALTERNATIVES

Each of the five alternate Frameworks described in Section 2 represents a mixture of advantages and disadvantages, costs and benefits, and risks and opportunities in fulfilling the Space Traffic Safety specified objectives. The stoplight chart in Figure 2 represents a subjective evaluation of each Framework’s ability to meet those objectives. A more in-depth evaluation of each Framework is presented thereafter. Note that these assessments apply at this particular point in time and in the expected near term (three to five years). Changes in a variety of contexts (such as Space Flight Safety risks, global and domestic political-military and economic issues, technical capabilities, etc.) could change the results of this analysis.
3.1 Assessment of Alternative Space Traffic Safety Governance Framework

3.1.1 Private Space Traffic Safety Monitoring and Coordination (Option 1)

- **Ensure the Safety of the Space Domain** – Some basic Space Traffic Safety functions may be judged inherently governmental. If so, this framework might not be plausible. A judgment will need to be made to determine those functions that are “inherently governmental” as defined in Federal Procurement Law and Guidance, before this option can be fully considered. Best practices, guidelines, and standards will continue to be developed in an ad hoc, un-facilitated, and un-codified manner by the private community. (Other governments and international organizations might otherwise lead these efforts.) The lack of a holistic and focused Space Traffic Safety Governance approach can result in not sufficiently addressing the overarching objective of sustaining the space environment. Lack of leadership fails to incentivize and promote the development of a domestic culture of safety. There is a medium to high likelihood that not all domestic private owner-operators will “buy in” to receive products and services. Proprietary data concerns may result in less than open and fully transparent self-SSA information release. It insufficiently addresses the need for a whole-USG approach to ensure synchronization of safety concerns across the USG–domestic private space enterprise (e.g., with NASA crewed spacecraft, DOD spacecraft). There are possible conflicts between commercially derived SSA and tracking data and USG-derived SSA and tracking data, without a clear understanding of the reasons for these differences, leading to less-than-efficient and possibly degraded Space Traffic Safety–related decisions involving USG and private owner-operators.

- **Protect and Enhance NSS Interests** – This Framework fails to enable the USG to play a leadership role in the development and maturation of safety-centric best practices, guidelines, and standards.

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that could serve as the foundation of international norms of behavior. It limits USG development of safety-focused areas of interest for potential international cooperation. It could be interpreted as failing to meet USG requirements of the Outer Space Treaty (e.g., continuing supervision). It does not allow the USG to play a leadership role in establishing reasonable and realistic space catalog data security policies.

- **Ensure the Economic Vitality of the Space Domain and Space Industrial Base**—Overall poor Space Traffic Safety risk mitigation performance adversely impacts the facilitation and promotion of space commerce. Although unlikely, this private model can be used by established owner-operators to create barriers for new entrants (especially in creating standards).

3.1.2 **DOD-Based Space Traffic Safety Monitoring and Data Sharing (Status Quo, Option 2)**

- **Ensure Safety of the Space Domain**—Best practices, guidelines, and standards will continue to be developed in a rather ad hoc, un-facilitated, and un-codified manner by the private community. (Other governments and international organizations might otherwise lead these efforts.) DOD lacks any regulatory authorities required to evolve the licensing process to further reduce Space Traffic Safety risks. The lack of a holistic and focused Space Traffic Safety Governance approach can result in not sufficiently addressing the overarching objective of sustaining the space environment. The DOD SSA network, which is not optimized for Space Traffic Safety requirements, underperforms in a safety mission role. Lacking confidence in predictions, private owner-operators may not fully trust provided products and services.

- **Protect and Enhance NSS Interests**—The DOD will continue to be burdened by the Space Traffic Safety role, limiting overall Operational Domain and Technical Domain architecture (e.g., sensors, computing platforms) effectiveness in the Title 10 role of Space Protection and Defense. The defense organization lacks full effectiveness in international Space Traffic Safety dialog.

- **Ensure the Economic Vitality of the Space Domain and Space Industrial Base**—Overall Space Traffic Safety risk mitigation performance adversely impacts the facilitation and promotion of space commerce. DOD otherwise has no authorities or obligations to facilitate or promote space commerce. Continued high false alarm rate to spacecraft owner-operators possibly adds to operations overhead.

3.1.3 **Civil-Based Space Traffic Safety Monitoring and Facilitation (Option 3)**

- **Ensure Safety of the Space Domain**—Safety-centric, codified best practices, guidelines, and standards can evolve through the leadership of the safety, security, and commerce-focused civil organization. Unlike the civil agency, DOD lacks any regulatory authorities required to evolve the licensing process to further reduce Space Traffic Safety risks. The commercial approach (less typical USG acquisition delays) option could lead to innovation and rapid development of a diversified set of SSA sensors, computing platforms, and applications, creating additional and improved Space Traffic Safety products and services and enabling more informed decision-making. There are potential conflicts between DOD-derived and civil agency–derived products and services (e.g., discrepancies between DOD and civil-agency catalogs if using this approach), but a common understanding of the differences in methods and models can ameliorate this concern.

- **Protect and Enhance NSS Interests**—The elimination of DOD overhead for development and delivery of Space Traffic Safety products and services allows for the DOD to focus on its space defense and protection mission and further enhances resiliency. DOD SSA systems become “tuned” to space defense and protection needs. This Framework provides mechanisms for the USG to develop safety-focused areas of interest for potential international cooperation. It enables
the USG to play a leadership role in the development and maturation of safety-centric best practices, guidelines, and standards that serve as the foundation of international norms of behavior. It allows the USG to play a leadership role in establishing reasonable and realistic domestically controlled space catalog data security policies.

- **Ensure the Economic Vitality of the Space Domain and Space Industrial Base**—The USG will facilitate but have limited input in the development of new best practices, guidelines, and standards from a bottom-up approach. This approach appropriately relies on commercial industry to be more technically informed based on full accounting of unique owner-operator values, needs, and capabilities. Reducing overhead and the number of false alarms leads to higher operational efficiencies. This Framework provides more certainty to new startups of Space Traffic Safety–related licensing expectations. The approach also incentivizes continued growth and maturation of a new commercial space sector offering SSA services and capabilities.

### 3.1.4 Civil-Based Space Traffic Safety Monitoring and Coordination (Option 4)

- **Ensure Safety of the Space Domain**—Safety-centric, codified best practices, guidelines, and standards can evolve through the clear, coordinated leadership of the safety- and commerce-focused civil organization. Unlike the civil agency, DOD lacks any regulatory authorities required to evolve the licensing process to further reduce Space Traffic Safety risks. The commercial approach (less USG acquisition delays) option could lead to innovation and rapid development of a diversified set of SSA sensors, computing platforms, and applications, creating additional and improved Space Traffic Safety products and services. There are potential conflicts between DOD-derived and civil agency–derived products and services (e.g., discrepancies between DOD and civil-agency catalogs if this approach is used), but a common understanding of differences in methods and models can ameliorate this concern. Overall, the safety related benefits of this Framework option are about the same as those presented in Option 3. However, because of the additional USG roles, it will take longer to implement.

- **Protect and Enhance NSS Interests**—The elimination of DOD overhead for development and delivery of Space Traffic safety products and services can allow for the DOD to focus on space defense and protection mission and further enhancing resiliency. This Framework provides mechanisms for the USG to develop safety-focused areas of interest for potential international cooperation. It enables the USG to play a leadership role in the development and maturation of safety-centric best practices, guidelines, and standards that serve as the foundation of norms of behavior. It allows the USG to play a leadership role in establishing reasonable and realistic catalog data security policies.

*Ensure the Economic Vitality of the Space Domain and Space Industrial Base*—This approach requires commercial industry to be more technically informed based on full accounting of unique owner-operator needs and capabilities. Reducing overhead and the number of false alarms leads to higher operational efficiencies. This Framework provides more certainty to new startups of Space Traffic Safety–related licensing expectations. The approach also incentivizes continued growth and maturation of a new commercial space sector offering SSA services and capabilities. The most significant difference presented by this Framework option, as compared to Option 3, is that the regulatory mandates of the approach could inhibit new startups and potentially begin to drive companies offshore due to actual or perceived compliance burdens.

### 3.1.5 Civil-Based Space Traffic Management (Option 5)

- **Ensure Safety of the Space Domain**—Clear safety-based rules and regulations are commonly understood and followed. Conversely, there is no guarantee that such new rules would be fully
technically informed and therefore contribute to effective Space Traffic Safety risk mitigation. The conventional acquisition of technical SSA capabilities lacks the agility required to maintain technological relevancy and therefore fails to provide the most effective SSA capabilities. There are potential conflicts between DOD-derived and civil agency-derived products and services (e.g., discrepancies between DOD and civil-agency catalogs if this approach is used), but a common understanding of differences in methods and models can ameliorate this concern.

- **Protect and Enhance NSS Interests**—The elimination of DOD overhead for development and delivery of Space Traffic Safety products and services can allow for DOD to focus on space defense and protection mission and further enhancing resiliency. The high potential for driving commercial capabilities overseas can limit the USG’s use of commercial spacecraft for national security related services. This approach could lead to poor international perceptions related to the U.S. approach using a very prescriptive role in managing domestic spacecraft owner operators.

- **Ensure the Economic Vitality of the Space Domain and Space Industrial Base**—Additional burdens (especially operational) on private owner-operators can inhibit the development of new space-based service businesses or drive those businesses offshore. Uninformed regulations and operations rules can be detrimental to business economics, while doing little to enhance Space Traffic Safety.

### 4.0 SUMMARY AND CONCLUSIONS

Spacecraft orbiting the Earth have become nodes in a global information network. Our national security and the overall public welfare rely heavily on this space-based critical infrastructure. The economic impact of orbiting spacecraft is significant. The global space industry alone accounts for hundreds of billions of dollars in revenue. The total value of the content delivered from space is many orders of magnitude more, because most personal and commercial business in some way foundationally rely on space-based services. Spacecraft continue to be vehicles of human exploration, and the future holds a promise of expanded participation in that exploration of space by the public.

In this decade, a new focus has been appropriately made on the defense and protection of spacecraft to ensure the continued flow of information to and from space. Just as there is risk to spacecraft that must be mitigated through defense and protection, there is risk to spacecraft because of the possibility of unintended collisions and physical interference from space objects in intersecting orbits. The likelihood of such events is low, but the consequences can be high, especially in cases involving crewed spacecraft. Therefore, it is in the U.S. national strategic and economic interests to have an improved domestic Space Traffic Safety Governance Framework that specifically aims to mitigate and reduce the risk of possible Space Traffic Safety Incidents, while at the same time protect the economic vitality of the space industry. Likewise it is important to enable the DOD to focus on its space protection and defense mission operationally, and allow its technical support systems to evolve based on protection and defense-centric requirements.

The current Framework does not provide a holistic approach by leading in the combined development of technically informed “rules of the road” and the provision of value-driven, safety-based products and services used during spacecraft operations. Such “rules of the road”, based on Space Traffic Safety concerns, could lead to the maturation of international norms of behavior, which would greatly enhance the strategic stability of the space domain.

Objectives for a Space Traffic Safety Governance Framework were created by the study team that focus on mitigating Space Traffic Safety–related risks, protecting and enhancing national security interests, and
ensuring the economic vitality of the space domain and industry. After review and assessment of a range of Framework options, conclusions and recommendations are provided as follows.

A Framework that best balances the needs for safety, national security, and economic interest is a framework led by a civil agency. That civil agency will perform the following activities:

1. Facilitate privately led, technically informed development of codified best practices, guidelines, and standards. These documented processes include improved approaches to reduce the risk of Space Traffic Safety Incidents. These processes can inform future licensing requirements for payloads.48

2. Provide advisory products and services that enhance operational safety, such as a public space catalog and conjunctions data messages. The agency should become the trusted open source of SSA data.

3. Provide leadership in technical and operations matters related to Space Traffic Safety in international fora and develop data-sharing relationships with international owner-operators and partners.

4. Balance the needs of Space Traffic Safety with the interests of space commerce and the space industrial base and, therefore, encourage, facilitate, and promote the uninterrupted and free flow of commerce in orbital space.

5. Use a business approach for providing SSA products and services in a manner that is most cost-effective, enables innovation to occur on commercial technology development timescales, and is consistent with the required data security policies needed for national security.

6. Interface appropriately with all interagency partners to ensure a whole-USG approach to Space Traffic Safety Governance.

A civil agency should be provided with appropriate liability indemnification, and at this time it should not have authorities to dictate real-time operational decisions (e.g. mandating a collision avoidance maneuver). The civil agency will be required to develop strong interagency processes and procedures with other USG spacecraft owner-operators (i.e. DOD, IC, and NASA). Strong consideration must be given to facility and personnel security requirements based on the requirements of these interagency interfaces.

This particular Framework is also the quickest and most affordable way to implement the civil-based options. It also offers the most flexibility by providing options to increase the role of the civil organization over time (and possibly transition to the more prescriptive Framework options) as is deemed appropriate.

Implementation of this Framework would require legislative authorities to be granted and appropriate funding to be provided. A time of transition will be required to ensure that expected flows of products and services, currently provided by the DOD, are uninterrupted.

48 This implies that reviews related to orbital debris mitigation are most appropriately conducted by this civil agency. This may require the transfer and/or consolidation of these activities from the agencies that are currently responsible for such reviews (FCC, FAA, NOAA) to this civil agency. Because the FCC will continue to license radio-frequency use, this will result in the need for most commercial space activities to obtain two authorizations—one for radio frequency use and another for the other safety-focused aspects of its space operations.
There are short-term actions to assist in this transition that can also add to the safety and security of the space domain that should be considered:

1. The most prominent issue that became apparent during the assessments was the development and the nature of a space catalog for use in delivering fundamental Space Traffic Safety operational products and services. Both the number of and nature of catalogs is somewhat disputed. Some stakeholders expressed concern with the development of a separate civil catalog. This second catalog would be separate from the catalog currently developed and used by DOD. The main issue driving this concern is the potential for lack of consistency between multiple catalogs, especially in the case where Space Traffic Safety issues arise involving both DOD and non-USG spacecraft. Those stakeholders expressing this concern desired a benchmark catalog for interagency use. Some stakeholders noted that more than one catalog already exists (e.g., those provided by commercial SSA organizations). The second concern deals with the issue of data security, specifically the issue of publicly publishing SSA data associated with certain USG and allied government spacecraft. The security protocols and procedures used to process observations, including any potential for spacecraft characterization, are also of concern. These issues should be resolved among interagency partners before a technical and business architecture is baselined in any civil-based Framework.

2. The civil agency could benefit greatly by taking part in on-the-job training at the JSpOC to understand current processes and procedures used to provide Space Traffic Safety products and services. This embedded training should include development of short-term and long-term training plans. Short-term plans should deal with development of the understanding of required functions that would ultimately transition to the civil agency. Post-transition and long-term, embedded training will still be valuable; operations staff for the civil agency will always require an understanding of, first, DOD processes and procedures used for Space Traffic Safety of USG spacecraft and, second, the interfaces of Space Traffic Safety operations processes with DOD protection and defense operations processes.

3. Prototyping and evaluation of potential civil-based SSA systems will be valuable in understanding capabilities and limitations in the development, integration, and purchase of future operational systems. Scenario-based vignettes will also be important to evaluate system, operator, and process limitations. Such vignette exercises should be run only after required system functional performance and operator knowledge have been verified.

4. Facilitation of the stand-up of safety-focused, community of interest–centered working groups, consortia, and other similar bodies can begin immediately and would be constructive to the evolution of valuable, technically based, best practices, guidelines, and standards.
APPENDIX A  Assessment of Best Practices and Industry Standards

Overview
A review of both domestic and international regulations, industry standards, guidelines, and best practices finds that, with the exception of requirements for orbital debris mitigation and post-mission disposal plans, there are no widely embraced, enforced, or integrated regulations, best practices, or industry standards focused on Space Traffic Safety risk mitigation. The Federal Communications Commission (FCC) implements review of the orbital debris mitigation and post-mission disposal plans through their rules as part of their spectrum licensing process (see Appendix B for more details). There are best practices in the private domain, but they remain un-codified and, in all cases investigated, organizationally unique. Space Traffic Safety procedural standards and guidelines (instructions, procedural requirements, flight rules, etc.) are used with the USG for DOD, NASA, and the Intelligence Community: they too are organizationally unique. DOD and NASA do utilize a common operating instruction for ISS collision avoidance processes (see Appendix E). The U.S. Air Force’s (USAF) Joint Space Operations Center (JSpOC) has created a document that provides guidance in the satellite conjunction assessment and collision avoidance process (see Appendix D), as well as a whitepaper that discusses best practices for CubeSat operators (see Appendix F).

Orbital Debris Mitigation Guidelines and Practices
In 1997, the United States began developing guidelines to mitigate orbital debris when it drafted the U.S. Government Orbital Debris Mitigation Standard Practices (USGODMSP), which was presented to the U.S. space industry in 1998 and adopted in 2001. The standard practices encompass all spacecraft program phases, from concept development to space hardware disposal. The standard practices focus on four areas, “consistent with mission requirements and cost:”

- Control of debris released during normal operations.
- Minimization of debris generated by accidental explosions.
- Selection of safe flight profile and operational configuration.
- Post mission disposal of space structures.

The standard practices apply to all U.S. government Departments and Agencies involved in space operations, including regulatory authorities. The standard practices serve as the U.S. government’s foundation for issuing specific orbital debris mitigation requirements and technical guidance.

The USGODMSP served as one of the primary sources for the development of the Inter-Agency Space Debris Coordination Committee (IADC) Space Debris Mitigation Guidelines and the later UN COPUOS Space Debris Mitigation Guidelines. The IADC Space Debris Mitigation Guidelines are space agency consensus set of guidelines that are designed to mitigate the growth of the orbital debris population. The

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49 Although “standard” is included in the name, these are not, strictly speaking, standards, but are more appropriately, “best practices”.
guidelines have three fundamental principles; preventing on-orbit break-ups, removing spacecraft and orbital stages that have reached the end of their mission operations from the useful densely populated orbit regions, and limiting the objects released during normal operations. There are 13 space agency organizations part of IADC, of which NASA is a leading member.\(^{52}\)

For U.S. private spacecraft, the FCC has implemented the USGODMSP and IADC post-mission disposal guidelines through their own rule making applied in the process for all spacecraft requiring FCC licensing. For instance, the FCC rules specify,

“... a satellite system operator requesting FCC space station authorization, or an entity requesting a Commission ruling for access to a non-U.S.-licensed space station under the FCC’s satellite market access procedures, must submit an orbital debris mitigation plan to the Commission regarding spacecraft design and operation in connection with its request.”\(^{53}\)

A specific orbital debris mitigation guideline, the 25-year guideline,\(^{54}\) deserves some attention. USGODMSP, IADC, and FCC rules establish a desired practice on the disposal of LEO satellites at end of life (EOL). This practice states that disposal at EOL should take place either through immediate atmospheric re-entry or through the placement of a spacecraft into an orbit from which it will re-enter the Earth’s atmosphere within 25 years. First appearing in the USGODMSP nearly two decades ago, the effectiveness of this guideline on reducing risk of orbital collisions is questionable, especially given current and projected LEO space object populations. A variety of studies show statistically significant improvements in reducing collision risk as the re-entry time is reduced from 25 years.\(^{55}\) In any Space Traffic Safety Governance Framework, this guideline should receive serious consideration for review and possible modification as a measure to further improve Space Traffic Safety.

**International Organization for Standardization**

The International Organization for Standardization (ISO) develops and issues consensus voluntary international standards for spaceflight. Within ISO, there are two sub-committees, SC13 and SC14, that deal specifically with space issues.\(^{56}\) SC13 members are Brazil, China, France, Germany, India, Italy, Israel, Japan, Kazakhstan, Russia, Ukraine, U.K. and the U.S. SC14 members are the same, less Kazakhstan. ISO space standards number in the hundreds. Those of note related specifically to Space Traffic Safety include ISO TR 16158, Best Practices for Avoiding Collisions among Spacecraft, which describes operational processes for estimating collision probabilities and developing evasive maneuvers. The best practices created information requirements for warning operators and enabling cooperative avoidance, which is the basis for Consultative Committee for Space Data Systems (CCSDS) Conjunction Data Messages (CDM’s) that were implemented by governments and commercial operators everywhere. This includes the format

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\(^{52}\) Inter-Agency Space Debris Coordination Committee, iadc-online.org. Last Accessed September 28, 2016.


\(^{54}\) Sometimes referred to as the “25 year rule. But, this truly is not a “rule” in that compliance is not monitored nor enforced.


used by the DOD to provide conjunction warnings to private operators. In 2011, ISO released ISO 24113, Space Systems: Space Debris Mitigation Requirements, which defines the primary space debris mitigation requirements applicable to all elements of unmanned systems launched into, or passing through, near-earth space, including launch vehicle orbital stages, operating spacecraft and any objects released as part of normal operations or disposal actions. The requirements are designed to reduce the growth of space debris and ensuring that spacecraft and launch vehicles are designed, operated, and disposed of in a way to prevent them from generating more orbital debris in their lifetime. The ISO Standard duplicates practices employed by the space agencies that belong to IADC; hence, most space agencies do not employ it specifically.

**NASA**

NASA created the NASA Procedural Requirements (NPR) for Limiting Orbital Debris (NPR 8715.6), which is a culmination of orbital debris mitigation policy at NASA. NPR 8715.6 establishes the organizations and personnel responsible for orbital debris mitigation within NASA, specific program and project responsibilities from development through end-of-operations, and the report structure necessary to document compliance with the NPR. The NPR is applicable to all objects launched into space in which NASA has lead involvement and control or partial involvement with control over design or operations via U.S. internal or international partnership agreements, including the launch vehicle. Companion and lengthier NASA Standard (NASA-STD) 8719.14, Process for Limiting Orbital Debris, and NASA-Handbook (NHBK) 8719.14, Handbook for Limiting Orbital Debris, provide details on engineering processes to limit orbital debris.

NASA also created the Debris Assessment Software to assist NASA programs in performing orbital debris assessments (for instance, many private organizations will utilize the software to compile their orbital debris mitigation plans required for submittal to the FCC). The software allows users to follow the structure of standards and it provides the user with tools to ensure that they are compliant with the orbital debris mitigation guidelines. If they are not compliant with the guidelines, the software will assess the debris mitigation options to bring a program within requirements.

For ISS operations, flight rules provide specific operations practices to limit risk of collision. These rules establish criteria, based on probability of collision, when a Debris Avoidance Maneuver (DAM) should be considered and conducted. These probabilities of collision thresholds range from 1 in 100,000 to 1 in 100. Along with the probability of collision data, various real-time mission-specific constraints are provided that must be considered prior to DAM execution (e.g. if a visiting vehicle is approaching the ISS). The flight rules also acknowledge that the uncertainties in the ISS and potentially hazardous space object decrease as time of conjunction approaches. Thus, DAM execution should not be based on the first notification of

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59 NASA Procedural Requirements for Limiting Orbital Debris, NPR 8715.6, 5.
a threshold probability being crossed. Rather, DAM decisions “should be made as late as practical prior to the predicted time of closest approach.”

**Department of Defense**

The Department of Defense issued Directive 3100.10 in October 2012, which promotes the responsible, peaceful, and safe use of space by following the USGODMSP to create a sustainable and stable space environment that is vital to U.S. national interest. The Department of Defense also created Instruction 3100.12 in September 2000 that aims to minimize the creation of space debris. The instructions recommend satellite operators consider following debris mitigation practices including, removing debris within 25 years, minimizing debris by accidental explosions, and limiting the probability of collision during launch and the orbital lifetime of the spacecraft.

Air Force Instruction 91-217 implements Air Force Policy Directive (AFPD) 13-6, Space Policy, AFPD 91-2, Safety Programs and “provides guidance to develop comprehensive Space Safety and Mishap Prevention Programs for existing and future space systems.” Chapter 5 of the document is dedicated to “Orbital Safety.” Specific items of interest include the following:

- Requires Air Force organizations controlling spacecraft to establish an “Orbital Safety Program.”
- Requires all spacecraft to implement a conjunction assessment and collision avoidance process using the 18th Space Control Squadron’s support.

**New Missions for Consideration**

Robotic satellite servicing initiatives have begun at NASA, DARPA, and in the private space industry. The controlled process of closing distance from one spacecraft to another, known as rendezvous, and subsequent proximity operations create a unique class of hazards to be considered. Beginning with the Gemini crewed spacecraft, the USG has a great deal of experience in establishing mission specific safety practices for rendezvous and proximity operations (RPO). Such safety practices can be used to inform the development of private best practices, but care must be taken to ensure that the mission capabilities and contexts of new satellite servicing programs be accounted for to avoid misinformed establishment of safety standards. With this in mind, DARPA has created The Consortium of Execution of Rendezvous and Servicing Operations (CONFERS) program. CONFERS has three initial goals that can be applied to nascent robotic satellite servicing industry. CONFERS aims at developing non-binding industry consensus and standards for safe operational rendezvous and proximity and servicing techniques, serves as a forum to discuss related policy issues and simplifying U.S. government collaboration with industry, and develops means to share data and experience between participants while protecting participants’ financial and/or strategic advantages. This “bottom-up” approach to the development of technically informed best practices, guidelines, and standards offers a good model that balances the safety and economic objectives necessary in any future Space Traffic Safety Governance Framework.

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62 Air Force Instruction 91-217, Space Safety and Prevention Program, 11 April 2014. An updated version is currently being reviewed.
Private Best Practices, Guidelines, and Standards

With the exception of orbital debris guidelines, no specific, all encompassing, and/or codified private best practices, guidelines, and standards were found to exist for orbital operations. Each organization creates and establishes Space Traffic Safety related best practices based on the context of their own specific risk and risk mitigation capabilities. This is a function of spacecraft orbit location, capability, and value. U.S. owner-operators interviewed display a keen awareness of safety issues, and do work together more frequently (e.g. the Space Data Association) in order to be more effective and efficient through coordination.

To date, The Commercial Spaceflight Federation (CSF) has published a few standards regarding human rated suborbital launch vehicles. CSF has recently partnered with ASTM; ASTM has developed a committee on commercial spaceflight in an attempt to streamline the process of standards development and approval. The committee was established in October 2016 and it will soon start the road-mapping process to determine the voluntary consensus standards to be developed. Areas to address in standards include, but are not limited to, design, manufacturing and operational use of vehicles used for spaceflight. One purpose of the committee is to create human spaceflight safety standards.64

Observations and Conclusions

With the exception of guidelines for orbital debris mitigation and associated post-mission disposal plans, there are no regulations, best practices, or standards focused on Space Traffic Safety risk mitigation that are widely embraced, enforced, or integrated across the domestic space enterprise. This condition does not present any significant immediate risk to Space Traffic Safety, but on the other hand, a more coordinated approach to development of safety related practices would be beneficial. Such an approach must account for the unique contexts driving Space Traffic Safety related risks (i.e. orbit location, spacecraft value, etc.) and the capabilities and costs of spacecraft owner-operators to mitigate those risks (i.e. propulsive maneuverability). Several organizations and nations have developed safety practices independently. Some, such as France, which has established its own practices in law, are unlikely to change based on any external consensus. It is very important that any new safety-related best practices, standards, and/or regulations are informed of these matters.

64 Personal communications with Jane Kinney, Assistant Director, CSF, November 7, 2016
APPENDIX B  Assessment of Current Statutory Authorities and Regulations

The Federal Communications Commission (FCC), the Department of Transportation (DOT), and the Department of Commerce (DOC) all have statutory authorities and regulations that apply to Space Traffic Safety Governance.

Federal Communications Commission

The FCC has statutory authority that applies to Space Traffic Safety Governance under the Communications Act of 1934 (47 USC. 151 et seq.) and regulations under 47, CFR Parts 5, 25, and 97. No person shall use or operate apparatus for the transmission of energy or communications or signals by space or Earth stations except under, and in accordance with, an appropriate authorization granted by the FCC. The FCC authorities and regulations also require applicants to submit an orbit description along with the design and operational strategies to mitigate orbital debris.

In the Second Report and Order, the FCC amended parts 5, 25, and 97 of the Commission’s rules to adopt new rules concerning orbital debris mitigation.

Adoption of these rules will help preserve the United States’ continued affordable access to space, the continued provision of reliable U.S. space-based services – including communications and remote sensing satellite services for U.S. commercial, government, and homeland security purposes – as well as the continued safety of persons and property in space and on the surface of the Earth. Under the rules as amended today, a satellite system operator requesting FCC space station authorization, or an entity requesting a Commission ruling for access to a non-U.S.-licensed space station under our satellite market access procedures, must submit an orbital debris mitigation plan to the Commission regarding spacecraft design and operation in connection with its request. This Second Report and Order provides guidance for the preparation of such plans. We also adopt requirements concerning the post-mission disposal of Commission-licensed space stations operating in or near the two most heavily used orbital regimes, low-Earth orbit (LEO), and geostationary-Earth orbit (GEO). Adoption of these rules will further the domestic policy objective of the United States to minimize the creation of orbital debris and is consistent with international policies and initiatives to achieve this goal.

The FCC reviewed and concluded that it is within the FCC’s authority and public interest obligations under the Communications Act to address orbital debris issues. The FCC found:

Orbital debris mitigation issues are a valid public interest consideration in the Commission’s licensing process and that the Communications Act provides the Commission with broad authority with respect to radio communications involving the United States. The Communications Act charges the FCC with encouraging “the larger and more effective use of radio in the public interest,” and provides for licensing of radio communications, upon a finding that the “public convenience, interest, or necessity
will be served thereby.” Satellite communications are an important component of the national and world-wide radio communications infrastructure. Because orbital debris could affect the cost, reliability, continuity, and safety of satellite operations, orbital debris issues have a bearing upon the “larger and more effective use of radio in the public interest.” In addition, orbital debris can negatively affect the availability, integrity, and capability of new satellite systems and valuable services to the public. Thus, orbital debris and related mitigation issues are relevant in determining whether the public interest would be served by authorization of any particular satellite system, or by any particular practice or operating procedure of satellite systems. Furthermore, debris prospectively generated from satellites licensed by, or authorized by, the FCC could affect the public interest in protecting the safety of manned space flight, as well as the safety of persons and property on the surface of the Earth. Because robotic spacecraft are typically controlled through radio communications links, there is a direct connection between the radio communications functions we are charged with licensing under the Communications Act and the physical operations of spacecraft.

Compliance with FCC regulations is mandatory and the licensing provisions apply to operations of Earth stations in the United States and mobile stations (including space stations) under the jurisdiction of the United States, except for U.S. Federal Government stations.

Department of Transportation

The DOT has statutory authority that applies to Space Traffic Safety Governance under 51 USC 509.

The Secretary of Transportation oversees and coordinates the conduct of commercial launch and reentry operations, issue permits and commercial licenses and transfer commercial licenses authorizing those operations, and protect the public health and safety, safety of property, and national security and foreign policy interests of the United States.

The regulations under 14 CFR Chapter 3, set forth the procedures and requirements applicable to the authorization and supervision under 51 USC subtitle 5 chapter 509 of commercial space transportation activities conducted in the United States or by a U.S. citizen. The procedures and requirements also ensure that the FAA consults with other agencies to determine whether launch of a proposed payload or payload class would present any issues affecting public health and safety, safety of property, U.S. national security

69 First Report and Order, 18 FCC Rcd at 10764 (para. 2)(observing that the satellite industry is a “crucial component of the global communications marketplace”).
70 Courts have held that the Commission may consider public safety factors as part of its licensing procedures. See Simmons v. FCC, 145 F.2d 578, 579 (D.C. Cir. 1944)(finding that the “public interest, convenience and necessity clearly require the Commission to deny applications for construction which would menace air navigation”); Deep South Broadcasting Co. v. FCC, 278 F.2d 264, 267 (D.C. Cir. 1960)(confirming FCC authority to consider structural aspects of a radio tower as a “clearly relevant public interest consideration”). For a discussion of the FCC’s legal authority concerning orbital debris, see also MEO/LEO Constellations: U.S. Laws, Policies, and Regulations on Orbital Debris Mitigation, American Institute of Aeronautics and Astronautics Special Project No. SP-016-2-1999 (1999).
or foreign policy interests, or international obligations of the United States. To determine if the purposed payload presents any issues affecting U.S. national security or foreign policy interests, or international obligations of the United States, the FAA shall:

- Consult with the DOD to determine whether launch of a proposed payload or payload class would present any issues affecting U.S. national security.
- Consult with the Department of State to determine whether launch of a proposed payload or payload class would present any issues affecting U.S. foreign policy interests or international obligations.
- Consult with other federal agencies, including NASA, authorized to address issues identified under the interagency consultation paragraph associated with an applicant's launch proposal.

In terms of orbital debris mitigation regulations, the FAA focuses on safety at the end of launch, which is defined as the last exercise of control over the launch vehicle. To obtain safety approval for any proposed launch of a launch vehicle with a stage or component that will reach Earth orbit, an applicant must ensure:

- There is no unplanned physical contact between the vehicle or any of its components and the payload after payload separation;
- Debris generation does not result from the conversion of energy sources into energy that fragments the vehicle or its components. Energy sources include chemical, pressure, and kinetic energy; and
- Stored energy is removed by depleting residual fuel and leaving all fuel line valves open, venting any pressurized system, leaving all batteries in a permanent discharge state, and removing any remaining source of stored energy.

For any reusable launch vehicle the mission operational requirements and restrictions include “no unplanned physical contact between the vehicle or its components and payload after payload separation and debris generation will not result from conversion of energy sources into energy that fragments the vehicle or its payload. Energy sources include, but are not limited to, chemical, pneumatic, and kinetic energy.”

**Department of Commerce**

The DOC has statutory authority that applies to Space Traffic Safety Governance under 51 USC Chapter 601. This statute explains the requirements that a remote sensing operator must dispose of any satellite upon termination in space in a manner satisfactory to the President and that they must furnish the Secretary of Commerce with the complete orbit information of the spacecraft.

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79 51 U.S.C. §431.43(c)(3).  
NOAA issues regulations establishing the agency’s requirements for the licensing, monitoring and compliance of operators of private Earth remote sensing space systems under the National and Commercial Space Programs Act (NCSPA), 51 USC Chapter 60101, et seq. The NCSPA states that no person who is subject to the jurisdiction or control of the U.S. may operate any private remote sensing space system without a license, and authorizes the Secretary of Commerce to license private sector parties to operate private remote sensing space systems. By law, the Secretary of Commerce can grant a license only upon determining, in writing that the applicant (licensee) will comply with the requirements of the NCSPA, any regulations issued pursuant to the NCSPA and any applicable international obligations and national security concerns of the United States. Under 15 CFR Part 960 in accordance with the NCSPA, a “licensee shall assess and minimize the amount of orbital debris released during the post-mission disposal of its satellite. Applicants are required to provide at the time of application a plan for post-mission disposition of remote sensing satellites.”

APPENDIX C  Treaties and Other (legally-binding) International Agreements

Treaties and other (legally-binding) International Agreements

Space Traffic Management Requirements

Simply stated there are no explicit or implicit national or international–level requirements for space traffic management (STM) under treaties and other legally-binding international agreements, to which the United States is a party. As such, U.S. compliance with such non-existent requirements is obviously not germane. However, three major, applicable treaties that make up the specialized body of relevant space law: the Outer Space treaty (1967), the Liability Convention (1972), and the Registration Convention (1975), may be interpreted to allow for space traffic management, within strict limits and depending on if the STM regime is intended for strictly domestic, national-level regulation of space activities, or intended to affect other states’ space activities without their consent.

First, national-level STM is allowed for in the treaties noted above. Indeed, advocates of STM may reason that the three applicable treaties bolster arguments for national-level STM. For example, the Outer Space Treaty says that states “shall bear international responsibility” for national space activities whether carried out by governmental or non-governmental entities (Article VI). Likewise, states shall be internationally liable for damage caused by their space objects to another State Party to the Outer Space Treaty (Article VII); and shall avoid harmful contamination of space and celestial bodies (Article IX). In addition, the Liability Convention establishes that states are responsible for space objects launched from their territory or launched by their nationals.

Furthermore, while there is no requirement for STM in the Registration Convention, any national-level STM regime would likely facilitate compliance with the Registration Convention. The Registration Convention states: “when a space object is launched into Earth orbit or beyond, the launching State shall register the space object by means of an entry in an appropriate registry which it shall maintain.” The minimum required contents of the registry entry are very general but the Convention also notes that states may, if so desired, provide additional information about a satellite to the UN Secretary General.

The U.S. State Department is responsible for registering satellites under the Registration Convention with the UN Office of Outer Space Affairs, which maintains the United Nations Register of Objects Launched into Outer Space. However, since the State Department does not oversee launch of satellites, it depends on receiving information from the DOD, NASA, NRO and the FCC. Although the Registration Convention does not provide a specific timeline for when objects must be registered, the United States is typically slow in satellite registration due to the sluggishness of its interagency process.

What the three applicable treaties allow for regarding a future STM regime that affects other states’ space activities, i.e. international-level STM, is less clear. For example, Article IX of the Outer Space Treaty states that parties to the treaty shall be guided by the principle of cooperation and mutual assistance and shall conduct their activities in outer space with due regard to the corresponding interests of all parties to the

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82 In this analysis, the term “Space Traffic Management” is used as provided in the original, primarily because this is the terminology used in international dialogue that is discussed in this assessment. This should not be confused with the later Framework Alternatives section which redefines Space Traffic Management writ large as “Space Traffic Safety Governance,” and labels just one of five specific framework alternatives as “Space Traffic Management.”

83 This assessment is conscious of the debates regarding how the international nature of the space domain, and international commercial competition, may make national-level STM impractical. However, that debate is outside the scope of this review.

84 The Registration Convention call for registration information to be provided “as soon as practicable.”
treaty. Moreover, the Registration Convention, which is seen by many space policy and legal analysts as a foundation stone for any future international space traffic management regime, states in Article II: “Each State of registry may, from time to time, provide the Secretary-General of the United Nations with additional information concerning a space object carried on its registry.” The Registration Convention further makes no differentiation between civil and military/intelligence satellites; indeed major space powers routinely register their military/intelligence satellites (if only by an alphanumeric designator, and if only at insertion orbit).

On the other hand, the Outer Space Treaty freedom of use and freedom of access clauses (Article I and Article II respectively) make clear that with regard to a potential international space traffic management regime, the creation of the equivalent to national airspace in outer space (e.g. national space lanes) would not be permitted without the consent of the affected state(s). As noted later in the discussion, if the affected states agree, the Outer Space Treaty would permit an international regime. Article I states, “Outer space, including the moon and other celestial bodies, shall be free for exploration and use by all States without discrimination of any kind, on a basis of equality and in accordance with international law, and there shall be free access to all areas of celestial bodies.” Article II states, “Outer space, including the moon and other celestial bodies, is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means.” It appears a new legally-binding international agreement would probably be required to enable one state, or international entity, to regulate or “manage” another state’s space activities. The Liability Convention may also need to be amended since liability for some incidents may reasonably need to reside with the new international entity performing space traffic management, more so than with the launching state. In fact, amending the provisions of the Liability Convention may need to be a first step, in order to enable creation of an international STM regime. Otherwise, it may be difficult to get states to cede freedom of action in space, and spacecraft control decisions, to a new international-level space traffic entity.

The International Telecommunication Union (ITU) is also relevant. A government must complete ITU coordination and notification procedures in order to obtain international recognition for the use of orbits and frequencies by space stations, including those used for geostationary satellites. Although the United States and other ITU Member States “retain their entire freedom” with respect to military satellite networks under Article 48 of the ITU Constitution, they are required to follow ITU Radio Regulations “so far as possible.” Most nations register their military satellites in order to obtain international recognition for satellite networks. The ITU does not have enforcement capabilities although dispute resolution processes exist. Any future international-level STM regime would need to take into account the ITU’s role in managing use of orbital/radio frequency resources.

In sum, there are no explicit or implicit national or international–level requirements for STM under treaties and other international agreements to which the United States is a party. However, while the current body of international space law could accommodate a national-level STM regime (setting aside the technical difficulties of such a framework), any STM regime that affects other states’ space activities would require other countries’ consent.

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85 The ITU, a specialized UN agency, establishes regulations for the international coordination of frequencies used by space stations. This report does not consider space radio-communications/spectrum management within its definition of STM and will not address such issues as part of this assessment.
**Orbital Debris**

The Space Debris Mitigation Guidelines of the UN Committee on the Peaceful Uses of Outer Space (COPUOS) defines debris as “all man-made objects, including fragments and elements thereof, in Earth orbit or re-entering the atmosphere, that are non-functional.” It goes on to state, “As the population of debris continues to grow, the probability of collisions that could lead to potential damage will consequently increase. In addition, there is also the risk of damage on the ground, if debris survives Earth’s atmospheric re-entry. The prompt implementation of appropriate debris mitigation measures is therefore considered a prudent and necessary step towards preserving the outer space environment for future generations.”

Nevertheless, other than the 1972 Liability Convention, which mandates that states are responsible for space objects launched from their territory, there are no additional explicit requirements regarding orbital debris under treaties and other binding international agreements to which the United States is a party. That said, customary international law might someday impose some obligations on states to avoid allowing their territory to be used in ways that impose significant pollution (in the form of debris) upon the global commons.

The Liability Convention establishes that parties are “absolutely” liable to pay compensation for damage by national (government or private sector) space objects on Earth or to aircraft in flight, and “fault-based” liability regarding damage to other space objects. It also establishes a process for claims and settlement. The Liability Convention holds the party responsible if compliance with those states’ domestic regulations caused harm to other states’ space objects, although the Liability Convention holds states responsible only “for fault” for damage to other states’ space objects. These responsibilities are applicable to orbital debris.

While not an explicit requirement, an implicit requirement regarding orbital debris may be derived from the Outer Space Treaty, Article IX which mandates that states act with “due regard” for the interests of other states, “avoid harmful contamination,” and undertake international consultations if an activity in space would cause “potentially harmful interference” with the space activities of other states. However, the applicability of Article IX to the orbital debris problem is subject to interpretation and there has been no state practice of invoking the consultation obligation of Article IX in a situation involving space debris.

**Non-Binding International Arrangements**

**Evolving Non-Binding Space Traffic Management and Orbital Debris Requirements**

As outlined above, there is a dearth of STM and orbital debris requirements based upon legally binding treaties or international agreements. This vacuum is driving the creation of non-binding international arrangements in order to develop pragmatic solutions to address these growing concerns. It is important to note, however, non-legally-binding agreements can sometimes evolve into binding law either in the form of a treaty or in the form of Customary International Law.

Assessing the growing body of nonbinding international arrangements concerning STM and orbital debris shows that there is momentum behind a growing number of relevant, voluntary, non-legally binding, guidelines, measures, and internationally acknowledged “best practices,” with which the United States attempts to comply or is considering.

Many of these initiatives are framed as promoting the long-term sustainability, safety, security and/or reliability of the space environment and therefore address the issues of orbital debris and space traffic management as part of the same problem. Therefore, much of the following review also takes a similar all-inclusive approach in its examination of non-binding STM and orbital debris requirements.
Committee on the Peaceful Uses of Outer Space (COPUOS) – Working Group on Long-Term Sustainability of Outer Space, 2010-2018

COPUOS was established in 1959 by the UN General Assembly (UNGA) to promote the peaceful uses of space, research on space, information sharing, and international cooperation to utilize space to benefit humankind, and to establish legal parameters around the peaceful use of outer space. It is the primary multilateral organization empowered to negotiate international space law. There are currently 83 Member States, and a large number of observers from nongovernmental and intergovernmental organizations. The work of COPUOS is broken into two subcommittees: the Legal Subcommittee and the Scientific and Technical Subcommittee, which meet annually and report to the annual June meeting of the full committee. Decisions are taken by member state voting, although the usual UN practice of consensus is always sought. COPUOS decisions are then sent to the UN General Assembly (via the Fourth Committee) for adoption.

While the COPUOS Legal Subcommittee has been stymied for many years, the Scientific and Technical Subcommittee has made slow progress in addressing technical challenges to the space environment. In 2007, COPUOS adopted a set of voluntary guidelines for mitigating creation of new space debris mitigation, subsequently adopted by the General Assembly in January 2008. The guidelines adopted were based on the technical work of the Interagency Debris Coordinating Committee and represent voluntary best practices for space activities in limiting the creation of dangerous space debris. Perhaps the most significant is Article 4, which pledges nations to avoiding the deliberate creation of long-lived debris. (For details see section devoted to space debris mitigation below).

In 2010, COPUOS launched a new working group under the Scientific and Technical Subcommittee on “Long-Term Sustainability of Outer Space Activities” (LTS) focused on crafting best practices for maintaining a safe, secure and sustainable space environment. The stated end-goal was a set of voluntary best-practice guidelines for activities in space, including launch, on-orbit operations, and satellite disposal. The General Assembly under Resolution A/AC.105/C.1/L.307/Rev.1 of February 2011 detailed the group’s objectives and organization into four expert groups: A. Sustainable Space Utilization and Supporting Sustainable Development on Earth; B. SSA; C. Space Weather; and D. Regulatory Regimes and Guidance for Actors in the Space Arena. Issues being addressed include: collection, sharing and dissemination of data on functional and non-functional space objects; re-entry notifications; and pre-launch and maneuver notifications. The work began in February 2012.

In February 2014, the expert groups recommended a total of 31 guidelines to the Scientific and Technical Subcommittee, and in February 2015 a draft working group report was submitted by the chair based on these findings, which also included issues for possible future consideration.

The working group was able at a June 2016 meeting in the margins of the annual COPUOS meeting to agree, in a draft report approved by COPUOS, to a set of 12 recommended guidelines, and to extend the LTS working group mandate to 2018 in hopes of reaching agreement on another 16 guidelines.

The COPUOS-approved draft guidelines will need to be submitted for approval to the UNGA Fourth Committee, as the compromise agreement reached in June was predicated on the fact that until negotiations about the other proposals was complete, no formal approval process would be completed. Once the full set of guidelines is approved by the Fourth Committee, the package will go before the full UN General Assembly, at which time, if approved, they will become not legal but political commitments by governments. The current mandate of the LTS Working Group runs through June 2018, by which time negotiations on new guidelines would need to conclude. The LTS guidelines should be considered in the development of a future space traffic management regime. Relevant sections of the 12 agreed upon guidelines are specified below.
A. Policy and Regulatory Framework for Space Activities.

Guidelines 1, 2, 3 and 4 provide guidance on the development of policies, regulatory frameworks and practices that support the long-term sustainability of outer space activities for Governments and relevant international intergovernmental organizations authorizing or conducting space activities. These include:

Guideline 1. Adopt, revise and amend, as necessary, national regulatory frameworks for outer space activities.

Guideline 2. Consider a number of elements when developing, revising or amending, as necessary, national regulatory frameworks for outer space activities.

(b) Implement space debris mitigation measures, such as the Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space, through applicable mechanisms;

(f) Consider the potential benefits of using existing international technical standards, including those published by the International Organization for Standardization (ISO), the Consultative Committee for Space Data Systems and national standardization bodies. In addition, States should consider the utilization of recommended practices and voluntary guidelines proposed by the Inter-Agency Space Debris Coordination Committee and the Committee on Space Research;

Guideline 3. Supervise national space activities.

3.1 In supervising space activities of non-governmental entities, States should ensure that entities under their jurisdiction and/or control that conduct outer space activities have the appropriate structures and procedures for planning and conducting space activities in a manner that supports the objective of enhancing the long-term sustainability of outer space activities, and that they have the means to comply with relevant national and international regulatory frameworks, requirements, policies and processes in this regard.

3.2 States bear international responsibility for national activities in outer space and for the authorization and continuing supervision of such activities, which are to be carried out in conformity with applicable international law. In fulfilling this responsibility, States should encourage each entity conducting space activities to:

(a) Establish and maintain all the necessary technical competencies required to conduct the outer space activities in a safe and responsible manner and to enable the entity to comply with the relevant governmental and intergovernmental regulatory frameworks, requirements, policies and processes;

(b) Develop specific requirements and procedures to address the safety and reliability of outer space activities under the entity’s control, during all phases of a mission life cycle;

(c) Assess all risks to the long-term sustainability of outer space activities associated with the space activities conducted by the entity, in all phases of the mission life cycle, and take steps to mitigate such risks to the extent feasible.

Guideline 4. Ensure the equitable, rational and efficient use of the radio frequency spectrum and the various orbital regions used by satellites.

4.3 Consistent with the purpose of article 45 of the ITU Constitution, States and international intergovernmental organizations should ensure that their space activities are conducted in such a manner as not to cause harmful interference with the reception and transmission of radio signals related to the space activities of other States and international intergovernmental organizations, as one of the means of promoting the long-term sustainability of outer space activities.
B. Safety of space operations.

Guidelines 12, 13, 16 and 17 provide guidance to Governments and relevant international intergovernmental organizations on the conduct of space operations in a manner that supports the long-term sustainability of outer space activities.

Guideline 12. Improve accuracy of orbital data on space objects and enhance the practice and utility of sharing orbital information on space objects.

Guideline 13. Promote the collection, sharing and dissemination of space debris monitoring information.

Guidelines 16 and 17 focus on space weather information sharing, models, and tools.

C. International cooperation, capacity-building and awareness.

Guidelines 25 and 26 provide guidance on international cooperation measures aimed at promoting the long-term sustainability of outer space activities for Governments and relevant international intergovernmental organizations authorizing or conducting space activities. The focus is on promoting and supporting capacity building, and raising awareness.

D. Scientific and technical research and development.

“Guidelines 27 and 28 provide guidance of a scientific and technical nature for Governments, international intergovernmental organizations, and national and international non-governmental entities that conduct space activities. They encompass, among other things, the collection, archiving, sharing and dissemination of information on space objects and space weather, and the use of standards for information exchange. These guidelines also address research into, and the development of, ways to support the sustainable use and exploration of outer space.

Guideline 28. Investigate and consider new measures to manage the space debris population in the long term.

COPUOS Legal Subcommittee: New Agenda Item on Space Traffic Management (STM)

At its April 2015 meeting, the COPUOS Legal Subcommittee agreed to two new agenda items with relevance to STM:

- “General exchange of views on the legal aspects of space traffic management.”
- “General exchange of views on the application of international law to small satellite activities.”

Germany instigated the discussion of STM and suggested that the discussions “reflect on the concept of STM, on what it entails and on what consequences it would have for the organization and governance of space activities. In particular, the contribution of STM to the safety of space operations benefitting all users of outer space (whether they are established users or recent and future users) could be investigated. The item would also provide the opportunity to discuss the status of academic research in that field and to possibly invite presentations of the technical and well as legal background of this issue.”

The German proposal followed discussion in the margins of an April 2015 informal seminar on STM. While the Legal Subcommittee has not defined STM or its scope, a 2006 study conducted by the International Academy of Astronautics “Cosmic Study on Space Traffic Management,” defined it as follows: “Space traffic management means the set of technical and regulatory provisions for promoting safe access to outer space, operations in outer space and return from outer space to Earth free from physical or radio-frequency interference.” The IAA intends to publish a follow-on study in 2016 that has not yet been released.
The Legal Subcommittee originally agreed to a year-long mandate for the discussion, but at the April 2016 meeting agreed to continue discussions. The report of that meeting (A/AC.105/1113), details the discussions and the general views expressed. On the issue of STM, the report states:

The Subcommittee noted that consideration of the concept of STM was of growing importance for all nations. The space environment was becoming increasingly congested and complex owing to the growing number of objects in outer space, the diversification of actors and the increase in space activities, all of which made it more difficult to ensure safe and sustainable space operations, and STM required a multilateral approach.

The Subcommittee noted that a number of measures being undertaken at both the national and international levels were essential to improving the safety and sustainability of space flight, such as the exchange of information and services related to space situational awareness, which were critical to avoiding collisions in outer space. The Subcommittee agreed that a continued exchange of information on best practices and standards associated with the management of space operations was essential.

On the issue of small satellites, the report states:

The Subcommittee noted with regard to small satellite activities a number of legal challenges, as well as existing and emerging practices and regulatory frameworks. The Subcommittee also noted the programs of States and international organizations in the field of the development and use of small satellites.

The Subcommittee agreed that in order to ensure the safe and responsible use of outer space in the future, it was important to include small satellite missions appropriately in the scope of application of international and national regulatory frameworks.

It should be noted that the Legal Subcommittee was the original venue for negotiations on all current international treaties related to outer space, according to its mandate. While the current discussions of STM within the subcommittee are at an initial stage, the development of any national STM regime should take into account these deliberations – which at some future point could acquire legal standing. Indeed, the U.S. would play a major role in the development of any STM discussions in the Legal Subcommittee. So it’s quite plausible that evolving U.S. attitudes about, and actions toward, a national STM system would feed into, and perhaps be reflected in, any international standards the Legal Subcommittee might develop.

**UN Group of Governmental Experts on Transparency and Confidence-Building in Outer Space Activities. 2011-2013**

In 2011, the UNGA First Committee (responsible for international security affairs) called upon the Secretary-General to establish a Group of Governmental Experts (GGE) on transparency and confidence-building measures (TCBMs) in space. GGEs are established by the Secretary-General to develop recommendations on issues that are not yet ripe for formal negotiations or UN decision-making, and usually include 15 members chosen by the Secretary-General based on equitable geographic distribution, with the exception that the P5 (permanent members of the Security Council) always have seats. The 15-member GGE on space TCBMs began work in 2012 and issued a report in July 2013, which was adopted by the General Assembly at its 68th Session. The GGEs remit was to develop recommendations to create mutual understanding and build trust among nations in order to reduce risks to space security. By way of explanation, TCBMs are an established tool of multilateral statecraft, designed to reduce risks of conflicts and often seen as a prelude to the negotiation of arms control treaties.
The GGE on TCBMs in space was chaired by Russia, and members were: Brazil, Chile, China, France, Italy, Kazakhstan, Nigeria, Republic of Korea, Romania, Russian Federation, South Africa, Sri Lanka, Ukraine, United Kingdom of Great Britain and Northern Ireland, and the United States. The work focused on TCBMs that “could be adopted voluntarily by states on a unilateral, bilateral, regional or multilateral basis.” The report’s recommendations were divided into five broad categories of activities: Enhancing the transparency of outer space activities; international cooperation; consultative measures; outreach; and coordination.

Recommended transparency measures included information exchanges on orbital parameters of satellites and conjunction potentials, and highlighted the need for improved compliance with current agreements including the Registration Convention. The report also recommended further notifications, including: planned launches; scheduled maneuvers that might result in risk to other space objects; uncontrolled “high risk” re-entries; emergency situations; and orbital break-ups.

The recommendations of the GGE report are voluntary, and so far, no country has moved to formally implement those recommendations. Nonetheless, the recommendations do have political significance, and would require consideration.

The above non-binding United Nations-based initiatives are still works in progress, so it is not yet possible to assess U.S. government compliance. Since the “UN Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space,” have been finalized for a number of years, it is possible to examine the manner and extent to which the U.S. government complies with those requirements.

**UN Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space**

The Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space reflect the existing practices as developed by a number of national and international organizations. They are not legally binding under international law. The Guidelines state: “Member States and international organizations should voluntarily take measures, through national mechanisms or through their own applicable mechanisms, to ensure that these guidelines are implemented, to the greatest extent feasible, through space debris mitigation practices and procedures.” Therefore, an assessment of how these guidelines are implemented through current U.S. national mechanism is discussed under Task 2.1.

These guidelines are applicable to mission planning and the operation of newly designed spacecraft and orbital stages and, if possible, to existing ones. There are seven guidelines:

1) Limit debris released during nominal operations.
2) Minimize the potential for break-ups during operational phases.
3) Limit the probability of accidental collision in orbit.
4) Avoid intentional destruction and other harmful activities.
5) Minimize the potential for post-mission break-ups resulting from stored energy.
6) Limit the long-term presence of spacecraft and launch vehicle orbital stages in the low-Earth orbit (LEO) region after the end of their mission.
7) Limit the long-term interference of spacecraft and launch vehicle orbital stages with the GEO region after the end of their mission.

USG space activities attempt to comply with these nonbinding requirements while balancing national security, industrial base, and budgetary consideration. Likewise, U.S. licensed and regulated private and commercial space activities also comply to the extent required by U.S law and regulations.

ITU-R S.1003.2 provides nonbinding guidance about disposal orbits for satellites in the geostationary satellite orbit (GSO). The goal is to facilitate establishment of a protected region above, below and around the geostationary orbital regime in order to reduce collision risks as this orbital region becomes more crowded. It recommends that satellites, at the end of their operational life, be maneuvered to a higher altitude to get out of the GSO region. The recommendations are:

- As little debris as possible should be released into the GSO region during the placement of a satellite in orbit.
- Every reasonable effort should be made to shorten the lifetime of debris in elliptical transfer orbits with the apogees at or near GSO altitude.
- Before complete exhaustion of its propellant, a geostationary satellite at the end of its life should be removed from the GSO region such that under the influence of perturbing forces on its trajectory, it would subsequently remain in an orbit with a perigee no less than 200 km above the geostationary altitude.
- The transfer to the graveyard orbit removal should be carried out with particular caution in order to avoid radio frequency interference with active satellites.

**UNGA Resolution 47/68 (December 14, 1992): Principles Relevant to the Use of Nuclear Power Sources in Outer Space.**

UNGA Res 47/68 recognizes the need for a set of principles containing the goals and guidelines to ensure the safe use of nuclear power sources in outer space. It may be argued that UNGA Res 47/68 provides a precedent relevant to a number of space traffic management concerns including the concept of “zoning” specific areas of orbital space for certain activities, establishing guidelines for the design and operation of spacecraft, providing criteria for safety assessments and the safe use of the space object, and providing a format for notifications of malfunctioning spacecraft with a risk of re-entry. Specifically:

- **Principle 3, paragraph 2,** states that nuclear power sources “may be operated ‘in sufficiently high orbits’ or in low-Earth orbits if they are stored in sufficiently high orbits after the operational part of their mission.”

- **Principle 3, paragraph 2 (d) and (e)** concern the design and operation of nuclear powered spacecraft including stating: “(d) Nuclear reactors shall not be made critical before they have reached their operating orbit or interplanetary trajectory and (e) The design and construction of the nuclear reactor shall ensure that it cannot become critical before reaching the operating orbit during all possible events, including rocket explosion, re-entry, impact on ground or water, submersion on water or water intruding into the core.”

Principle 4 includes safety criteria and arrangements among actors regarding safety assessments. Principle 5 is concerned with notifications of re-entry.

**Conclusion**

A review of all STM and orbital debris requirements under treaties and other international agreements to which the United States is a party, and other nonbinding international arrangements in which the United States participates, and the manner and extent to which the federal government complies with those requirements and arrangements shows that there are few clear requirements, and where requirements exist, such as regarding the Registration Convention or for example, orbital debris mitigation, the United States is sufficiently within compliance.
APPENDIX D  Assessment of Federal Government Space Traffic Management and Space Situational Awareness Assets

The federal government’s STM and SSA assets can be categorized within two main operational concepts; 1) Individual spacecraft day-to-day mission / safety-of-flight operations, and 2) remote observations of space objects through ground and space-based sensors.

Mission Operations Assets

The specific mission operations elements that comprise the “technology domain” stack vary across federal agencies and for each individual spacecraft the USG operates. It is not the intent of this report to provide a detailed description for each and every spacecraft the USG operates. However the majority of USG spacecraft mission operations, as well as private operators, follow the operational concept depicted below. Once a spacecraft is on-orbit, the primary function of mission operations is to remotely control the spacecraft through one or more forms of radio frequency (RF) transmission. The primary services provided by mission operations is the command and control (C2) of the spacecraft vehicle (commonly referred to as the spacecraft bus), C2 of the spacecraft’s payload(s), and maintaining overall health and safety of both the vehicle and payload(s). Supporting applications and computing platforms are commonly combined within a single computing system which is located within the spacecraft’s operation center and operated by a set of spacecraft operators. In many cases these spacecraft operations centers are manned 24 hours a day, 7 days a week, 365 days a year. However in some cases spacecraft operations is done in what is referred to as “light-out operations” where the spacecraft operations center is unmanned and the spacecraft performs a set a pre-defined commands; these forms of operations are more common for deep space scientific missions and more recently academic CubeSats and commercial smallsat operators. Lastly, one or more ground stations are used to transmit command to the spacecraft and receive spacecraft telemetry or payload data back from the spacecraft. Although typically not considered a STM asset, C2 systems are inherently such for two reasons. First, the C2 system provides a means by which to determine a spacecraft’s orbit. This can be performed using radio ranging systems (in which ground receivers can measure the properties of a radio beacon transmitted by the spacecraft to determine the orbit) and/or onboard GPS. Second, it is through C2 that spacecraft maneuver commands are transmitted. Such maneuvers include those needed for collision avoidance.

Space Situational Awareness Assets

An operational summary of the USG current SSA architecture, representing each layer of the “technology domain” stack, is depicted in Figure 3 below. The USG’s SSA architecture executes two main functions; 1) develops the space operational picture that provides the technical foundation for the operational protection/defense of DOD spacecraft, and 2) executes the government SSA data sharing functions. The SSA architecture provides these functions through a series of products and services. These products and services are described in more detail below, but include maintenance of the space catalog, conducting conjunction assessments (CA), and providing collision warning/alerts messages to spacecraft owner-operators regardless of international designation. Various applications are used to support these services, the key ones being the Space Defense Operations Center (SPADOC)/Analyst Support Workstation (ASW) and Space-Track.org. Underlying these applications are traditional information technology computer platforms. Lastly, enabling the entire SSA architecture is a worldwide network of observation sensors (the Space Surveillance Network - SSN) that detect and measure the position of space objects. The following sections describe in more details the individual elements that make up the USG’s SSA architecture.
SSA Functions

The 18th Space Control Squadron (18 SPCS) under the 14th Air Force is tasked with promoting the responsible use of space, advances spaceflight safety, and enhances SSA through the exchange of SSA information with the global space community. To carry out this function, the 18 SPCS provides foundational SSA analysis, assessments, and reporting, while JFCC-Space is responsible for Battle Management Command and Control (BMC2) of USAF space assets. For the purpose of this assessment, BMC2 functions are considered to be a defensive mission - protection of US government assets – and as such were not examined in this report.

SSA Products and Services

Space Catalog

The 18 SPCS is responsible for the development and maintenance of the US space object catalog, which includes both spacecraft and orbital debris. The space catalog comprises approximately 23,000 tracked space objects and is updated on a daily basis. 18,000 of these space objects are tracked with sufficient confidence that they are disseminated via a public catalog via the Space-Track.org web service. These 18,000 objects are comprised of payloads, rocket bodies, debris, and unknown objects. Figure 4 depicts the population and composition of cataloged objects dating back to 1961. Of particular note is the increase in the number of cataloged objects as a result of the Chinese anti-satellite missile (ASAT) test in 2007 and Iridium-33 spacecraft/Cosmos-2251 collision in 2009. Some proposed new large constellations of small satellites could add thousands more spacecraft to the space catalog over a few years. Also, it is estimated that once the new Space Fence SSA radar system becomes operational, the number of space objects in the space catalog could increase by approximately 60,000. This estimated increase will add complexity to the current conjunction assessment process, although the additional burden may be offset by a beneficial reduction in space object orbit uncertainty used to determine probability of collisions.

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86 Personal communications Air Force Space Command, 15 November 2016. Note that these space objects are currently in orbit, but current SSN capabilities do not allow them to be tracked.
Figure 4. Number of Tracked Space Objects within U.S. Space Catalog\(^87\)

Figure 5 below provides a detailed look into the population density of space objects ion Low Earth Orbit (100km – 2,000km). Significant growth has occurred within the region of 500 – 1,000km since 2007.

Conjunction Assessment (CA) Services

The USAF conducts 24/7 CAs for approximately 1400 active spacecraft in the space catalog. CA is the process of identifying a close approach between a spacecraft and another space object. CAs utilize a standard conjunction assessment screening process – see Figure 6. The process begins with screening and updating the space catalog based on observational sensor data. Then the 18 SPCS performs an initial screening of all spacecraft against the catalog to identify conjunction candidates. The candidates are then reevaluated by the 18 SPCS Orbital Safety Analysts to ensure the most current observations are incorporated. The 18 SPCS conducts a refinement screening to update the conjunction estimates of the conjunction candidates. If the parameters of the conjunction are within the criteria that identify a close approach, the 18 SPCS will notify the owner-operator of the conjunction.89

Figure 6. JSPOC Conjunction Screening Process

If a conjunction is identified, the 18 SPCS will contact the owner-operator of the conjunction candidate through a standardized process. Owner-operators will receive email notifications depending on the screening performed and results. The emails are generated and transmitted via Space-Track.org and the messages can be:

- A Close Approach Notification that are sent for every prediction that meets emergency reportable criteria;90

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90 Emergency reportable criteria includes primary, secondary, miss distances, TCA, and for near earth events, and Probability of Collision (Pc).
• Conjunction Data Messages (CDMs) that notify the owner-operator that new conjunction data is available on Space-Track.org for their organization. In 2015, the DOD issued 1,297,891 CDMs.91
• Negative Result emails that confirms that a specific orbit has been screened and states that there are no collision results within the orbit screening volume;
• Expanded Results emails that confirm that a specific orbit has been screened, and that there are results that are within the orbit screening volumes, but not within emergency reportable criteria.92

DOD Products and Services:

Using a variety of software applications and analysis conducted by operations staff, DOD provides numerous products and services to private and international owner-operators. These products and services include early stakeholder engagement, Launch Collision Avoidance, Launch Support, Early Orbit Conjunction Assessment, Collision Avoidance, End-of-Life Disposal, Deorbit, and Re-entry, Human Spaceflight Safety, and NASA/NOAA robotic spacecraft collision avoidance support.

Early Stakeholder Engagement:

Early engagement has increasingly become important to the USSTRATCOMs SSA Sharing Program. The 18 SPCS reaches out to new operators and complex missions to exchange mission briefs well ahead of mission execution. Early engagement includes public conferences & workshops, communications with owners-operators to encourage spacecraft registration, identify upcoming missions and request contact info for alert notification, CubeSat recommendations, development of a Spaceflight Safety Handbook for Operators, and sharing of SSA data via Space-Track.org. Early engagement has benefited USSTRATCOMs role of promoting the responsible use of space and advancing spaceflight safety.

Launch Collision Avoidance (LCOLA):

Launch Collision Avoidance (LCOLA) is identification of potential conjunctions that may result in a collision between launching objects and space objects. Using owner-operator-provided information, the 18 SPCS screens the launch vehicle against the space catalog and identifies periods during the launch window, which may put the rocket and payload at increased risk for collision. Screening begins at an altitude of 150km or greater and continues until either location uncertainty makes performing the screening no longer feasible or until the rocket body/sub-orbital components descend to 150km or less.

After the spacecraft is in orbit, the 18 SPCS conducts an early orbit CA that screens the owner-operator provided orbit against the catalog to facilitate the safe maneuvering of a newly launched object into its final orbit.93

Launch Support:

The 18 SPCS provide predicted tracking, including pre-launch coordination and post-launch early orbit determination (EODET), for those launch agencies that provide launch parameters. After launch, the 18 SPCS can confirm nominal tracking by each sensor, and provide initial element sets, as well as work directly with the spacecraft operators to expedite cataloging and identification of all spacecraft, which is

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exceptionally important for multi-payload launches. In the event of launch anomalies (such as a booster failure, a launch failure, a spacecraft achieving the incorrect orbit, etc.), the 18 SPCS may provide anomaly resolution support.

Early Orbit Conjunction Assessment (CA):

Early Orbit CA includes pre-screening of owner-operator-provided ephemeris against the space catalog to facilitate safe maneuvering. Owner-operators may provide more than one ephemeris file for each early maneuver to allow analysis of multiple scenarios. It is important to note that the 18 SPCS does not recommend collision avoidance courses of action (i.e. tell an operator to maneuver or not) as a result of DOD’s limited authority over commercial entities, combined with legal liability and indemnification. Operators may develop their own collision avoidance maneuver and submit this plan ahead of time to the 18 SPCS to determine any reduction in the probability of collision and/or miss distance.

Collision Avoidance (COLA):

Collision avoidance (COLA) is the process of planning and possibly executing a maneuver in response to a close approach identified during the CA process. Based on the CA results, the owner-operator decides whether or not to perform collision avoidance by maneuvering their spacecraft. If they do not perform COLA, the 18 SPCS will continue to monitor the conjunction and provide updates based on data from the SSN until the time of closest approach (TCA) has passed. If the owner-operator decides to perform COLA, they may send the 18 SPCS their predictive ephemeris data, which the JSpOC will then screen against the catalog and send updated notifications to the owner-operator so that they may decide how to proceed. This exchange of data may continue until the TCA, after which the 18 SPCS will resume routine screening of the spacecraft.

It is important to note that submission of a maneuver plan and or acknowledgement of an avoidance message is strictly voluntary.

Figure 7 provides a summary of the confirmed maneuvers since 2010 due to the issuing of CDM message.\(^{94}\) In 2015 DOD provided 1,297,891 CDMs to spacecraft owner-operators, a 93 percent increase over the previous year.

\(^{94}\) “Near Earth” objects are LEO spacecraft, while “Deep Space” objects are GEO spacecraft.
An important observation made during the assessment was that the 18 SPCS does not always have contact information for the operator so as to deliver the conjunction message, as registration of spacecraft operators is not standardized. Operators are asked to report collision avoidance maneuvers to the 18 SPCS. Compliance on the part of the owner-operator is purely voluntary and submitted by email. In the hope of improving the consistency of maneuver reporting and allow the 18 SPCS to integrate the notifications into orbit determination solutions, the 18 SPCS is implementing the ability to submit maneuver notifications using the CCSDS Orbital Parameter Message (OPM) through Space-Track.org.

**End-of-Life/Disposal:**

If an owner/operator decides to move a spacecraft to a less-populated orbit at the end of its lifetime, the 18 SPCS will assist the owner-operator by screening maneuver ephemeris and providing results. All owner-operator-provided ephemeris will be screened using standard ephemeris screening volumes, and results will be provided in accordance with basis or advanced reporting criteria.

**Deorbit:**

A deorbit is the controlled reentry of a spacecraft into the earth’s atmosphere. If an owner-operator decides to deorbit a spacecraft or rocket stage through a series of maneuvers, the 18 SPCS can provide CA screenings, as well as coordinate with NASA to ensure the deorbiting spacecraft safely descends through the ISS’ orbit. After the spacecraft completes their maneuvers, the 18 SPCS can confirm final reentry.

**Reentry:**

A reentry is an uncontrolled reentry of an object into the earth’s atmosphere. Support includes reentry predictions through Space-Track.org, and ground traces and tracking confirmations with an approved orbital data request. Reentry assessments are predictions of the time and location where an object will reenter the atmosphere (not where the object will impact the ground).
Reentry Assessments (RAs) are initialized 7-10 days prior to the predicted reentry date. At this point sensor tasking is increased and assessments run once per day, but aren’t published due to extreme variability of predications at this point. Then four days prior to reentry, the 18 SPCS continues to increase tasking, and begins issuing Tracking and Impact Predications (TIP) messages once per day through Space-Track.org. For entities with an approved Orbital Data Request, the 18 SPCS will also provide ground traces and observations from select sensors. Within 24 hours of reentry RAs increase, and TIP messages are updated at the 12-, 6-, and 2-hour points. Finally once the predicted reentry time passed, SSN is tasked for expanded time period surrounding object TLE. Only after three (3) sensors confirm no tracking of the object (“no-show”) will the 18 PSCS confirm final reentry.

Anomaly Support:
In the event of a non-nominal situation during any phase of operations, the 18 SPCS can provide anomaly support to help the spacecraft owner-operator resolve the situation. The support that can be provided is contingent on classification and releasability of the information.

Human Space Flight Safety:
The 18 SPCS provides 24/7 collision avoidance assessment for ISS in support of NASA. These assessments include coordination with NASA on all operational events (docking, undocking, CubeSat releases, etc.). A civilian employee at the JSpOC / 18 SPCS serves a Human Spaceflight Safety coordination function and interfaces with NASA personnel at the Johnson Spaceflight Center. More details on the operations processes used are provided in Appendix E.

NASA Conjunction Assessment Risk Analysis (CARA) group support
Headquartered at the Goddard Space Flight Center (GSFC), CARA provides conjunction risk analysis services for NASA’s robotic missions (e.g. the NASA A-Train, Morning Constellation, etc.) in all phases of the mission lifecycle. CARA personnel (government contractor staff) physically sit in the JSpOC and interface with their other members of their team at GSFC. JSpOC products and service are made directly available to CARA. CARA staff provide advisory services directly to the mission operations staff for each spacecraft. It is the operations staff for each spacecraft mission that ultimately makes collision avoidance maneuvering decisions.

Computing Platforms: Space Defense Operations Center (SPADOC) /Joint Space Operations Center (JSpOC) Mission System (JMS) and Astrodynamics Workstation (AWS)
The SPADOC is a legacy system that was originally deployed in the late 1970s and was designed to support consolidated space surveillance and missile warning functions within the NORAD Cheyenne Mountain Complex (vice a Space Traffic Safety function). Today SPADOC remains the primary means to ingest all 300,000-400,000 daily observations from the SSN and perform General Perturbation (GP) orbital solutions for objects within the space catalog.

JMS will replace legacy SPADOC and space-specific portions of the Correlation, Analysis, and Verification of Ephemerides Network systems, both of which are aging and unsustainable, and cannot meet changing threat, operating environment, and mission requirements.

AWS, which resides upon the JSpOC’s CaveNET, is a companion tool that is fed SSN observations from SPADOC. AWS is the primary means to compute the High Accuracy Catalog and performs all conjunction assessment analysis.
Data Sensors: United States Space Surveillance Network (SSN)

Figure 8 provides an overview of the U.S. SSN that comprises the data sensors layer within the “Technology Domain”. The SSN is a worldwide network of 30+ space surveillance sensors (radar and optical telescopes, both military and civilian) to observe space objects. Each day the SSN generates between 380,000 to 420,000 observations of space objects.

Across the SSN are three distinct sensor categories: dedicated, collateral, and contributing. Dedicated sensors are primarily used in support of the space surveillance mission. Collateral sensors have other primary missions, such as missile warning, but still provide support to space surveillance. Lastly, contributing sensors are mainly comprised of other parities sensors (commercial, university, etc.) that provide data in support of space surveillance. Because of the limits of the current SSN (number of sensors, geographic distribution, capability, and availability), the 18 SPCS utilizes a “predictive” technique to monitor space objects, i.e. it spot checks them rather than tracking them continually. In terms of sensor tasking, 18 SPCS control where and when to point these sensors ranges from complete control in terms of dedicated sensors to little or no control over contributing sensors. Below is a brief description of each type of sensor:

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• Conventional radars use moveable tracking antennas or fixed detection and tracking antennas to observe objects in space. These observations are achieved by the tracking antenna steering a narrow beam of energy toward a spacecraft and uses the returned (reflected) energy to compute the location of the spacecraft. By following the spacecraft's motion, more data can be collected and a more precise orbit can be determined for the space object. Examples of conventional radars include the Altair complex at the Reagan Test Site in the Kwajalein Atoll and the Haystack Millstone facility at the Massachusetts Institute of Technology Lincoln Laboratory.

• Phased-array radars can maintain tracks on multiple spacecraft simultaneously and scan large areas of space in a fraction of a second. Phased-array radars observe and track space objects the same as conventional radars, but they do so without the use of mechanically steered antennas. Because the radar energy is steered electronically, there is no limit to the speed of the radar scan. Two examples of phased-array radars include Cavalier AFS in North Dakota and Eglin AFB in Florida.

• Electro-optical sensors consist of telescopes linked to video cameras and computers. The video cameras feed their space pictures into a nearby computer where it is analyzed in real-time. Various characteristics of the space object, including its position, can be obtained from imagery analysis. Ground-Based Electro-Optical Deep Space Surveillance (GEODSS) sites assigned to Air Force Space Command (AFSPC) play a vital role in tracking deep space objects. Between 4,200 and 4,400 objects, including geostationary communications spacecraft, are in deep space orbits more than 22,500 miles from Earth.

• Space based sensors have the ability to detect debris, spacecraft, or other distant space objects without interference from weather, atmosphere, or time of day. Space based sensors use optical or infrared sensors that either scan, or quickly focus between space objects. These observations are then sent to the ground where they are processed.

**Data Sensors: Owner-Operators Ephemeris**

Additionally, the USG utilizes alternative means (such as spacecraft generated ephemeris, on-board GPS, and geo-location of communications beacons) of spacecraft orbit determining for its own assets. These means provide a more accurate, timely, and trusted data source over remote observations systems. However these alternative means have their limitations; this approach only works for 1) operational spacecraft, and 2) spacecraft to which the USG is the owner-operator or has been granted access to the satellite telemetry data by the owner-operator. Because of the critical nature of the JSpOC's space defense mission, there are strict SSA data validation requirements which limit the ability to ingest owner-operator data for use in the space catalog.

**Summary**

DOD supplies a sizeable number of valuable Space Traffic Safety related products and services across the USG, private, and international space enterprise. These products and services are relied upon by a growing number of private and international owner-operators. The effectiveness of these products and services, however, is limited as the DOD SSA and C2 systems are not optimized for the Space Traffic Safety function. This limits SSA data transparency, quality, and timeliness and in addition, it impacts the DOD ability to focus on its main mission and appropriate tune their systems to warfighting requirements.
APPENDIX E  Unique Human Spaceflight Safety Considerations

The protection of the health and safety of humans involved in space activities is of paramount importance. In the context of a space traffic management paradigm, there are unique safety considerations needed for human spaceflight needed to minimize hazards in the space environment. These hazards include:

- Micro-Meteoroid/Orbital Debris (MM/OD) and operational space objects that, in a collision, could penetrate a crewed space system, resulting in catastrophic failure or loss of pressurization.
- Solar flares that could expose crew to dangerous levels of high-energy radiation.
- Ground-based lasers that could cause temporary or permanent eye damage.
- Ground-based radars that could expose crew to dangerous levels of radio-frequency radiation.
- Hostile space events.

Safety considerations for the International Space Station (ISS) are especially vital, as

- The ISS is continuously occupied by three to six crew members.
- The large size (cross-sectional area) of the ISS increases the probability of collision with MM/OD and operational space objects, relative to other space vehicles.
- The ISS is maneuverable in orbit (i.e. can raise or lower its orbit), but maneuvers in attitude are limited (e.g. cannot rotate in a way to present a lower cross-sectional area to a threatening piece of orbital debris).
- The ISS is in a LEO which most launch vehicles cross while ascending, and most other LEO orbital debris cross while decaying prior to reentry. Also, this relatively low altitude means that energy from ground based lasers and radars is still high enough to present a crew safety hazard.

Probabilistic risk assessment (PRA) calculations show that MM/OD impact risk with the ISS are a significant, and in most cases primary, contributor to the risk that the entire ISS crew will require evacuation, one or more crew members is lost, or that all crew members and the ISS are lost in a catastrophic event. **Table 4** shows the odds of these possible events over the course of six months, all the result of a MM/OD impact.96

<table>
<thead>
<tr>
<th>MM/OD Root Cause Event</th>
<th>Odds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evacuation: Scenarios that are not immediately catastrophic but pose a threat to the crew, and would result in crew evacuation.</td>
<td>1 in 112</td>
</tr>
<tr>
<td>Loss of Crew: Scenarios that result in the death of one or more crewmembers. It is restricted to those cases where death is immediate or evacuation is not possible.</td>
<td>1 in 228</td>
</tr>
<tr>
<td>Loss of Crew and Vehicle: Scenarios that result in the immediate loss of the ISS and crew. The crew would have insufficient time to take corrective action or evacuate.</td>
<td>1 in 5,000</td>
</tr>
</tbody>
</table>

As debris populations grow in LEO, the odds of MM/OD root cause events on ISS will become higher (i.e. worsen); but, this study did not find any analysis that quantified this increased risk. Recent analysis by the Aerospace Corporation on new large LEO constellations (discussed in detail in Appendix F) found that such constellations could increase the number of collision warnings with ISS six-fold, for example, as the

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96 ISS Version 2.3 PRA Results (briefing slides), ISS Risk Team, November 16, 2011.
decommissioned spacecraft in those constellations decay through the ISS orbit. This result does not correspond to a direct increase in the odds of a MM/OD root cause event, but does show that risk can go up.

The overall approach for ISS/Man Visiting Vehicles (MVV) MM/OD is summarized in Figure 9. The intent is to shield ISS from debris that can’t be tracked and maneuver away from debris that can. This requires a model of the environment whereby testing of shielding design can be performed on sized objects that cannot be tracked.

Figure 9. Overall ISS MM/OD Approach

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ISS is currently in an assembly complete configuration with shield designs based on older environmental models. The latest model predicts an increased risk of penetration of the pressurized sections. The ISS program accepted this risk with additional mitigation of potentially adding additional shielding/repair techniques to some hardware. Figure 10 shows pictures of ISS MM/OD damage. NASA imagery database documented approximately 300 MM/OD strikes on ISS. None of the MM/OD objects were tracked prior to striking the ISS.

Figure 10. MM/OD Hits

To reduce the risk of the hazards to government astronauts, DOD and NASA created processes and procedures for the interchange of technical data to be used for informed decision-making by NASA while conducting operations of ISS, vehicles visiting ISS (to include both manned and robotic vehicles), and other vehicles carrying government astronauts. Two documents guide these processes and procedures:

1) Memorandum of Agreement (MOA) between DOD and NASA for Support to NASA Spaceflight Operations, 15 Mar 05. This MOA establishes NASA requirements for DOD Support of both NASA human and robotic missions (and others crewed by NASA personnel or with NASA payloads). For human spaceflight missions, it implements recommendations identified by the Columbia Accident Investigation Board. Specific NASA requirements are listed in appendices.

2) USSTRATCOM Joint Functional Component Command for Space and NASA Office of Space Operations Interagency Operating Instruction (OI) for Human Spaceflight Support. This OI focuses on space surveillance and related surveillance analysis support provided by USSTRATCOM and its components to Johnson Space Center for the ISS and other vehicles used for human spaceflight missions.
Combined, these documents establish NASA’s detailed technical needs and interagency procedures to conduct the following safety focused activities for human spaceflight:

- **Space Environment Characterization.** This data, from all orbital regimes, provides information that can be used to determine the overall risk to human spaceflight safety due to orbital debris.
- **Track and Debris Catalog Maintenance.**
- **Launch Trajectory Support.** This includes monitoring of both arrival and departure of Visiting Vehicles (VV, e.g. SpaceX Dragon, Orbital Cygnus) to the ISS (either manned or robotic).
- **On-orbit Support.** This primarily includes CA and tracking of ISS and any other vehicles carrying government astronauts. ISS CA is performed a minimum of once every 8 hours. The CA information is provided by DOD for the ISS using the special perturbations Resident Space Objects catalog. The information includes, at a minimum, miss distance and time of conjunction, state vectors for both the asset and the conjuncting object, and state vector uncertainty (covariance) for both the asset and conjuncting object. NASA will use CA information (vehicle state vectors and covariances) to compute the probability of collision between the asset and the conjuncting object. If the probability of collision exceeds 1 in 10,000, a maneuver may be planned and executed. **Figure 11** shows the number of times by year the ISS was commanded to conduct a debris avoidance maneuver (DAM) using onboard propulsion or using an attached Space Shuttle. This activity consumes most of the daily DOD-NASA operational interaction.
- **Re-entry support.**
- **Space Object Identification.** This includes monthly imaging support of the ISS, which is used to locate and identify possible structural anomalies (e.g. created by debris impact or shedding events).
- **Advisories and Warnings of Potential Threats to Space Operations.**

**Figure 11. ISS Debris Avoidance Maneuvers (DAMs) since 1999**

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The above Human Space Flight (HSF) related data and information is collected, developed, and disseminated by the JSpOC to NASA JSC. A government employee, working for the 18 Space Control Squadron, is assigned the 24/7 crew task of HSF Orbital Safety Analyst support on the JSpOC floor. This HSF OSA liaises with a Trajectory Operations Officer (TOPO), who is a NASA employee at JSC acting as trajectory operations controller for all ISS operations.99 The TOPO coordinates with ISS Mission Control Center to determine courses of action (e.g. to maneuver to avoid space debris).

**Implications/Considerations**

The STRATCOM/NASA JSC process for HSF is well understood, efficient, practiced, and effective. In any future Space Traffic Management Safety Governance Framework, this would remain an inter-agency operation. Future commercial HSF endeavors would require an orbital safety practice and process and would be informed by the existing process used to protect government astronauts. There remain unique DOD capabilities used for HSF orbital safety monitoring that would be difficult to immediately transition to a civil agency. This would add complexity to any near-term future construct in which a civil organization would be made responsible for HSF safety, especially for NASA missions.

99 It is congressionally mandated for TOPOs to accomplish training with the JSpOC (now 18 SPCS) as a part of certification program with NASA.
APPENDIX F  Risk Associated with Smallsats

In conducting this assessment, it was necessary first to address the meaning of “smallsats”. There is some inconsistency, even in the space community, in definition of the term. For the purpose of this assessment we assume that “smallsats” are any spacecraft with a wet mass (i.e. fueled) of 500 kg or less. Of particular concern and interest are CubeSats, which are 10 cm x 10 cm x 10 cm and have a mass of about 1 kg. These dimensions and mass represent a CubeSat “Unit” (U). Multiple CubeSats Units can be attached together to create a larger and more capable smallsat. After 2013 the “3U” or three Unit CubeSats became the most frequently launched type of spacecraft in the 1-50 kg range. 6U and 12U CubeSats are also common. Also of interest are smallsats that make up large constellations that consist of hundreds to thousands of spacecraft placed into one specific orbital altitude (for each constellation) in LEO. These spacecraft are about 100-200 kg in wetmass.

A growing population of smallsats has raised concern for orbital safety. The major risk drivers creating this concern include:

- Smallsats typically have less maneuverability than larger spacecraft, to include many that have no maneuverability at all. This limits the ability to reduce the probability of potential collisions, as well as the ability to accelerate orbital decay leading to re-entry (for LEO spacecraft).
- Lowered barriers to entry enable inexperienced entrants, from high schools to small countries, to gain space launch access and operate smallsats, possibly leading to poor operational decision-making.
- Inexperience on the part of new entrants building smallsats (particularly CubeSats) leads to higher incidence of quality control and/or design issues, thereby increasing odds of failure. Limited size and mass restrict redundancy used for reliable design, thereby limiting robustness to failure. For instance, historic data found that of the first 100 CubeSats launched (between 2000 and 2012), 17 failed in the first 10 days of orbit, with another 9 failing in the first 100 days of orbit. Even those CubeSats that operate for their designed lifetimes do not remain functional for more than a period of a few years due to intolerance to the space environment (e.g. radiation). The overall impact to reduced quality, reliability, and design life, coupled with the inability to maneuver is that CubeSats in LEO spend a large percentage of their orbital lifetimes in a non-operational state.
- The small size, especially of CubeSats and smaller spacecraft (down to the “chip” level) present a SSA challenge to track, identify, and maintain custody (i.e. continue to identify a given spacecraft). This is especially true during initial deployments, when multiple spacecraft are released in the same vicinity over a short period of time.
- The launch frequency of smallsats is accelerating. 2016 forecasts show that over 200 spacecraft will be launched in the 1-50 kg range (mostly CubeSats). That rate could double by 2021. Typical LEO orbits of small spacecraft present a potential hazard to the ISS while they decay towards the upper atmosphere.
- LEO large constellations of spacecraft in the 100-500 kg potentially create new orbit zones (above 1000 km) with significant densities of satellites. Also, these satellites must be replenished on timescales of about five years. Therefore, a significant number of spacecraft will de-orbit and/or decay through a region of LEO that is populated with orbital debris and other spacecraft.

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In contemplating the need to mitigate safety risks created by smallsats, it is important to consider their relative current and future impact to Space Traffic Safety.

- Smallsat populations overall are currently fractions of the total debris population, especially those debris populations in sizes that are of major concern. Figure 12, provided by the NASA JSC Orbital Debris Program Office, shows the debris populations statistics by size. CubeSats, of size 10–50 cm, have populations at least two orders of magnitude less than the current total for all debris of that size. 1 cm size debris (which is concern because of the hazard it presents while being difficult to track) has a total population 1,000 more than that of CubeSats. Conclusions from this data must be tempered with the fact that collision risk is driven by space object spatial density, not by raw total numbers.

- CubeSats accounted for only three of the 121 maneuvers larger spacecraft had to perform in 2014 to avoid a potential collision.\(^{102}\)

\[\text{Figure 12. Debris Population by Size}\]

- New Aerospace Corporation modeling has been conducted to evaluate collision risk created by planned CubeSats and potential new large constellations\(^ {103}^{104}\) A summary of findings include:
  - The near-term assessment is that the likelihood of increased collisions is not appreciably increased, as long as maneuvers for collision avoidance are performed for spacecraft both


during normal operations and controlled disposals. (If that disposal method is available). Over longer periods of time—decades to centuries—failed satellites in these constellations would create the likelihood of about one to two additional collision per year.

- LEO large-constellations can significantly increase conjunction warnings. For a 4,000+ spacecraft constellation, conservative modeling found that 64 million collision warnings per year would result, just among spacecraft in the constellation.
- CubeSats that are launched in lower LEO orbits (and thereby follow the 25-year rule) do not significantly raise risk of collision and, for the assumed model of future CubeSat activity, result in maximum of 10 percent additional orbital debris population (greater than 1 cm).
- CubeSats that are launched in higher LEO orbits (and thereby do not follow the 25-year rule) dominate debris production created by all LEO CubeSats.

Current formal government coordination of small spacecraft activities consists of

- FCC Licensing of spectrum per 47 CFR Part 25, Part 5 (experimental), or Part 97 (amateur). As part of these reviews, regardless of vehicle, submission of an orbital debris assessment report (ODAR) is required. The general requirements for completion of the ODAR are no different than any other spacecraft licensed by the FCC.
- FAA payload review as part of the Launch Licensing process per Commercial Space Transportation Licensing Regulations, 14 CFR Part 415.51 through 14 CFR Part 415.6: “The FAA issues a favorable payload determination unless it determines that launch of the proposed payload would jeopardize public health and safety, safety of property, U.S. national security or foreign policy interests, or international obligations of the United States.”

These reviews provide a mechanism to verify best practices are generally being followed to limit orbital debris risk.

The JSpOC has created guidelines for optimal CubeSat operations. These include:

- Identification markers (passive or active) for satellites that are deployed on multi-spacecraft dispensers.
- A design that includes some maneuver capability.
- Additional of capability for controlled or expedited un-controlled re-entry.
- Operational lifetime greater than 2/3 of total orbital lifetime.
- Deployment from or below the ISS and into high inclination orbits (to improve tracking capabilities).
- Multi-second deployment intervals during propulsive maneuvers by carrier or 60 second intervals during coast of the carrier.
- Engagement with the JSpOC during pre-mission planning, during deployment, and sharing of orbit and other relevant data in the operations phase.

These represent thoughtful recommendations, based on experience, that can mitigate Space Traffic Safety risks and add to overall SSA (and therefore is likewise beneficial to space defense and protection).

A number of considerations should be made when evaluating possible USG coordination of smallsat activities:
• Issues and concerns (risk drivers) associated with smallsats are not necessarily exclusive to spacecraft of small size. Therefore, any coordination activities considered should not be designated based on spacecraft size, but rather on spacecraft and operator capabilities, limitations, and attributes including:
  – Orbital Lifetimes
  – Operational Lifetimes
  – Maneuverability
  – Planned Orbits
  – De-orbit planning and capabilities
• As with all Space Traffic Safety issues, the development of smallsats is an international issue. For instance, in 2015, 40% of all smallsats in the 1-50 kg range were launched on foreign launch vehicles105.
• The recent Aerospace Corporation analysis on smallsat risks is a good beginning to quantifying the possible hazards of smallsats. Such research must continue to provide a technical basis for development of future best practices, guidelines, standards, and possible rules and regulations. One of the most important results of the current studies is modeling validation that orbital lifetimes of spacecraft in LEO (e.g. CubeSats) significantly influences collision risk; therefore, evaluation and reconsideration of the 25 year rule that is part of orbital debris mitigation guidelines could provide a good near-term means of Space Traffic Safety risk mitigation.
• The JSpOC CubeSat operation guidelines are a good beginning for the possible development of best practices and standards to be embraced by the community that can lead to possible formal policies and regulations. Once again, these need not be specific to CubeSats.
• It is observed that the deployment of large number of smallsats on a carrier vehicle requires a central coordinating organization representing the equities of all smallsat owner-operators involved. The need for such an organization needs to be stressed in future launches involving carrier vehicles.
• Information assurance practices are important to limit risks. Currently there is no best practice, guideline, standard, or rule to encrypt command and control of smallsats. This represents a risk of remote disabling and/or commanding of a spacecraft, which could result in purposeful creation of a Space Traffic Safety hazard.

Finally, identification schemes, both active and passive, add to situational awareness of smallsat position. Approaches can be created that especially provide better awareness of smallsat position after failure or end-of-life of a spacecraft. Such SSA capability adds to better decision-making and a more informed evaluation of risk. But this is a two-way street. The organization responsible for Space Traffic Safety must also be capable of ingesting this source of SSA in near real-time and rapidly updating the space catalog.

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APPENDIX G  Assessment of Private Sector Information Sharing Activities

Multiple options for sharing SSA data are available to the operational space community. The primary reason for sharing SSA data among the private sector is to promote the safe and efficient space operations. Today data sharing activities generally involve the exchange of spacecraft owner-operator information, top-level spacecraft characteristics (i.e. function), spacecraft position and location data, and RF characteristic (i.e. transmission / receive frequencies). Private sector information sharing activities can be summarized as either private-private or government-private sharing agreements. Private-government sharing agreements consist of data sharing agreements between the USG and commercial entities. Private-private data sharing agreements have a variety of models that include membership associations, corporate-to-corporate data sharing, and open source / publicly available data sets. These two categories of agreements are discussed in further detail in the following sections.

USSTRATCOM SSA Sharing Program

The UGS’s SSA sharing agreements consist of sharing USG SSA products and services, described in Appendix D, with non-USG entities. Examining the policy domain stack, the responsibility of overseeing USG SSA sharing agreements is assigned to the DOD. Authorities are described in Title 10 USC 2274, which assigns the Secretary of Defense (SECDEF) authority to provide SSA services and information to, obtain SSA data and information from, non-USG entities. These actions may be taken only if the SECDEF determines that such action is consistent with the national security interests of the United States. Furthermore the SECDEF may not provide SSA services and information under subsection (a) to a non-USG entity unless that entity enters into an agreement with the Secretary under which the entity agrees to: 106

- Pay an amount that may be charged by the SECDEF under subsection (d);
- Not transfer any data or technical information received under the agreement including the analysis of data, to any other entity without the express approval of the SECDEF; and
- Any other terms and conditions considered necessary by the SECDEF.

In addition to SSA sharing with non-USG entities, the National Space Policy (PDD-4) 28 June 2010 directs the sharing of SSA information to support: national security, civil space agencies, HSF, commercial and foreign space operations. The National Security Space Strategy (Jan 11) expands on this by stating the DOD will foster cooperative SSA relationships; support safe space operations; protect U.S. and allied space capabilities and operations; encourage other space operators to share their spaceflight safety data; and continue to expand provision of safety of flight services to USG agencies, other nations, and commercial firms. These activities include provide orbital tracking information, and predictions of space object conjunction as described in Appendix D.

Today USSTRATCOM is responsible for the SSA sharing program, which today is executed through the JSpOC and 18 SPCS.107 USSTRATCOM directs what SSA data can be shared with non-USG entities. SSA sharing with non-U.S. entities (individual foreign governments, governmental organizations and national/international corporations) is conducted in accordance with USSTRATCOM SSA Strategy (Feb

106 Title 10 USC 2274, Subsection C.
107 As outlined in the JFCC SPACE Capstone CONOPS (2016).
Over the years, the number of spacecraft and operating organizations has steadily climbed, and as space launch becomes less expensive and more accessible. In 2010, the DOD screened 890 satellites, for 108 organizations. Now, the DOD screens approximately 1400 spacecraft for 260 distinct organizations (see Figure 13).

The USG SSA Sharing Program is focused on spaceflight safety, which includes a range of services intended to prevent human casualty, damage to property on the surface of the earth, and mission degradation, failure, or damage to any active on-orbit asset. Currently the USG offers three SSA sharing levels:

1. **Basic**: The USG basic level of SSA sharing is available to anyone with a user account on Space-Track.org. This level of services includes orbit information (Two Line Element sets) for unclassified objects, space catalog data, collision avoidance, and reentry predictions. As part of USSTRATCOM’s SSA Sharing Program, collision avoidance is provided for everyone who operates a spacecraft, at no cost. SSA data for this level of service is derived from the legacy SPADOC system and is planned capability for the future JMS system. Consumers of these services include commercial entities, non-U.S. governments, academia, and even hobbyists. As space becomes more accessible, participants become more diverse with varying levels of experience and differing motivations. Currently, Space-Track.org has approximately 116,000 registered users from nearly every country in the world.

2. **Emergency**: The USG Emergency level of SSA sharing is typically provided to spacecraft operators for spaceflight safety support. This level of service does not require a formal agreement or orbital

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108 Per USC~2274 as delegated to CDRUSSTRATCOM by the Office of the Under Secretary of Defense for Space Policy (OUSD-P).
109 Currently in coordination for update.
data request, however it doesn’t require that the operator have a registered account on SpaceTrack.org.

3. Advanced: The USG advanced level of SSA sharing is available for entities that have an SSA Sharing Agreement with USSTRATCOM. These sharing agreements provide more information of a higher quality, with an expedited approval process. As of the state of this report, USSTRATCOM currently has SSA Sharing Agreements with 52 commercial, 13 governments, and 2 inter-governmental entities.

Currently, information sharing occurs as a one-way data exchange (i.e. download) between the USG and the non U.S.-entity. USSTRATCOM is evolving past this one-way data exchange capability towards two-way and multi-lateral data exchanges in order to leverage the capabilities and expertise of partners to achieve and maintain SSA data. These two-way data exchanges will be implemented as a new series of standardized data messages that can be uploaded via Space-Track.org. From Space-Track.org, partner SSA data can be screened and then integrated into the space catalog; providing more accurate and timely SSA data.

Private – Private/Private - USG Data Sharing

With the increased concern for orbital collisions, several private entities are or have established commercial SSA services offerings. Similar to the DOD data sharing program, these commercial services offer a combination of spacecraft registration, space catalog maintenance, and collision avoidance products and services. In addition, some commercial providers provide expanded services such as radio frequency interference (RFI) assessment not offered through the DOD Sharing program. A summary of current and future commercial SSA providers is provided in Table 5 below.

Table 5. Current and Future Private SSA Providers

<table>
<thead>
<tr>
<th>Entity</th>
<th>Description</th>
<th>Products / Services</th>
<th>Fee</th>
</tr>
</thead>
</table>
| Space Data Association (SDA)/Space Data Center (SDC) | Industry association established to improve operations for conjunction assessments, RF interference and geo-location support, and contact information for a given space object. | • Satellite Registration  
• Conjunction Assessment  
• RFI Assessment | Membership fee. |
| Analytical Graphics, Inc (AGI) Commercial Space Operations Center (COMSPOC) | AGI’s ComSpOC™ is a SSA facility that fuses spacecraft-tracking measurements from a continually growing global network of commercial sensors.  
• Leverages more than 28 optical sensors and one radar site to track 5,000+ total space objects. | • High Definition Ephemeris  
• Resident space object characterization  
• Near real-time maneuver characterization | Subscription-based. |

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<table>
<thead>
<tr>
<th>Entity</th>
<th>Description</th>
<th>Products / Services</th>
<th>Fee</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEO spacecraft primary focus</td>
<td>SpaceBook® - Provides data including, status, orbit mission and owner information of all tracked objects.</td>
<td>Not yet defined.</td>
<td></td>
</tr>
</tbody>
</table>
| DARPA's Orbit Outlook | OrbitOutlook (O2) is a DARPA program that aims to improve the SSN by adding more data more often from more diverse sources, by:  
- Including new telescopes and radar from diverse locations providing diverse data types;  
- Providing a central database for this newly extended network of telescopes and radar;  
- And, creation of a validation process to ensure the data is accurate.  
O2 will engage civil, academic and commercial entities in an effort to bring more sensors online:  
- SpaceView which seeks to provide technically-minded amateur astronomers with the opportunity to make a difference in the task of space situational awareness through modern, remotely controlled telescopes.  
- StellarView, seeks to make a similar outreach as SpaceView to the academic community. | O2 focuses on development of Computing and Application stack layer capabilities. This could enhance current Products and Services in the community with options to create additional ones. |
APPENDIX H  Inherently Governmental Functions

Definitions of “Inherently Governmental Function” in Federal Procurement Law and Guidance

Kate M. Manuel
Legislative Attorney

December 23, 2014
<table>
<thead>
<tr>
<th>Type of definition</th>
<th>FAIR Act</th>
<th>OMB Circular A-76</th>
<th>FAR</th>
<th>OFPP Policy Letter 11-01</th>
</tr>
</thead>
<tbody>
<tr>
<td>Used for</td>
<td>Legal definition</td>
<td>Policy-based definition</td>
<td>Legal definition</td>
<td>Policy-based definition</td>
</tr>
<tr>
<td>Compiling lists of agency functions, classified as commercial or inherently governmental, for Congress and the public</td>
<td>Determining which agency functions are commercial and may be contracted out; establishing procedures for contracting them out</td>
<td>Determining which agency functions are commercial and may be contracted out; establishing procedures for contracting them out</td>
<td>Ensuring that only federal employees perform work that is inherently governmental or otherwise needs to be reserved to the public sector (e.g., to maintain control of agency’s mission)</td>
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<tr>
<td>Basic definition</td>
<td>The term “inherently governmental function” means a function that is so intimately related to the public interest as to require performance by Federal Government employees.</td>
<td>Inherently Governmental Activity[x]. An activity that is so intimately related to the public interest as to mandate performance by government personnel.</td>
<td>“Inherently governmental function,” as defined in Section 5 of the Federal Activities Inventory Reform Act, P.L. 105-270, means a function that is so intimately related to the public interest as to require performance by Federal Government employees.</td>
<td></td>
</tr>
<tr>
<td>Functions Included</td>
<td>The term includes activities that require either the exercise of discretion in applying Federal Government authority or the making of value judgments in making decisions for the Federal Government, including judgments relating to monetary transactions and entitlements. An inherently governmental function involves, among other things, the interpretation and execution of the laws of the United States so as—</td>
<td>These activities require the exercise of substantial discretion in applying Federal Government authority and/or in making decisions for the government. Inherently governmental activities normally fall into two categories: the exercise of sovereign government authority or the establishment of procedures and processes related to the oversight of monetary transactions or entitlements. An inherently governmental activity involves:</td>
<td>An inherently governmental function includes activities that require either the exercise of discretion in applying Federal Government authority, or the making of value judgments in making decisions for the Government. Governmental functions normally fall into two categories: the act of governing, i.e., the discretionary exercise of Government authority, and monetary transactions and entitlements. An inherently governmental function involves, among other things, the interpretation and execution of the laws of the United States so as—</td>
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<tr>
<td>(i) to bind the United States to take or not to take some action by contract, policy, regulation, authorization, or otherwise;</td>
<td>(i) Binding the United States to take or not to take some action by contract, policy, regulation, authorization, order, or otherwise;</td>
<td>(i) to bind the United States to take or not to take some action by contract, policy, regulation, authorization, order, or otherwise;</td>
<td>(i) to bind the United States to take or not to take some action by contract, policy, regulation, authorization, order, or otherwise;</td>
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<tr>
<td>FAIR Act</td>
<td>OMB Circular A-76</td>
<td>FAR+</td>
<td>OFPP Policy Letter 11-01</td>
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<td>(i) to determine, protect, and advance United States economic, political, territorial, property, or other interests by military or diplomatic action, civil or criminal judicial proceedings, contract management, or otherwise;</td>
<td>(2) Determining, protecting, and advancing economic, political, territorial, property, or other interests by military or diplomatic action, civil or criminal judicial proceedings, contract management, or otherwise;</td>
<td>(ii) Determine, protect, and advance United States economic, political, territorial, property, or other interests by military or diplomatic action, civil or criminal judicial proceedings, contract management, or otherwise;</td>
<td>(2) to determine, protect, and advance United States economic, political, territorial, property, or other interests by military or diplomatic action, civil or criminal judicial proceedings, contract management, or otherwise;</td>
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<td>(iii) to significantly affect the life, liberty, or property of private persons;</td>
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<td>(iii) Significantly affect the life, liberty, or property of private persons;</td>
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<tr>
<td>(iv) to commission, appoint, direct, or control officers or employees of the United States; or</td>
<td></td>
<td>(iv) Commission, appoint, direct, or control officers or employees of the United States; or</td>
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<td>(v) to exert ultimate control over the acquisition, use, or disposition of the property, real or personal, tangible or intangible, of the United States, including the collection, control, or disbursement of appropriated and other federal funds.</td>
<td></td>
<td>(v) Exert ultimate control over the acquisition, use, or disposition of the property, real or personal, tangible or intangible, of the United States, including the collection, control, or disbursement of Federal funds.</td>
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<tr>
<td>FAIR Act</td>
<td>OMB Circular A-76</td>
<td>FAR*</td>
<td>OFPP Policy Letter 11-01</td>
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<tr>
<td>Functions excluded</td>
<td>The term does not normally include—</td>
<td>Inherently governmental functions do not normally include gathering information for or providing advice, opinions, recommendations, or ideas to Federal Government officials. They also do not include functions that are primarily ministerial and internal in nature, such as building security, mail operations, operation of cafeterias, housekeeping, facilities operations and maintenance, warehouse operations, motor vehicle fleet management operations, or other routine electrical or mechanical services.</td>
<td>The term does not normally include—</td>
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<tr>
<td>(i) gathering information for</td>
<td>(1) gathering information for or providing advice, opinions, recommendations, or ideas to Federal Government officials; or</td>
<td>(1) gathering specified ranges of acceptable decisions or conduct and (2) subject the discretionary authority to final approval or regular oversight by agency officials.</td>
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<tr>
<td>or providing advice, opinions, recommendations, or ideas to Federal Government officials; or</td>
<td>(2) any function that is primarily ministerial and internal in nature (such as building security, mail operations, operation of cafeterias, housekeeping, facilities operations and maintenance, warehouse operations, motor vehicle fleet management operations, or other routine electrical or mechanical services).</td>
<td></td>
<td>(i) gathering information for or providing advice, opinions, recommendations, or ideas to Federal Government officials; or</td>
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<td>(ii) any function that is</td>
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<td>(2) any function that is primarily ministerial and internal in nature</td>
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<td>(such as building security, mail operations, operation of cafeterias, housekeeping, facilities operations and maintenance, warehouse operations, motor vehicle fleet management operations, or other routine electrical or mechanical services).</td>
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<td>or other routine electrical</td>
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CRS-24
<table>
<thead>
<tr>
<th>Definition of commercial activities</th>
<th>FAIR Act</th>
<th>OMB Circular A-76</th>
<th>FAR*</th>
<th>OFPP Policy Letter 11-01</th>
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<tr>
<td>None</td>
<td>A commercial activity is a recurring service that could be performed by the private sector and is resourced, performed, and controlled by the agency through performance by government personnel, a contract, or a fee-for-service agreement. A commercial activity is not so intimately related to the public interest as to mandate performance by government personnel. Commercial activities may be found within, or throughout, organizations that perform inherently governmental activities or classified work.</td>
<td>None</td>
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<td>Definition of critical functions</td>
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a. This definition is the one given in the “definitions” section of the FAR and used for purposes of Subpart 7.3 (“inherently governmental functions”). Subpart 7.3 of the FAR (“contractor versus government performance”) incorporates by reference the definition of inherently governmental functions given in OMB Circular A-76.
APPENDIX I  U.S. Commercial Space Launch Competitiveness Act (2015)

PUBLIC LAW 114–90—NOV. 25, 2015

U.S. COMMERCIAL SPACE LAUNCH
COMPETITIVENESS ACT
PUBLIC LAW 114–90—NOV. 25, 2015

Public Law 114–90
114th Congress

To facilitate a pro-growth environment for the developing commercial space industry by encouraging private sector investment and creating more stable and predictable regulatory conditions, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. SHORT TITLE; TABLE OF CONTENTS; REFERENCES.

(a) SHORT TITLE.—This Act may be cited as the “U.S. Commercial Space Launch Competitiveness Act”.

(b) TABLE OF CONTENTS.—The table of contents of this Act is as follows:

Sec. 1. Short title; table of contents; references.

TITLE I—SPURRING PRIVATE AEROSPACE COMPETITIVENESS AND ENTREPRENEURSHIP

Sec. 101. Short title.

Sec. 102. International launch competitiveness.

Sec. 103. Launch license flexibility.

Sec. 104. Licenses. Flexible launch license.

Sec. 105. Federal jurisdiction.

Sec. 106. Federal waivers.

Sec. 107. Space authorization.

Sec. 108. Orbital traffic management.

Sec. 109. Space situational awareness data.

Sec. 110. Space situational awareness data.

Sec. 111. Consensus standards and extension of current safety regulations.

Sec. 112. Governmental astronauts.

Sec. 113. Streamlining commercial space launch activities.

Sec. 114. Operations and utilization of the ISS.

Sec. 115. Space commercialization facilities.

Sec. 116. Space support vehicles study.

Sec. 117. Space launch system update.

TITLE II—COMMERCIAL REMOTE SENSING

Sec. 201. Annual report.


TITLE III—OFFICE OF SPACE COMMERCE

Sec. 301. Renaming of office of space commercialization.

Sec. 302. Functions of the office of space commerce.

TITLE IV—SPACE RESOURCE EXPLORATION AND UTILIZATION

Sec. 401. Short title.

Sec. 402. Title 51 amendment.

Sec. 403. Disclaimer of extraterritorial sovereignty.

(c) REFERENCES TO TITLE 51, UNITED STATES CODE.—Except as otherwise expressly provided, wherever in this Act an amendment or repeal is expressed in terms of an amendment to, or
PUBLIC LAW 114–90—NOV. 25, 2015 129 STAT. 705

repeal of, a section or other provision, the reference shall be considered to be made to a section or other provision of title 51, United States Code.

TITLE I—SPURRING PRIVATE AEROSPACE COMPETITIVENESS AND ENTREPRENEURSHIP

SEC. 101. SHORT TITLE.

This title may be cited as the “Spurring Private Aerospace Competitiveness and Entrepreneurship Act of 2015” or “SPACE Act of 2015”.

SEC. 102. INTERNATIONAL LAUNCH COMPETITIVENESS.

(a) SENSE OF CONGRESS.—It is the sense of Congress that it is in the public interest to update the methodology used to calculate the maximum probable loss from claims under section 50914 of title 51, United States Code, with a validated risk profile approach in order to consistently compute valid and reasonable maximum probable loss values.

(b) IMPLEMENTATION.—Not later than 180 days after the date of enactment of this Act, the Secretary of Transportation, in consultation with the commercial space sector and insurance providers, shall—

(1) evaluate the methodology used to calculate the maximum probable loss from claims under section 50914 of title 51, United States Code, and, if necessary, develop a plan to update that methodology;

(2) in evaluating or developing a plan under paragraph (1)—

(A) ensure that the Federal Government is not exposed to greater costs than intended and that launch companies are not required to purchase more insurance coverage than necessary; and

(B) consider the impact of the cost to both the industry and the Government of implementing an updated methodology; and

(3) submit the evaluation, and any plan, to the Committee on Commerce, Science, and Transportation of the Senate and the Committee on Science, Space, and Technology of the House of Representatives.

(c) INDEPENDENT ASSESSMENT.—Not later than 270 days after the date the evaluation is submitted under subsection (b)(3), the Comptroller General shall submit to the Committee on Commerce, Science, and Transportation of the Senate and the Committee on Science, Space, and Technology of the House of Representatives an assessment of—

(1) the analysis and conclusions provided by the Secretary of Transportation in the evaluation, and any plan, under subsection (b);

(2) the implementation schedule proposed by the Secretary in the plan described in paragraph (1); and

(3) the suitability of the plan described in paragraph (1) for implementation; and
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(a) In general.—Chapter 509 is amended—

(d) LAUNCH LIABILITY EXTENSION.—Section 50915(f) is amended by striking “December 31, 2016” and inserting “September 30, 2025”.

SEC. 103. INDEMNIFICATION FOR SPACE FLIGHT PARTICIPANTS.

SEC. 104. LAUNCH LICENSE FLEXIBILITY.
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SEC. 105. LICENSING REPORT.

Not later than 120 days after the date of enactment of this Act, the Secretary of Transportation shall submit to the Committee on Commerce, Science, and Transportation of the Senate and the Committee on Science, Space, and Technology of the House of Representatives a report on approaches for streamlining the licensing and permitting process of launch vehicles, reentry vehicles, or components of launch or reentry vehicles, to enable non-launch flight operations related to space transportation. The report shall include approaches to improve efficiency, reduce unnecessary costs, resolve inconsistencies, remove duplication, and minimize unwarranted constraints. The report shall also include an assessment of existing private and government infrastructure, as appropriate, in future licensing activities.

SEC. 106. FEDERAL JURISDICTION.

Section 50914 is amended by adding at the end the following: "(q) FEDERAL JURISDICTION.—Any claim by a third party or space flight participant for death, bodily injury, or property damage or loss resulting from an activity carried out under the license shall be the exclusive jurisdiction of the Federal courts."

SEC. 107. CROSS WAIVERS.

Section 50914(b)(1) is amended to read as follows: "(1)(A) A launch or reentry license issued or transferred under this chapter shall contain a provision requiring the licensee or transferee to make a reciprocal waiver of claims with applicable parties involved in launch services or reentry services under which each party to the waiver agrees to be responsible for personal injury to, death of, or property damage or loss sustained by it or its own employees resulting from an activity carried out under the applicable license."

"(B) In this paragraph, the term 'applicable parties' means—

(i) contractors, subcontractors, and customers of the licensee or transferee;

(ii) contractors and subcontractors of the customers;

and

(iii) space flight participants."

"(C) Clause (iii) of subparagraph (B) ceases to be effective September 30, 2025."

SEC. 108. SPACE AUTHORITY.

(a) IN GENERAL.—Not later than 120 days after the date of enactment of this Act, the Director of the Office of Science and Technology Policy, in consultation with the Secretary of State, the Secretary of Transportation, the Administrator of the National Aeronautics and Space Administration, the heads of other relevant Federal agencies, and the commercial space sector, shall—

(1) assess current, and proposed near-term, commercial non-governmental activities conducted in space;

(2) identify appropriate authorization and supervision authorities for the activities described in paragraph (1);
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Recommendations.  

(3) recommend an authorization and supervision approach that would prioritize safety, utilize existing authorities, minimize burdens to the industry, promote the U.S. commercial space sector, and meet the United States obligations under international treaties; and

(4) submit to the Committee on Commerce, Science, and Transportation of the Senate and the Committee on Science, Space, and Technology of the House of Representatives a report on the activities described in paragraphs (1), (2), and (3).

(b) EXCEPTION.—Nothing in this section shall apply to the activities of the ISS national laboratory as described in section 304 of the National Aeronautics and Space Administration Authorization Act of 2010 (42 U.S.C. 18354), including any research or development projects utilizing the ISS national laboratory.

SEC. 109. ORBITAL TRAFFIC MANAGEMENT.

(a) SENSE OF CONGRESS.—It is the sense of the Congress that an improved framework may be necessary for space traffic management of United States Government assets and United States private sector assets in outer space and orbital debris mitigation.

(b) STUDY.—Not later than 90 days after the date of enactment of this Act, the Administrator of the National Aeronautics and Space Administration, in consultation with the Secretary of Transportation, the Chair of the Federal Communications Commission, the Secretary of Commerce, and the Secretary of Defense, shall enter into an arrangement with an independent systems engineering and technical assistance organization to study alternate frameworks for the management of space traffic and orbital activities.

(c) CONTENTS.—The study shall include the following:

(1) An assessment of current regulations, best practices, and industry standards that apply to space traffic management and orbital debris mitigation.

(2) An assessment of current statutory authorities granted to the Federal Communications Commission, the Department of Transportation, and the Department of Commerce that apply to space traffic management and orbital debris mitigation and how these agencies utilize and coordinate those authorities.

(3) A review of all space traffic management and orbital debris requirements under treaties and other international agreements to which the United States is a signatory, and other nonbinding international arrangements in which the United States participates, and the manner and extent to which the Federal Government complies with those requirements and arrangements.

(4) An assessment of existing Federal Government assets used to conduct space traffic management and space situational awareness.

(5) An assessment of the risk to space traffic management associated with smallsats and any necessary Government coordination for their launch and utilization to avoid congestion of the orbital environment and improve space situational awareness.

(6) An assessment of existing private sector information sharing activities associated with space situational awareness and space traffic management.
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(7) Recommendations related to the appropriate framework for the protection of the health, safety, and welfare of the public and economic vitality of the space industry.

(d) REPORT.—Not later than 1 year after the date of enactment of this Act, the Administrator shall submit to the Committee on Commerce, Science, and Transportation of the Senate and the Committee on Science, Space, and Technology of the House of Representatives the study required in subsection (b).

(2) DEPARTMENT OF DEFENSE AUTHORITIES.—

(1) SENSE OF CONGRESS.—It is the sense of Congress that the Department of Defense plays a vital and unique role in protecting national security assets in space.

(2) RULE OF CONSTRUCTION.—Nothing in this section may be construed to affect the authority of the Secretary of Defense as it relates to safeguarding the national security.

SEC. 119. SPACE SURVEILLANCE AND SITUATIONAL AWARENESS DATA.

Not later than 120 days after the date of enactment of this Act, the Secretary of Transportation in concurrence with the Secretary of Defense shall—

(1) in consultation with the heads of other relevant Federal agencies, study the feasibility of processing and releasing space situational awareness data and information to any entity consistent with national security interests and public safety obligations of the United States; and

(2) submit a report on the feasibility study to the Committee on Commerce, Science, and Transportation of the Senate and the Committee on Science, Space, and Technology of the House of Representatives.

SEC. 111. CONSENSUS STANDARDS AND EXTENSION OF CERTAIN SAFETY REGULATION REQUIREMENTS.

Section 59905(c) is amended—

(1) in paragraph (1), by inserting “IN GENERAL.—” before “The Secretary”;

(3) in paragraph (2), by inserting “REGULATIONS.—” before “Regulations”;

(3) by striking paragraph (3);

(4) by redesignating paragraph (4) as paragraph (10);

(5) by inserting after paragraph (2) the following:

(3) FACILITATION OF STANDARDS.—The Secretary shall continue to work with the commercial space sector, including the Commercial Space Transportation Advisory Committee, or its successor organization, to facilitate the development of voluntary industry consensus standards based on recommended best practices to improve the safety of crew, government astronauts, and space flight participants as the commercial space sector continues to mature.

(4) COMMUNICATION AND TRANSPARENCY.—Nothing in this subsection shall be construed to limit the authority of the Secretary to discuss potential regulatory approaches, potential performance standards, or any other topic related to this subsection with the commercial space industry, including observations, findings, and recommendations from the Commercial Space Transportation Advisory Committee, or its successor organization, prior to the issuance of a notice of proposed rulemaking. Such discussions shall not be construed to permit
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the Secretary to promulgate industry regulations except as otherwise provided in this section.

(6) INTERIM VOLUNTARY INDUSTRY CONSENSUS STANDARDS REPORTS—

(A) IN GENERAL.—Not later than December 31, 2016, and every 30 months thereafter until December 31, 2021, the Secretary, in consultation and coordination with the commercial space sector, including the Commercial Space Transportation Advisory Committee, or its successor organization, shall submit to the Committee on Commerce, Science, and Transportation of the Senate and the Committee on Science, Space, and Technology of the House of Representatives a report on the progress of the commercial space transportation industry in developing voluntary industry consensus standards that promote best practices to improve industry safety.

(B) CONTENTS.—The report shall include, at a minimum—

(i) any voluntary industry consensus standards that have been accepted by the industry at large;

(ii) the identification of areas that have the potential to become voluntary industry consensus standards that are currently under consideration by the industry at large;

(iii) an assessment from the Secretary on the general progress of the industry in adopting voluntary industry consensus standards;

(iv) any lessons learned about voluntary industry consensus standards, best practices, and commercial space launch operations;

(v) any lessons learned associated with the development, potential application, and acceptance of voluntary industry consensus standards, best practices, and commercial space launch operations; and

(vi) recommendations, findings, or observations from the Commercial Space Transportation Advisory Committee, or its successor organization, on the progress of the industry in developing voluntary industry consensus standards that promote best practices to improve industry safety.

(6) REPORT.—Not later than 270 days after the date of enactment of the SPACE Act of 2015, the Secretary, in consultation and coordination with the commercial space sector, including the Commercial Space Transportation Advisory Committee, or its successor organization, shall submit to the Committee on Commerce, Science, and Transportation of the Senate and the Committee on Science, Space, and Technology of the House of Representatives a report specifying key industry metrics that might indicate readiness of the commercial space sector and the Department of Transportation to transition to a safety framework that may include regulations under paragraph (9) that considers space flight participant, government astronaut, and crew safety.

(7) REPORTS.—Not later than March 31 of each of 2018 and 2022, the Secretary, in consultation and coordination with the commercial space sector, including the Commercial Space...
Transportation Advisory Committee, or its successor organization, shall submit to the Committee on Commerce, Science, and Transportation of the Senate and the Committee on Science, Space, and Technology of the House of Representatives a report that identifies the activities, described in this subsection and subsection (d) most appropriate for a new safety framework that may include regulatory action, if any, and a proposed transition plan for such safety framework. Deadline. 

(9) LEARNING PERIOD.—Beginning on October 1, 2023, the Secretary may propose regulations under this subsection without regard to subparagraphs (C) and (D) of paragraph (2). The development of any such regulations shall take into consideration the evolving standards of the commercial space flight industry as identified in the reports published under paragraphs (5), (6), and (7). Effective date.

SEC. 112. GOVERNMENT ASTRONAUTS. 

(a) FINDINGS AND PURPOSE.—Section 50901(15) is amended by inserting "government astronauts," after "crew" each place it appears.

(b) SENSE OF CONGRESS.—The National Aeronautics and Space Administration needs to fly government astronauts (as defined in section 50902 of title 51, United States Code, as amended) within commercial launch vehicles and reentry vehicles under chapter 509 of that title. This need was identified by the Secretary of Transportation and the Administrator of the National Aeronautics and Space Administration due to the intended use of commercial launch vehicles and reentry vehicles developed under the Commercial Crew Development Program, authorized in section
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It is the sense of Congress that the authority delegated to the Administration by the amendment made by subsection (d) of this section should be used for that purpose.

(c) DEFINITION OF GOVERNMENT ASTRONAUT.—Section 50902 is amended—

(1) by redesignating paragraphs (4) through (22) as paragraphs (7) through (25), respectively; and
(2) by inserting after paragraph (3) the following:

"(4) ‘government astronaut’ means an individual who—

(A) is designated by the National Aeronautics and Space Administration under section 20113(n);

(B) is carried within a launch vehicle or reentry vehicle in the course of his or her employment, which may include performances of activities directly relating to the launch, reentry, or other operation of the launch vehicle or reentry vehicle; and

(C) is either—

(i) an employee of the United States Government, including the uniformed services, engaged in the performance of a Federal function under authority of law or an Executive act; or

(ii) an international partner astronaut.

(5) ‘international partner astronaut’ means an individual designated under Article 11 of the International Space Station Intergovernmental Agreement, by a partner to that agreement other than the United States, as qualified to serve as an International Space Station crew member.

(6) ‘International Space Station Intergovernmental Agreement’ means the Agreement Concerning Cooperation on the International Space Station, signed at Washington January 29, 1998 (TIAS 12927)."

(d) POWERS OF THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION IN PERFORMANCE OF FUNCTIONS.—Section 20113 is amended by adding at the end the following:

"(p) IDENTIFICATION OF GOVERNMENT ASTRONAUTS.—For purposes of a license issued or transferred by the Secretary of Transportation under chapter 509 to launch a launch vehicle or to reenter a reentry vehicle carrying a government astronaut (as defined in section 50902), the Administration shall designate a government astronaut in accordance with requirements prescribed by the Administration.

(q) DEFINITION OF LAUNCH.—Paragraph (7) of section 50902, as redesignated, is amended by striking "and any payload, crew, or space flight participant" and inserting "and any payload or human being".

(r) DEFINITION OF LAUNCH SERVICES.—Paragraph (9) of section 50902, as redesignated, is amended by striking "payload, crew (including crew training), or space flight participant" and inserting "payload, crew (including crew training), government astronaut, or space flight participant".

(g) DEFINITION OF REENTER AND REENTRY.—Paragraph (16) of section 50902, as redesignated, is amended by striking "and its payload, crew, or space flight participants, if any," and inserting "and its payload or human beings, if any,".
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(h) DEFINITION OF REENTRY SERVICES.—Paragraph (17) of section 50902, as redesignated, is amended by striking “payload, crew (including crew training), or space flight participant, if any,” and inserting “payload, crew (including crew training), government astronaut, or space flight participant, if any.”

(i) DEFINITION OF SPACE FLIGHT PARTICIPANT.—Paragraph (20) of section 50902, as redesignated, is amended to read as follows:

“(20) ‘space flight participant’ means an individual, who is not crew or a government astronaut, carried within a launch vehicle or reentry vehicle.”

(j) DEFINITION OF THIRD PARTY.—Paragraph (24)(E) of section 50902, as redesignated, is amended by inserting “. government astronauts,” after “crew”.

(k) RESTRICTIONS ON LAUNCHES, OPERATIONS, AND REENTRIES; SINGLE LICENSE OR PERMIT.—Section 50904(d) is amended by striking “activities involving crew or space flight participants” and inserting “activities involving crew, government astronauts, or space flight participants”.

(l) LICENSE APPLICATIONS AND REQUIREMENTS; APPLICATIONS.—Section 50905 is amended—

(1) in subsection (a)(2), by striking “crews and space flight participants” and inserting “crew, government astronauts, and space flight participants”;

(2) in subsection (b)(2)(D), by striking “crew or space flight participants” and inserting “crew, government astronauts, or space flight participants”;

and

(3) in subsection (c)—

(A) in paragraph (1), by striking “crew and space flight participants” and inserting “crew, government astronauts, and space flight participants”; and

(B) in paragraph (2), by striking “to crew or space flight participants” each place it appears and inserting “to crew, government astronauts, or space flight participants”.

(m) MONITORING ACTIVITIES.—Section 50907(a) is amended by striking “at a site used for crew or space flight participant training” and inserting “at a site not owned or operated by the Federal Government or a foreign government used for crew, government astronaut, or space flight participant training”.

(n) ADDITIONAL SUSPENSIONS.—Section 50908(d)(1) is amended by striking “to crew or space flight participants” each place it appears and inserting “to any human being”.

(o) RELATIONSHIP TO OTHER EXECUTIVE AGENCIES, LAWS, AND INTERNATIONAL OBLIGATIONS; NONAPPLICATION.—Section 50919(g) is amended to read as follows:

“(g) NONAPPLICATION.—

“(1) IN GENERAL.—This chapter does not apply to—

“(A) a launch, reentry, operation of a launch vehicle or reentry vehicle, operation of a launch site or reentry site, or other space activity the Government carries out for the Government; or

“(B) planning or policies related to the launch, reentry, operation, or activity under subparagraph (A).

“(2) RULE OF CONSTRUCTION.—The following activities are not space activities the Government carries out for the Government under paragraph (1):
SEC. 113. STREAMLINE COMMERCIAL SPACE LAUNCH ACTIVITIES.

(a) SENSE OF CONGRESS.—It is the sense of Congress that eliminating duplicative requirements and approvals for commercial launch and reentry operations will promote and encourage the development of the commercial space sector.

(b) REAFFIRMATION OF POLICY.—Congress reaffirms that the Secretary of Transportation, in overseeing and coordinating commercial launch and reentry operations, should—

(1) promote commercial space launches and reentries by the private sector;
(2) facilitate Government, State, and private sector involvement in enhancing U.S. launch sites and facilities;
(3) protect public health and safety, safety of property, national security interests, and foreign policy interests of the United States; and
(4) consult with the head of another executive agency, including the Secretary of Defense or the Administrator of the National Aeronautics and Space Administration, as necessary to provide consistent application of licensing requirements under chapter 509 of title 51, United States Code.

(c) REQUIREMENTS.—

(1) IN GENERAL.—The Secretary of Transportation under section 50918 of title 51, United States Code, and subject to section 50905(b)(2)(B) of that title, shall consult with the Secretary of Defense, the Administrator of the National Aeronautics and Space Administration, and the heads of other executive agencies, as appropriate—

(A) to identify all requirements that are imposed to protect the public health and safety, safety of property, national security interests, and foreign policy interests of the United States relevant to any commercial launch of a launch vehicle or commercial reentry of a reentry vehicle; and

(B) to evaluate the requirements identified in subparagraph (A) and, in coordination with the licensee or transferee and the heads of the relevant executive agencies—

(i) determine whether the satisfaction of a requirement of one agency could result in the satisfaction of a requirement of another agency; and

(ii) resolve any inconsistencies and remove any outdated or duplicative requirements or approvals of the Federal Government relevant to any commercial launch of a launch vehicle or commercial reentry of a reentry vehicle.

(2) REPORTS.—Not later than 180 days after the date of enactment of this Act, and annually thereafter until the Secretary of Transportation determines no outdated or duplicative requirements or approvals of the Federal Government exist, the Secretary of Transportation, in consultation with the Secretary of Defense, the Administrator of the National Aeronautics and Space Administration, the commercial space sector,
and the heads of other executive agencies, as appropriate, shall submit to the Committee on Commerce, Science, and Transportation of the Senate, the Committee on Science, Space, and Technology of the House of Representatives, and the congressional defense committees a report that includes the following:

(A) A description of the process for the application for and approval of a permit or license under chapter 509 of title 51, United States Code, for the commercial launch of a launch vehicle or commercial reentry of a reentry vehicle, including the identification of—

(i) any unique requirements for operating on a United States Government launch site, reentry site, or launch property; and

(ii) any inconsistent, outdated, or duplicative requirements or approvals.

(B) A description of current efforts, if any, to coordinate and work across executive agencies to define interagency processes and procedures for sharing information, avoiding duplication of effort, and resolving common agency requirements.

(C) Recommendations for legislation that may further—

(i) streamline requirements in order to improve efficiency, reduce unnecessary costs, resolve inconsistencies, remove duplication, and minimize unwarranted constraints; and

(ii) consolidate or modify requirements across affected agencies into a single application set that satisfies the requirements identified in paragraph (1)(A).

(3) DEFINITIONS.—For purposes of this subsection—

(A) any applicable definitions set forth in section 50902 of title 51, United States Code, shall apply;

(B) the terms “launch”, “reenter”, and “reentry” include landing of a launch vehicle or reentry vehicle; and

(C) the terms “United States Government launch site” and “United States Government reentry site” include any necessary facility, at that location, that is commercially operated on United States Government property.

SEC. 114. OPERATION AND UTILIZATION OF THE ISS.

(a) SENSE OF CONGRESS.—It is the sense of Congress that—

(1) maximum utilization of partnerships, scientific research, commercial applications, and exploration test bed capabilities of the ISS is essential to ensuring the greatest return on investments made by the United States and its international partners in the development, assembly, and operations of that unique facility; and

(2) every effort should be made to ensure that decisions regarding the service life of the ISS are based on the station’s projected capability to continue providing effective and productive research and exploration test bed capabilities.

(b) CONTINUATION OF THE INTERNATIONAL SPACE STATION.—

(1) IN GENERAL.—Section 501 of the National Aeronautics and Space Administration Authorization Act of 2010 (42 U.S.C. 18351) is amended—

(A) in the heading, by striking “THROUGH 2029”;}
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SEC. 115. STATE COMMERCIAL LAUNCH FACILITIES.

(a) SENSE OF CONGRESS.—It is the sense of Congress that—

(1) State involvement, development, ownership, and operation of launch facilities can enable growth of the Nation’s commercial suborbital and orbital space endeavors and support both commercial and Government space programs;
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(2) State launch facilities and the people and property in the affected launch areas of those facilities may be subject to risks resulting from an activity carried out under a license under chapter 609 of title 51, United States Code; and

(3) to ensure the success of the commercial launch industry and the safety of the people and property in the affected launch areas of those facilities, States and State launch facilities should seek to take proper measures to protect themselves, to the extent of their potential liability for involvement in launch services or reentry services, and compensate third parties for possible death, bodily injury, or property damage or loss resulting from an activity carried out under a license under chapter 509 of title 51, United States Code, to which the State or State launch facility is involved in the launch services or reentry services.

(b) REPORT.—Not later than 1 year after the date of enactment of this Act, the Comptroller General shall submit to the Committee on Commerce, Science, and Transportation of the Senate and the Committee on Science, Space, and Technology of the House of Representatives a report on the potential inclusion of all government property, including State and municipal property, in the existing indemnification regime established under section 5914 of title 51, United States Code.

SEC. 116. SPACE SUPPORT VEHICLES STUDY.

(a) IN GENERAL.—Not later than 1 year after the date of enactment of this Act, the Comptroller General shall submit to the Committee on Commerce, Science, and Transportation of the Senate and the Committee on Science, Space, and Technology of the House of Representatives a report on the use of space support vehicles services in the commercial space industry.

(b) CONTENTS.—This report shall include—

(1) the extent to which launch providers rely on such services as part of their business models;

(2) the statutory, regulatory, and market barriers to the use of such services; and

(3) recommendations for legislative or regulatory action that may be needed to ensure reduced barriers to the use of such services if such use is a requirement of the industry.

SEC. 117. SPACE LAUNCH SYSTEM UPDATE.

(a) IN GENERAL.—Chapter 701 is amended—

(1) in the heading by striking “SPACE SHUTTLE” and inserting “SPACE LAUNCH SYSTEM”;

(2) in section 70101—

(A) in the heading, by striking “space shuttle” and inserting “space launch system”;

(B) by striking “space shuttle” and inserting “space launch system”;

(3) by amending section 70102 to read as follows:

“§ 70102. Space launch system use policy

(a) IN GENERAL.—The Space Launch System may be used for the following circumstances:

(1) Payloads and missions that contribute to extending human presence beyond low-Earth orbit and substantially benefit from the unique capabilities of the Space Launch System.
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“(2) Other payloads and missions that substantially benefit from the unique capabilities of the Space Launch System.

“(3) On a space available basis, Federal Government or educational payloads that are consistent with NASA’s mission for exploration beyond low-Earth orbit.

“(4) Compelling circumstances, as determined by the Administrator.

“(b) AGREEMENTS WITH FOREIGN ENTITIES.—The Administrator may plan, negotiate, or implement agreements with foreign entities for the launch of payloads for international collaborative efforts relating to science and technology using the Space Launch System.

“(c) COMPPELLING CIRCUMSTANCES.—Not later than 30 days after the date the Administrator makes a determination under subsection (a)(4), the Administrator shall transmit to the Committee on Commerce, Science, and Transportation of the Senate and the Committee on Science of the House of Representatives written notification of the Administrator’s intent to select the Space Launch System for a specific mission under that subsection, including justification for the determination.”;

51 USC 70103.

(4) in section 70103—

(A) in the heading, by striking “SPACE SHUTTLE” and inserting “SPACE LAUNCH SYSTEM”; and

(B) in subsection (b), by striking “space shuttle” each place it appears and inserting “space launch system”; and

(5) by adding at the end the following:

51 USC 70104.

“§ 70104. Definition of Space Launch System

“In this chapter, the term ‘Space Launch System’ means the Space Launch System authorized under section 302 of the National Aeronautics and Space Administration Authorization Act of 2010 (42 U.S.C. 18322).”;

51 USC proc. 10101.

(b) TECHNICAL AND CONFORMING AMENDMENTS.—

(1) TABLE OF CHAPTERS.—The table of chapters of title 51 is amended by amending the item relating to chapter 701 to read as follows:

701. Use of space launch system or alternatives 70101

(2) TABLE OF CONTENTS OF CHAPTER 701.—The table of contents of chapter 701 is amended—

(A) in the item relating to section 70101, by striking “space shuttle” and inserting “space launch system”;

(B) in the item relating to section 70102, by striking “Space shuttle” and inserting “Space launch system”;

(C) in the item relating to section 70103, by striking “space shuttle” and inserting “space launch system”; and

(D) by adding at the end the following:

70104. Definition of Space Launch System.”;

51 USC proc. 70101.

(3) REQUIREMENT TO PROCUREMENT COMMERCIAL SPACE TRANSPORTATION SERVICES.—Section 50131(a) of chapter 51 is amended by inserting “or in section 70102” after “in this section”.

51 USC 50131.
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TITLE II—COMMERCIAL REMOTE SENSING

SEC. 901. ANNUAL REPORTS.
(a) IN GENERAL.—Subchapter III of chapter 601 is amended by adding at the end the following:

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§ 60126. Annual reports
(a) IN GENERAL.—The Secretary shall submit a report to the Committee on Commerce, Science, and Transportation of the Senate and the Committee on Science, Space, and Technology of the House of Representatives not later than 180 days after the date of enactment of the U.S. Commercial Space Launch Competitiveness Act, and annually thereafter, on—
(1) the Secretary’s implementation of section 60121, including—
(A) a list of all applications received in the previous calendar year;
(B) a list of all applications that resulted in a license under section 60121;
(C) a list of all applications denied and an explanation of why each application was denied, including any information relevant to the interagency adjudication process of a licensing request;
(D) a list of all applications that required additional information; and
(E) a list of all applications whose disposition exceeded the 120 day deadline established in section 60121(c), the total days overdue for each application that exceeded such deadline, and an explanation for the delay;
(2) all notifications and information provided to the Secretary under section 60125; and
(3) a description of all actions taken by the Secretary under the administrative authority granted by paragraphs (4), (5), and (6) of section 60129(a).
(b) CLASSIFIED ANNEXES.—Each report under subsection (a) may include classified annexes as necessary to protect the disclosure of sensitive or classified information.
(c) SUNSET.—The reporting requirement under this section terminates effective September 30, 2020.
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(b) TABLE OF CONTENTS.—The table of contents of chapter 601 is amended by inserting after the item relating to section 60125 the following:

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*§ 60126. Annual reports.*
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SEC. 902. STATUTORY UPDATE REPORT.

Not later than 1 year after the date of enactment of this Act, the Secretary of Commerce, in consultation with the heads of other appropriate Federal agencies and the National Oceanic and Atmospheric Administration’s Advisory Committee on Commercial Remote Sensing, shall submit to the Committee on Commerce, Science, and Transportation of the Senate and the Committee on Science, Space, and Technology of the House of Representatives a report on statutory updates necessary to license private remote sensing space systems. In preparing the report, the Secretary shall
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take into account the need to protect national security while maintaining United States private sector leadership in the field, and reflect the current state of the art of remote sensing systems, instruments, or technologies.

TITLE III—OFFICE OF SPACE COMMERCE

SEC. 301. RENAMING OF OFFICE OF SPACE COMMERCIALIZATION.

(a) CHAPTER HEADING.—

1. Amendment.—The heading for chapter 507 is amended by striking “COMMERCIALIZATION” and inserting “COMMERCE”.

2. CONFORMING AMENDMENT.—The item relating to chapter 507 in the table of chapters for title 51 is amended by striking “Commercialization” and inserting “Commerce”.

3. DEFINITION OF OFFICE.—Section 50701 is amended by striking “Commercialization” and inserting “Commerce”.

(b) RENAMING.—Section 50702(a) is amended by striking “Commercialization” and inserting “Commerce”.

SEC. 302. FUNCTIONS OF THE OFFICE OF SPACE COMMERCE.

Section 50702(c) is amended by striking “Commerce” and inserting “Commerce, including—

“(1) to foster the conditions for the economic growth and technological advancement of the United States space commerce industry;

“(2) to coordinate space commerce policy issues and actions within the Department of Commerce;

“(3) to represent the Department of Commerce in the development of United States policies and in negotiations with foreign countries to promote United States space commerce;

“(4) to promote the advancement of United States geospatial technologies related to space commerce, in cooperation with relevant interagency working groups; and

“(5) 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.”

TITLE IV—SPACE RESOURCE EXPLORATION AND UTILIZATION

SEC. 401. SHORT TITLE.

This title may be cited as the “Space Resource Exploration and Utilization Act of 2015”.

SEC. 402. TITLE 51 AMENDMENT.

(a) In General.—Subtitle V is amended by adding at the end the following:
PUBLIC LAW 114–90—NOV. 25, 2015

*CHAPTER 513—SPACE RESOURCE COMMERCIAL EXPLORATION AND UTILIZATION*

Sec. 51301. Definitions.
51302. Commercial exploration and commercial recovery.
51303. Asteroid resource and space resource rights.

§ 51301. Definitions

"In this chapter:

(a) ASTEROID RESOURCE.—The term ‘asteroid resource’ means a space resource found on or within a single asteroid.

(b) SPACE RESOURCE.—

(A) IN GENERAL.—The term ‘space resource’ means an abiotic resource in situ in outer space.

(B) EXCLUSIONS.—The term ‘space resource’ includes water and minerals.

(c) UNITED STATES CITIZEN.—The term ‘United States citizen’ has the meaning given the term ‘citizen of the United States’ in section 50902.

§ 51302. Commercial exploration and commercial recovery

(a) IN GENERAL.—The President, acting through appropriate Federal agencies, shall—

(1) facilitate commercial exploration for and commercial recovery of space resources by United States citizens;

(2) discourage government barriers to the development in the United States of economically viable, safe, and stable industries for commercial exploration for and commercial recovery of space resources in manners consistent with the international obligations of the United States; and

(3) promote the right of United States citizens to engage in commercial exploration for and commercial recovery of space resources free from harmful interference, in accordance with the international obligations of the United States and subject to authorization and continuing supervision by the Federal Government.

(b) REPORT.—Not later than 180 days after the date of enactment of this section, the President shall submit to Congress a report on commercial exploration for and commercial recovery of space resources by United States citizens that specifies—

(1) the authorities necessary to meet the international obligations of the United States, including authorization and continuing supervision by the Federal Government; and

(2) recommendations for the allocation of responsibilities among Federal agencies for the activities described in paragraph (1).

§ 51303. Asteroid resource and space resource rights

"A United States citizen engaged in commercial recovery of an asteroid resource or a space resource under this chapter shall be entitled to any asteroid resource or space resource obtained, including to possess, own, transport, use, and sell the asteroid resource or space resource obtained in accordance with applicable law, including the international obligations of the United States."
129 STAT. 722
PUBLIC LAW 114-90—NOV. 25, 2015

(b) TABLE OF CHAPTERS.—The table of chapters for title 51 is amended by adding at the end of the items for subtitle V the following:

513. Space resource commercial exploration and utilization .......................................................51301.

SEC. 403. DISCLAIMER OF EXTRATERRITORIAL SOVEREIGNTY.

It is the sense of Congress that by the enactment of this Act, the United States does not thereby assert sovereignty or sovereign or exclusive rights or jurisdiction over, or the ownership of, any celestial body.

Approved November 25, 2015.

LEGISLATIVE HISTORY.—H.R. 2362:
HOUSE REPORTS: No. 114–119 (Comm. on Science, Space, and Technology).
May 21, considered and passed House.
Nov. 10, considered and passed Senate, amended.
Nov. 16, House concurred in Senate amendment.
APPENDIX J  NASA Study Contract Statement of Work

Statement of Work
Orbital Traffic Management Study
May 16, 2016

1. Purpose
The purpose of Orbital Traffic Management Study (OTMS) is to perform an independent assessment of alternate frameworks for the management of space traffic and orbital activities in response to the following statement contained in the U.S. Commercial Space Launch Competitive Act, 2015:

   It is the sense of the Congress that an improved framework may be necessary for space traffic management of United States Government assets and United States private sector assets in outer space and orbital debris mitigation.

   --U.S. Commercial Space Launch Competitiveness Act, (Public Law 114-90, Section 109)

In undertaking the tasks below, the contractor shall consult with U.S. government stakeholders engaged in space traffic and orbital activities, including NASA, Federal Communications Commission, Department of Transportation, Department of Commerce, Department of State and the Department of Defense.

2. Scope of Work / Study Approach
The study is composed of these eight tasks:

   TASK 2.1: An assessment of current regulations, best practices, and industry standards that apply to space traffic management and orbital debris mitigation.

   TASK 2.2: An assessment of current statutory authorities granted to the Federal Communications Commission, the Department of Transportation, and the Department of Commerce that apply to space traffic management and orbital debris mitigation and how those agencies utilize and coordinate those authorities.

   TASK 2.3: A review of all space traffic management and orbital debris requirements under treaties and other international agreements to which the United States is a signatory, and other nonbinding international arrangements in which the United States participates, and the manner and extent to which the Federal Government complies with those requirements and arrangements.

   TASK 2.4: An assessment of existing Federal Government assets used to conduct space traffic management and space situational awareness.

   TASK 2.5: An assessment of the unique safety considerations needed for human space flight, particularly the International Space Station.
**TASK 2.6:** An assessment of the risk to space traffic management associated with smallsats and any necessary Government coordination for their launch and utilization to avoid congestion of the orbital environment and improve space situational awareness.

**TASK 2.7:** An assessment of existing private sector information sharing activities associated with space situational awareness and space traffic management.

**TASK 2.8:** Recommendations related to the appropriate framework for the protection of the health, safety, and welfare of the public and economic vitality of the space industry.

3. **Milestones and Deliverables:**

The contractor shall provide all deliverables/reports as specified below:

<table>
<thead>
<tr>
<th>Deliverable</th>
<th>Quantity</th>
<th>Delivery Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kickoff Meeting</td>
<td>1</td>
<td>Within 1 week of contract award</td>
</tr>
<tr>
<td>Monthly Status Reports w/ technical interchange meetings as necessary</td>
<td>6</td>
<td>Due on the 24(^{th}) day of each month after contract award</td>
</tr>
<tr>
<td>Mid-Term Summary Meeting</td>
<td>1</td>
<td>Due not later than September 7, 2016</td>
</tr>
<tr>
<td>Mid-Term Report of Tasks 2.1 thru 2.7</td>
<td>1</td>
<td>Due after completion of Tasks 2.1 thru 2.7, but not later than September 7, 2016. Due at least two days prior to Mid-Term Summary Meeting.</td>
</tr>
<tr>
<td>Final Summary Meeting</td>
<td>1</td>
<td>Due not later than October 31, 2016</td>
</tr>
<tr>
<td>Final Report (Draft)</td>
<td>1</td>
<td>Due at Final Summary Meeting</td>
</tr>
<tr>
<td>Final Report</td>
<td>1</td>
<td>Due not later than November 7, 2016</td>
</tr>
</tbody>
</table>

3.1 This contract shall be completed not later than November 14, 2016. A kickoff meeting shall be conducted within 1 week of contract award. A mid-term summary meeting shall be conducted to review Tasks 2.1 through 2.7. A final summary meeting to review completion of all tasks, including a review of the draft Final Report, shall be conducted before the end the study.

3.2 The contractor shall provide monthly reports containing accomplishments, activities planned for the next month, and any issues or assistance required to complete the work.
- Each monthly report shall be delivered electronically by the 24th day of each month.
- If requested, the contractor shall provide supplemental background information produced by the contractor in support of the tasks of this SOW.

3.3 Mid-term report and a briefing shall be provided at the completion of the Tasks 2.1 through 2.7 two days prior to the Mid-Term Summary Meeting.
3.4 The contractor shall review the results of Tasks 2.1-2.7 at the Mid-Term Summary Meeting. In addition, the contractor will outline progress related to integrating the assessments of Tasks 2.1-2.7 into the recommendations of Task 2.8.

3.5 A draft Final Report shall be provided one week prior to the Final Summary Meeting. The Final Report shall be provided at the end of the study’s period of performance.

- Prior to the conclusion of this effort copies of all products (reports, analyses, etc.) produced shall be provided with the final report.

3.6 NASA will help facilitate initial meetings between the contractor and various USG stakeholders.

4. **Classified Information:**

This contract will involve access to classified information, including TS/SCI material. However, the final report will be an unclassified document and is expected to be of a predecisional nature and should be protected from dissemination beyond the NASA customer. Following receipt of the final report, NASA will submit it to Congress in accordance with P.L. 114-90, Sec. 109.

5. **Government Furnished Equipment:**

None.

6. **Travel:**

Non-local travel will be required to various USG stakeholders. At least 3 trips are anticipated, one each to California, Texas, and Colorado. Local travel will be required to NASA Headquarters at the beginning of the contract, at the midterm meeting, at the final presentation, and, as proposed, to accomplish the statement of work, e.g., local travel may also be required to Goddard Space Flight Center, MD, and other USG stakeholders in the DC area.

7. **Period of Performance:**

Award through November 14, 2016.

8. **Place of Performance:**

Contractor’s Facility

9. **Contact Information:**

The Contractor shall keep the Contracting Officer’s Technical Representative (COTR) and the Technical Monitor (TM) informed of task status and progress by regular correspondence or meetings. The contractor shall provide all deliverables/reports via e-mail to the Task Monitor and the COTR at the e-mail address shown below.
Technical Monitors:

Name: Ave Kludze  
Phone: (202) 358-2098  
Email: ave.k.kludze@nasa.gov

Name: Patrick Besha  
Phone: (202) 358-2636  
Email: patrick.besha@nasa.gov

Mailing address:
NASA Headquarters  
Mail Code AB00  
300 E Street SW  
Washington DC 20546-0001

COTR:

Name: Michael Chatman  
Phone/Fax Number: 202.358.0085  
E-mail Address: michael.d.chatman@nasa.gov

Mailing address is:
NASA Headquarters  
Mail Stop 4M20  
300 E Street SW  
Washington DC 20546-0001
APPENDIX K  Approach and Plan

1.0 INTRODUCTION

SAIC is conducting the Orbital Traffic Management Study (OTMS) on behalf of NASA to perform an independent assessment of alternate frameworks for the management of space traffic and orbital activities to meet the requirements set out by Congress in the U.S. Commercial Space Launch Competitive Act, 2015, which states it is the sense of the Congress that an improved framework may be necessary for space traffic management of the United States Government assets and United States private sector assets in outer space and orbital debris mitigation (U.S. Commercial Space Launch Competitiveness Act, Public Law 114-90, Section 109).

The framework is a basic implementation plan for an OTM scheme guided by policy and enabled and contextualized by technology and operations. A framework provides planning structures for implementation of policy downward. But in the reverse, technology and operations can provide new contexts to inform the creation of necessary policy. We explore not only policies and technologies in existence, but those also we consider feasible for future evolution. From the feasible set of frameworks, we must then apply objective mission success criteria to compare one framework to another.

The study is composed of eight tasks

- An assessment of current regulations, best practices, and industry standards that apply to space traffic management and orbital debris mitigation.
- An assessment of current statutory authorities granted to the Federal Communications Commission, the Department of Transportation, and the Department of Commerce that apply to space traffic management and orbital debris mitigation and how those agencies utilize and coordinate those authorities.
- A review of all space traffic management and orbital debris requirements under treaties and other international agreements to which the United States is a signatory, and other nonbinding international arrangements in which the United States participates, and the manner and extent to which the Federal Government complies with those requirements and arrangements.
- An assessment of existing Federal Government assets used to conduct space traffic management and space situational awareness.
- An assessment of the unique safety considerations needed for human space flight, particularly the International Space Station.
- An assessment of the risk to space traffic management associated with smallsats and any necessary Government coordination for their launch and utilization to avoid congestion of the orbital environment and improve space situational awareness.
- An assessment of existing private sector information sharing activities associated with space situational awareness and space traffic management.
- Recommendations related to the appropriate framework for the protection of the health, safety, and welfare of the public and economic vitality of the space industry.

The mission success criteria are the following:
## Objective

<table>
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<tr>
<th>Considerations</th>
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<tbody>
<tr>
<td>I. Ensure and Enhance Safety of the Space Domain</td>
</tr>
<tr>
<td>- Protect workforce health (i.e., prevent death or injury of USG astronauts by</td>
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<tr>
<td>reducing the risk of Space Traffic Safety incidents involving crewed</td>
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<tr>
<td>spacecraft)</td>
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<tr>
<td>- Protect public health (i.e., prevent death or injury of space flight</td>
</tr>
<tr>
<td>participants by reducing the risk of Space Traffic Safety incidents</td>
</tr>
<tr>
<td>involving crewed spacecraft)</td>
</tr>
<tr>
<td>- Protect private and public orbital space assets by reducing the risk of</td>
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<tr>
<td>Space Traffic Safety incidents</td>
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<tr>
<td>- Ensure the long-term sustainability of the orbital space environment by</td>
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<tr>
<td>limiting the creation and effects of orbital debris caused by Space Traffic</td>
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<tr>
<td>Safety incidents</td>
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<tr>
<td>- Protect the public general welfare by reducing the risk of Space Traffic</td>
</tr>
<tr>
<td>Safety incidents that could result in loss of vital space-based information</td>
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<tr>
<td>services</td>
</tr>
<tr>
<td>II. Protect and Enhance National Security Space (NSS) Interests</td>
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<tr>
<td>- Enable and enhance the objectives of the National Space Policy, National</td>
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<tr>
<td>Security Space Strategy, and other derived NSS policies, strategies, and</td>
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<tr>
<td>plans</td>
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<tr>
<td>- Develop transparency and confidence-building measures to encourage responsible</td>
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<tr>
<td>actions in and the peaceful use of orbital space</td>
</tr>
<tr>
<td>III. Ensure Economic Vitality of the Space Domain and Space Industrial Base</td>
</tr>
<tr>
<td>- Encourage, facilitate, and promote the uninterrupted and free flow of</td>
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<tr>
<td>commerce in orbital space</td>
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<tr>
<td>- Minimize engineering, operations, and sustainment cost burdens on orbital</td>
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<tr>
<td>space system and orbital space operators</td>
</tr>
<tr>
<td>- Limit restraints on the traditional space industrial base and new orbital</td>
</tr>
<tr>
<td>space startups and initiatives</td>
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<tr>
<td>- Maximize opportunities for timely delivery and return of orbital space systems to and from orbit</td>
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## 2.0 IMPLEMENTATION PLAN

### 2.1 Step 1: Formulate

This first step immediately following the customer kick-off meeting is gathering the entire team to formulate the study approach in detail and review mission success criteria, study implementation plans, baseline OTM approach risks, and baseline framework solution options that will be the focus of the subsequent phases. Based on inputs, we will improve these plans, identified risks, and the framework tradespace.

### 2.2 Step 2: Research

The purpose of this step is to conduct a systematic investigation of numerous resources to inform the policy and technology and operations assessments and to understand past proposals and current opinions for OTM frameworks. In a literature review, we will collect reference materials and place them electronically into an online repository and physically into a library.
Site visits and workshops will elicit stakeholders’ understanding of OTM policies and technologies and operations relevant to their expertise and responsibilities. Site visits will begin in early July and will run into August. The first and second workshop will be held at the end of July and the final workshop will occur in the beginning of August at the 2016 Small Satellite Conference in Utah.

Site visits will focus on collecting stakeholder inputs on areas of policy and/or technology and operations relevant to their responsibilities and areas of expertise. As appropriate, we will collect their preferences for an OTM framework. At our site visits, we will conduct the stakeholder interviews with the aid of a uniform survey prepared during the formulation phase. Dr. Brown and Mr. Long will conduct these stakeholder meetings.

We also will use workshops to further gather input from multiple stakeholders in a group setting and will focus on specific areas of policy or technology and operations.

2.3 Step 3. Synthesize

In this step, we integrate the data collected in the research phase. We place reference material compiled into structures (e.g., taxonomies) and develop statistics and conclusions from stakeholder surveys. We also summarize workshop observations. These assessments are created in the context of our Mission Success criteria for an OTM framework. Specifically, we evaluate task risks related to the Mission Success criteria and provide impacts to a beneficial framework. We also develop and provide risk mitigation steps, including unique considerations of new approaches to applicable policy and technology and operations.

2.4 Step 4. Strategize

This study leads to the creation of the recommended OTM framework. This is the final step of the study, but it is conducted concurrently during with the first three serial study steps as framework development informs and is informed by all other study activities.
## APPENDIX L  Interview and Workshop List

### Congress

<table>
<thead>
<tr>
<th>Office</th>
<th>Personnel</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>House Committee</td>
<td>Pamela Whitney</td>
<td>October 12, 2016</td>
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<tr>
<td>Science, Space, and Technology</td>
<td>Jonathan Charlton</td>
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<tr>
<td>Subcommittee on Space</td>
<td>Brian Corcoran</td>
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<td></td>
<td>Michael Mineiro</td>
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<td>Ryan Faith</td>
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<td>Allen Li</td>
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<td>Phillip Putter</td>
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<tr>
<td>Defense Advanced Research Projects Agency</td>
<td>Pam Melroy</td>
<td>July 19, 2016</td>
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### Department of Defense (DOD)

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<td>Josef Koller</td>
<td>July 6, 2016</td>
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<tr>
<td>Office of the Secretary of the Air Force</td>
<td>Steven Henry</td>
<td>July 7, 2016</td>
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<tr>
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<td>Michael Draper</td>
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<tr>
<td>Office of the Secretary of Defense</td>
<td>Josef Koller</td>
<td>July 15, 2016</td>
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<tr>
<td>Office of the Secretary of Defense</td>
<td>Douglas Loverro</td>
<td>August 24, 2016</td>
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<tr>
<td>Office of Space Policy</td>
<td>Josef Koller</td>
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<tr>
<td></td>
<td>Elizabeth Phu</td>
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<td>Winston Beauchamp</td>
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### Department of State

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<td>Amber Charlesworth</td>
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<tr>
<td>Office of Emerging Security Challenges</td>
<td>Richard Buenneke</td>
<td>August 1, 2016</td>
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<tr>
<td>International Bureau Satellite Division</td>
<td>Karl Kensinger</td>
<td>August 24, 2016</td>
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<td>Stephen Duall</td>
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<td>Jose Albuquerque</td>
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<tr>
<td>International Bureau Office of the Bureau Chief</td>
<td>Troy Tanner</td>
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<tr>
<td>Office of Engineering and Technology,</td>
<td>Walter Johnston</td>
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<tr>
<td>Electromagnetic Compatibility Division</td>
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<td>Federally Funded Research and Development Center</td>
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<td>Aerospace Corporation</td>
<td>Barbara Braun</td>
<td>September 22, 2016</td>
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<td>Massachusetts Institute of Technology</td>
<td>Jay Donnelly</td>
<td>September 27, 2016</td>
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<td>Glenn Peterson</td>
<td>November 2, 2016</td>
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<td></td>
<td>William Ailor</td>
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<td>Industry</td>
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<tr>
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<td>Mark Brown</td>
<td>July 19, 2016</td>
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<td>Michael Griffin</td>
<td>August 23, 2016</td>
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<tr>
<td>Company/Office</td>
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<tr>
<td>Intelsat General</td>
<td>Mark Daniels</td>
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<td>Clinton Clark</td>
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<td>SpaceX</td>
<td>Mark Krebs</td>
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<td>XL Catlin</td>
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<td>Travis Blake</td>
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<tr>
<td>OneWeb</td>
<td>Tim Maclay</td>
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<td>Interagency Meeting June 22, 2016</td>
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<tr>
<td>NASA Headquarters</td>
<td>Patrick Besha</td>
<td>June 22, 2016</td>
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<tr>
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<td>Ave Kludze</td>
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<tr>
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<tr>
<td>NASA Headquarters</td>
<td>Anne Sweet</td>
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## National Reconnaissance Office

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### Office of Management and Budget

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<td>Sam Black</td>
<td>July 1, 2016</td>
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<td>Force Structure and Investment Branch</td>
<td>Matt O’Kane</td>
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<td>Andrea Petro</td>
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### Office of Science and Technology Policy

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### Other Interest Groups

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<td>James Dunstan</td>
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<td>Scott Pace</td>
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