CENTER FOR SPACE POLICY AND STRATEGY

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# ESTABLISHING SPACE TRAFFIC MANAGEMENT STANDARDS, GUIDELINES, AND BEST PRACTICES

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# Summary

**U.S. Space Policy Directive - 3 (SPD-3), "National Space Traffic Management Policy," identifies the need for more than 40 different space traffic management (STM)-related standards, guidelines, and best practices to be developed to address a wide range of STM issues. In this paper, we describe why standards, guidelines, and best practices are important, assess the completeness of those called out in SPD-3, identify gaps, and discuss how the United States and other stakeholders might prioritize their development. Finally, we identify existing standards development organizations and call for increased investment, faster work, and new mechanisms to facilitate the formation and proliferation of necessary STM standards, guidelines, and best practices.**

## Introduction

On June 18, 2018, the U.S. National Space Council released SPD-3. One of SPD-3's primary goals is the development of STM standards, guidelines, and best practices. The policy states that a critical first step "is to develop U.S.-led minimum safety standards and best practices to coordinate space traffic." It also states that the U.S. should lead the world in developing improved space situational awareness (SSA) data standards, develop a set of standard techniques for mitigating collision risks, and internationally promote a range of norms of behavior, best practices, and standards for safe operations in space. It states:

> The Secretaries of Defense, Commerce, and Transportation, in coordination with the Secretary of State, the NASA Administrator, the Director of National Intelligence and in consultation with the Chairman of the FCC, shall develop space traffic standards and best practices, including technical guidelines, minimum safety standards, behavioral norms, and orbital conjunction protocols related to pre-launch risk assessment and on-orbit collision avoidance support services.[1]

In total, SPD-3 identifies the need for more than 40 different STM-related standards, guidelines, and best practices. However, it did not capture all the top-level standards, guidelines, and best practices that effective STM will require. In addition, with the exception of updating the U.S. government's Orbital Debris Mitigation Standard Practices (ODMSP) first, SPD-3 did not identify which standards, guidelines, and best practices should receive priority in their development. Here, we assess the completeness of the list of standards, guidelines, and best practices called out in SPD-3, identify gaps, and discuss different prioritization methods. Finally, we identify existing standards development organizations and call for increased investment, faster work, and new mechanisms to facilitate the formation and proliferation of necessary STM standards, guidelines, and best practices.

## Background: The Issues

The need for development of international STM standards, guidelines, and best practices is driven by the rapid growth of space activity since the turn of the century and plans for breathtaking increases in space activity over the next 10 years. Since the space age began more than 60 years ago, about 8,950 satellites have been placed in orbit, with about 5,000 remaining in orbit as of January 2019.[2] Now, a variety of companies have announced plans to launch more than 16,000 new satellites into orbit over the next decade.[3] Due primarily to improved sensors as well as continued on-orbit breakups, the amount of tracked space debris is also set to rise from about 20,000 trackable space debris objects today to hundreds of thousands of pieces of trackable space junk. Clearly, we are on the cusp of a fundamental change in the space environment. The new space age requires new models, new technologies, and new rules and regulations. But what is the best way to arrive at new rules and regulations?

Increased government regulation of space traffic seems inevitable. To that end, on October 25, 2018, the Federal Communications Commission (FCC) released the "Notice of Proposed Rulemaking and Order on Reconsideration, IB Docket No. 18-313."[4] The notice sought comments from the public on the proposed update to the orbital debris mitigation rules for all FCC-authorized satellites. The proposed update offers many potential new regulations, for example, new rules regarding space object trackability, information sharing requirements, orbit selection, post-mission disposal reliability, and dozens more technical and operational requirements.

However, tension exists between the government's need for regulation to protect the safety, security, and sustainability of the space environment and industry's desire to have minimal, clear, and consistent regulatory constraints. While most space industry players acknowledge the importance of orbital sustainability, increasing regulatory constraints on space activities could increase design and operational costs, frustrate commercial innovation, and discourage venture capital investments. Indeed, the rapidly evolving need for STM is a contemporary example of the conflict between the "Guardian" and "Merchant" cultures described by Scott Pace in 1999.[5] Pace describes Guardians mostly as governmental actors while Merchants refer mostly to groups of people from the business community. As Pace explains, the role of the Guardians is to protect some larger goal or system, often involving public safety. To do so, Guardians can collect taxes, establish rules and regulations, and negotiate agreements with other states. In the case of managing space traffic, the Guardians' goal is to protect the safety, security, and sustainability of the space environment.

Merchants, on the other hand, rely upon contractual relationships, engage in economic competition, and generally desire the freedom to maximize their economic gain. Indeed, the new space age is being driven largely by U.S.-based commercial space companies. The United States benefits from commercial space industry successes that bring high technology jobs, leading technologies, economic growth, and prestige to the United States. But these U.S. companies could chafe if the U.S. government imposes new regulatory burdens, raises costs, and otherwise inhibits their freedom of action in the marketplace. Ultimately, in today's globalized marketplace, less regulation in other countries could drive offshoring of U.S. companies to countries with fewer regulatory costs.

To alleviate some of these concerns, the FCC notice-and-comment rulemaking process, alluded to above, provides the public, industry, and other stakeholders the opportunity to provide input on a proposed rule before it becomes final.[6] In addition, the FCC often identifies specific issues on which it asks for public comment and data. The FCC usually allows 30 days for the public to file comments, after which the FCC considers the comments while developing the final rules. In this way, stakeholders are provided an opportunity to point out unduly complex or burdensome proposed rules and suggest ways to improve them.

Ideally, stakeholders will buy in to a new rule brought about through this process. However, the FCC only "considers" the public comments and is not required to change course due to the inputs. Hence, the government, with a perceived heavy hand, may still decide on a course of action that will negatively affect an industry's bottom line, and industry may look to go offshore to find a country with a more accommodating regulatory environment. The other country's gain would be an economic loss for the United States and a loss for U.S. leadership, and the space environment would be no better off.

This highlights the fact that space activities occur in an inherently international context. The 1967 Outer Space Treaty, "Treaty on the Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and other Celestial Bodies," establishes in international law that all states are equally free to use space and have the right of freedom of access to space. It also establishes that no state can claim sovereignty over any part of space. There are no international, legally binding agreements that constrain a country's freedom of action in space, with the exception of prohibitions on nuclear weapons tests in space and prohibition on the placement of nuclear weapons, or other weapons of mass destruction, in space.[7] This means no state can presume to "manage" space traffic on behalf of other countries without their consent. Moreover, in the current context of growing geopolitical tension, it is difficult to foresee a new, legally binding, international treaty regime emerging to address the issues of growing space traffic.

The tensions among the growing need for STM, the risk to industry of overly burdensome regulation by the government, and the right of all states to freely access space and use space lead to the idea that a promising first step for protecting the space environment is for commercial actors, in collaboration with government and international stakeholders, to develop internationally accepted, voluntary standards, guidelines, and best practices. However, this does not mean that other tensions can be easily swept away. For example, U.S. national security stakeholders may disagree with U.S. civil government agencies and commercial stakeholders on details, such as what STM data can be shared and to what degree national security space actors should be subject to such standards and practices. These sorts of issues are likely to consume significant time in the U.S. interagency coordination process.

Regardless of the balance between voluntary and regulatory actions, delivering on SPD-3's goals requires clarifying what is meant by standards, guidelines, and best practices. While frequently referred to collectively, as this paper does, the following definitions show that each has a distinct meaning:

- Standards are defined as a set of codified rules describing requirements, specifications, or characteristics that can be used consistently to ensure that materials, products, processes, and services are interoperable. In short, standards encourage uniformity, common practice, and interoperability. Adhering to standards confers credibility for the user's products.[8]

- Guidelines are defined as a set of recommendations and advice that are provided by one or more organizations.[9]

- Best practices are techniques or methodologies that have proven to reliably lead to a desired result through experience and research.

Voluntary standards, guidelines, and best practices for space activities matter for several additional reasons. First, Merchants and Guardians, so to speak, working together to develop consensus-based standards, guidelines, and best practices for space foster the legitimacy critical to successfully manage space traffic and protect the sustainability of the space environment. As such, they provide mechanisms for achieving consensus across stakeholders, stimulate a predictable and supportive environment for all actors, and help limit the amount of dangerous actions in space. Ideally, the legitimacy of the standards, guidelines, and best practices will also reduce incentives for commercial stakeholders to offshore their activities. Satellite operators should also be better able to optimize their operating capabilities and improve their efficiency and operational safety with settled standards and best practices. In addition, new space actors will be able to learn more quickly how to be responsible space operators. Ultimately, voluntary standards, guidelines, and best practices for outer space will facilitate the growth of space commerce.[10]

| Table 1: Why Standards, Guidelines, and Best Practices Matter |
|---|
| Provide broad-based legitimacy |
| Provide a mechanism for achieving consensus across stakeholders |
| Protect the sustainability of the space environment |
| Stimulate predictable and supportive space governance |
| Reduce dangerous actions in space |
| Reduce offshoring incentives |
| Improve efficiency and safety of operations |
| Guide new space actors in responsible space operations |

Domestic and international stakeholders are in growing agreement that the best way to safeguard the emerging space environment involves a three-step process. First, the expert community of commercial space actors, government officials, standards organizations, think tanks, and academia develop voluntary, technical and operational standards, guidelines, and best practices for specific space activities. Second, as the voluntary standards, guidelines, and best practices gain general acceptance across stakeholders, governments around the world begin to incorporate them into domestic law, regulation, and licensing criteria. Finally, using this bottom-up strategy, as illustrated in Figure 1, a broad international consensus emerges on the best way to conduct safe, secure, and sustainable space activities, not based on a treaty, but based on congruent domestic law and customary practice.

Using this roadmap, key spacefaring nations of the world have attained a general consensus on orbital debris mitigation guidelines. The United States provided the initial catalyst when it developed the U.S. government ODMSP in 1998 and mandated the compliance of U.S. private spacecraft companies in order to obtain FCC licensing.[11] ODMSP influenced the development of the Inter-Agency Space Debris Coordination Committee (IADC) Space Debris Mitigation Guidelines, which in turn influenced the later United Nations (UN) Committee on the Peaceful Uses of Outer Space (COPUOS) Space Debris Mitigation Guidelines and related International Organization for Standardization (ISO) standards, specifically ISO Standard 24113. Today, the United States and the 13 IADC-member countries, as well as European Space Agency (ESA) member states, have incorporated these debris mitigation standards into their domestic regulation and law.[12] SPD-3 endorses this game plan for development of a new international STM approach,[13] although other countries have not necessarily agreed to the United States taking a leadership role.

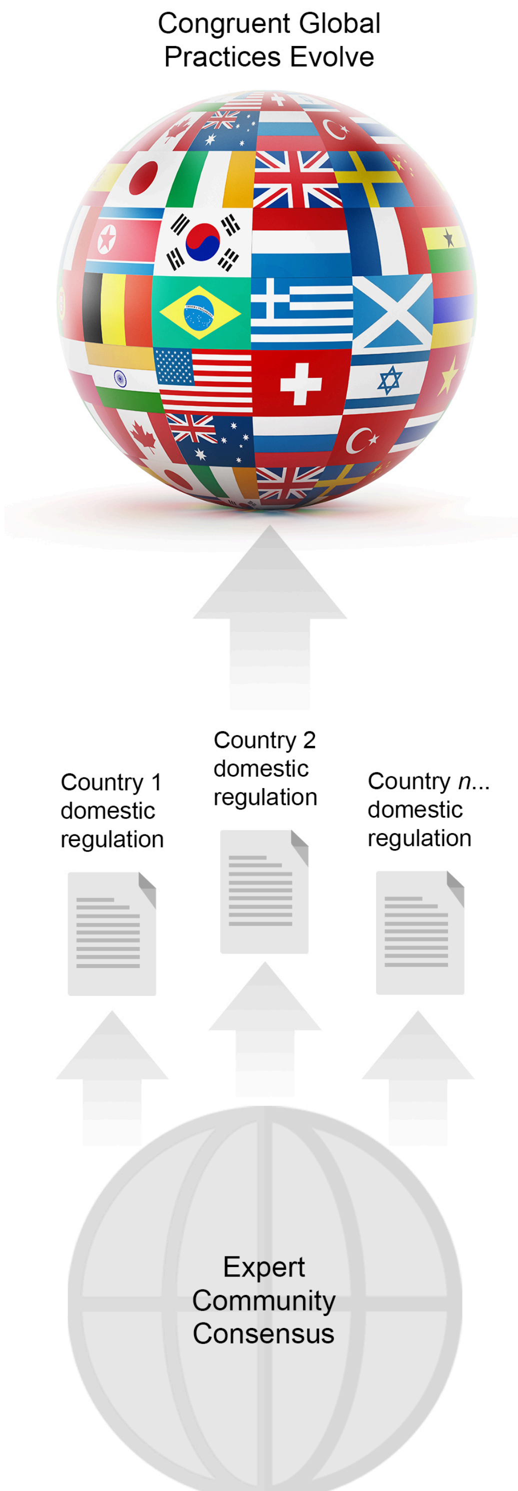


*Figure 1: The Bottom-Up Process*

## Gaps and Prioritization

The space community has identified a broad assortment of standards, guidelines, and best practices related to managing orbital activities, as identified in Tables 3 through 6. The tables indicate that development of STM standards, guidelines, and best practices is lagging in a few critical areas. For example, issues associated with large constellation operations and the identification of an organization devoted to appropriate standards development appear to warrant much more attention. The same may be said for satellite disposal and debris removal standards development and other areas. Since resources and expertise are limited, the question becomes how to prioritize efforts.

The space community may choose to prioritize the establishment of the critical standards, guidelines, and best practices in a variety of rational ways, as shown in Table 2. For example, analysts may determine priorities by identifying the chronological order in which standards, guidelines, and best practices must be set (i.e., some standards must be set before other standards can be agreed upon and set). Not everything can be done in parallel. Alternatively, if making quick progress is the top priority, then working toward adoption of well understood, non-controversial standards, guidelines, and best practices may focus efforts. With this prioritization strategy in mind, SPD-3 prioritized updates to ODMSP.

| Table 2: Rational Prioritization Strategies |
|---|
| Chronological order |
| Well understood, non-controversial |
| Exemplar case |
| National security |
| Economic/commercial profit maximizing |
| National preferences |

Another prioritization strategy may be to pick one difficult, exemplar case that drives development of standards, guidelines, and best practices across a wide swath of STM issues.[14] Process participants uncover roadblocks, learn how to overcome the bumps in the road, and make incremental progress in many productive lines of effort. The Consortium for Execution of Rendezvous and Servicing Operations (CONFERS) might illustrate this approach through the consortium's collaborative efforts to research, develop, and publish voluntary, consensus principles, best practices, and technical and safety standards for commercial rendezvous and proximity operations and on-orbit servicing.[15] In addition, the national security community may drive priorities that are in tension with other stakeholder priorities. Likewise, the commercial space sector may create friction by prioritizing standards, guidelines, and best practices that lower costs and maximize profit as quickly as possible. Finally, stakeholders in the international community will have their own national preferences, which may diverge from other nations' stakeholders' preferences.

The tensions among these rational but significantly different prioritization schemes make it difficult for stakeholders to agree on a way ahead. Furthermore, there is little practical experience in some of these areas, making development of standards, guidelines, and best practices difficult, to say the least. Hence, the domestic and international space standards development community may end up relying on a "muddling through" strategy, which is not ideal.[16]

## Mechanisms/Organizations

The following key organizations are leading in the development of various STM-related standards, guidelines, and best practices, as outlined in Tables 3 through 6. The list is not meant to be comprehensive. Many countries have their own standards organization, such as Japan and many European countries, but they are not listed. In addition, the organizations often agree upon similar standards, and the standards are sometimes used and published concomitantly across organizations. The organizations also have methods and strategies to manage and move forward in the face of industry actors that may advocate only for their technology to be the standard, which would give them a competitive advantage.[17] The following list is in no particular order and is not all-inclusive. There are many standards development organizations with overlapping areas of interest. For example, standards for race car seat belts may be judged adequate for human spaceflight, so there is no need for a new standard to be developed just for spaceflight.[18] The difficulty in creating a comprehensive list, the overlapping areas of interest, and the complexity of trying to clearly understand the roles of each organization illustrate some of the significant challenges in developing needed STM standards, guidelines, and best practices.

### *International Organization for Standardization (ISO)*[19]

ISO develops and issues voluntary consensus international standards for spaceflight. Within ISO, there are two subcommittees, SC13 and SC14, that deal specifically with space issues. SC13 voting members are Brazil, China, France, Germany, Iran, Italy, Japan, Kazakhstan, Mexico, Mongolia, Russia, Ukraine, U.K., and the United States. SC14 voting members are Brazil, China, Finland, France, Germany, India, Italy, Japan, Norway, Russia, Ukraine, U.K., and the United States.[20]

ISO space standards and technical reports number in the hundreds and those that relate specifically to STM include ISO TR 16158, *Best Practices for Avoiding Collisions among Spacecraft* (note that this is a technical report rather than a standard), which describes the operational processes for assessing collision probabilities and developing evasive maneuvers. These 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 (CDMs) that were implemented by governments and commercial operators worldwide. These best practices include the format used by the Department of Defense (DOD) to provide conjunction warnings.

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. ISO 24113 is designed to reduce the growth of space debris and ensure that spacecraft and launch vehicles are designed, operated, and disposed of in a way to prevent them from generating more orbital debris in their orbital lifetime. ISO 24113 It has been adopted by the European Cooperation for Space Standardization (ECSS) and through ECSS, the European Commission for Standardization included it as a European Standard. It has also been adopted by the European Space Agency and is used by the Japanese government as a requirement for their industry as well as by China and to some extent Russia.[21]

The Orbital Debris working group at ISO is in the process of consolidating some of these standards. The updated ISO 24113, to be published in the summer of 2019, will be the top-level standard along with two mid-level standards, one for spacecraft and one for upper stages. This will consolidate several smaller standards.

### *Inter-Agency Space Debris Coordination Committee (IADC)*[22]

There are 13 space agencies that take part in the IADC, of which NASA is a leading member. The IADC Space Debris Mitigation Guidelines were arrived at through consensus and designed to mitigate the growth of the orbital debris population. The guidelines have three fundamental principles:

1. Preventing on-orbit breakups—both collisions and explosions
2. Removing spacecraft and orbital stages that have reached the end of their mission operations from the useful densely populated orbit regions no more than 25 years after completion of the mission
3. Limiting the objects released during normal operations

### *Consultative Committee for Space Data Systems (CCSDS)*[23]

CCSDS develops data and information systems standards including orbital data message and CDM formats. CCSDS CDMs have been implemented by governments and commercial operators worldwide. These best practices include the format used by the DOD to provide conjunction warnings.

### *The Consortium for Execution of Rendezvous and Servicing Operations (CONFERS)*

CONFERS collaborates on research, development, and publication of voluntary consensus principles, best practices, and technical and safety standards related to commercial rendezvous and proximity operations and on-orbit servicing.[24]

In February 2019, CONFERS published "Recommended Design and Operational Practices," which covers a broad swath of lessons learned from prior government rendezvous and proximity operations and current industry plans. The numerous practices described are categorized as (1) design for mission success, (2) design satellites to facilitate safe and effective satellite servicing, (3) design serving operations to minimize the risk and consequence of mishaps, (4) avoid physical or electro-magnetic interference during all phases of operations, (5) share information on resolution of spacecraft anomalies/failures and related root cause analysis, and (6) promote the long-term sustainability of space activities.[25]

### ASTM[26] Committee F47

ASTM International, the international voluntary standards development body, has partnered with the Commercial Spaceflight Federation (CSF) in an effort to streamline the process of standards development and approval. Established in October 2016, one purpose of ASTM is to create human spaceflight safety standards. The committee also works to develop voluntary consensus standards in the areas of design, manufacturing, and operational use of spaceflight vehicles.[27]

### International Association for Space Safety (IAASS)

The IAASS exists to help shape and advance an international space safety culture contributing to making space missions, vehicles, stations, extraterrestrial habitats, equipment, and payloads safer for the general public, ground personnel, crews, and flight participants. The IAASS also advocates for the sustainability of the space environment to enable access to space for future generations.[28]

The IAASS is working toward proposing and establishing a commercial Space Safety Institute to offer safety certification services on a commercial basis. The applicable performance safety requirements are defined in IAASS-SSI-1700, *Safety Standard: Commercial Human-Rated Space Systems*, published by SAE International. These requirements are intended to protect the flight personnel (i.e., crew and flight participants), the vehicle and relevant launcher or carrier, and any other interfacing system from spaceflight hazards.[29]

### Global VSAT Forum (GVF)

GVF is a non-profit industry association representing the global satellite communications industry. GVF endorses and participates with other space companies in development of space sustainability best practices. GVF's efforts regarding best practices are being driven by the looming proliferation of large constellations. The best practices under development cover all phases of spaceflight and address operator exchange of information, launch vehicle selection, constellation design, spacecraft designed for disposal within five years of end of mission, collision avoidance, minimal fragmentation, trackability, on-orbit servicing, and passivation.[30] GVF also endorses the COPUOS Long-Term Sustainability Guidelines and endorses ISO 24113 and IADC guidelines for space debris mitigation.

### Space Data Association (SDA)

According to the SDA website, "SDA is a non-profit international association of satellite operators that supports the controlled, reliable and efficient sharing of data critical to the safety and integrity of the space environment and the RF spectrum."[31] Most satellite operators are members of SDA.

### The Center for Space Standards & Innovation (CSSI)

CSSI conducts standards research as part of Analytical Graphics, Inc. (AGI). CSSI facilitates development of mutually acceptable standards for space communities.[32]

### United Nations (UN) Committee on the Peaceful Uses of Outer Space (COPUOS)

Only states may be members of UN COPUOS and all 87 member states must reach consensus for a decision. Member states have agreed upon

21 guidelines for the long-term sustainability of space and agreed to continue discussions under the auspices of the COPUOS Scientific and Technical Subcommittee. The guidelines are grouped into four categories: (1) policy and regulatory framework for space activities, (2) safety of space operations, (3) international cooperation, capacity building, and awareness, and (4) scientific and technical research and development.[33] The full text can be found at http://www.unoosa.org/res/oosadoc/data/documents/2018/aac_1052018crp/aac_1052018crp_20_0_html/AC105_2018_CRP20E.pdf.

Many more organizations may be actively involved in developing various standards, guidelines, and best practices and may be added with future research for a follow-on paper.

## Tables

Tables 3 through 6 highlight several important points. First, the tables identify the wide variety and complexity of the STM-related standards, guidelines, and best practices called for in SPD-3 and in various other sources. Over 75 high-level standards, guidelines, and best practices are captured in the tables. Second, the tables identify some consensus-based, voluntary standards development organizations and roughly match them to the standards, guidelines, and best practices they are developing and promoting. A careful analysis of the tables shows the diverse assortment of entities and associated experts working on various pieces of the STM puzzle. In addition, the tables help identify where existing organizational mechanisms may need to be adapted, strengthened, or created to facilitate the development, international acceptance, and implementation of voluntary, consensus-based STM standards, guidelines, and best practices. For example, the tables show that CONFERS is involved in developing and promoting many standards, guidelines, and best practices, even though it is the newest organization. Next, the tables group the standards, guidelines, and best practices in four arbitrary categories: operations and safety, debris mitigation, SSA data and modeling, and spectrum. Based on the difficulties in rationally prioritizing the standards, guidelines, and best practices, as discussed earlier, the tables do not attempt to list the standards, guidelines, and best practices in any type of priority order. Although this is not a perfectly clean categorization and is subject to debate, it highlights the range of topics the space community is grappling with in standards, guidelines, and best practices development.

The ultimate purpose of the tables is to help identify where gaps in the development of standards, guidelines, and best practices exist, identify where overlapping efforts may create inefficiencies, and highlight the need for a widely accepted strategy to be formulated to guide the standards, guidelines, and best practices development community forward. Due to limits in time and resources, it is not possible to comprehensively list every contributing organization and important standard, guideline, and best practice under development in these tables. Ideally, future research will expand the findings in this paper.

| Table 3: Operations and Safety | |
|---|---|
| **Identified in SPD-3** | **Organizations Working to Some Extent on Corresponding Activities** |
| Encryption of telemetry, tracking, and command (TT&C) links | CCSDS |
| Large constellation operations | Corresponds with IADC, GVF |
| Establish a common process addressing the volume of space used by a large constellation | IADC |
| Establish a common process addressing the volume of space used by a large constellation in proximity to an existing constellation | IADC |
| Small satellite operations | None found |
| Rendezvous and proximity operations | CONFERS |
| Reliability<br>◆ Minimum reliability based on type of mission<br>◆ Minimum reliability based on phase of operation<br>◆ Reliability standards to minimize the long-term effects of constellation operations | CONFERS<br>Corresponds with IADC Statement on Large Constellations of Satellites in Low Earth Orbit<br>Corresponds with IADC<br>Corresponds with IADC |
| Standards for maneuverability | None found |
| Safety through all stages of satellite operation from design through end of life | UN COPOUS LTS, CONFERS<br>Corresponds with GVF efforts |
| Establish a common process by which individual spacecraft may transit volumes used by existing satellites or constellations | UN COPOUS LTS |
| Data protection measures for ground site operations | CCSDS. Corresponds with ISO Technical Committee (TC) 20, SC13, “Space Data and Information Transfer Systems.” There is significant standards “co-use” between CCSDS and ISO TC20/SC13. |
| **Identified in Various Sources But Not in SPD-3** | |
| On-orbit servicing | CONFERS |
| Operations insured to reasonably covered risk to the activity of third parties | CONFERS |
| Ensure sufficient communication and coordination with entities that could reasonably be affected by the party’s activity | CONFERS |

| Table 3: Operations and Safety | |
|---|---|
| **Identified in Various Sources But Not in SPD-3** | |
| Provide timely public notification of anomalies or mishaps that could have an adverse impact on other entities or the space environment | CONFERS |
| Trained, qualified, experienced, disciplined, rehearsed spacecraft operators | CONFERS |
| Commercial spaceflight safety standards[34] | ASTM International F-47 in partnership with CSF<br>IAASS-SSI-1700, *Safety Standard: Commercial Human-Rated Space Systems*, published by SAE International |
| Design of spaceflight vehicles | ASTM F-47 |
| Manufacturing of spaceflight vehicles | ASTM F-47 |
| Operational use of spaceflight vehicles | ASTM F-47 |
| Design of spaceflight vehicles | ASTM F-47 |
| F47.01 Occupant Safety of Suborbital Vehicles subcommittee | ASTM F-47 |
| WK59508 Fault tolerance guide for occupant safety of suborbital vehicles | ASTM F-47 |
| F47.02 Occupant Safety of Orbital Vehicles | ASTM F-47 |
| F47.03 Unoccupied Launch and Re-entry Vehicles<br>• WK61254 New Classification for Spacecraft Vehicle Types<br>Scope: Collate information that sets definitions for spacecraft vehicle types.<br>• WK64814 New Guide for Flight Controller Training<br>Scope: This guide is focused on vehicle operations. Any maintenance and ground ops would be contained in other guides or standards. | ASTM F-47 |
| F47.05 Cross-Cutting | ASTM F-47 |
| WK65152 Reportable safety events<br>Scope: Reportable incidents (public, proprietary, anonymous). What is reportable? Taxonomy of what is to be reported. List of all things that should be voluntarily reported. Includes a guide on formats and templates to accept as outputs of data that are useful for lessons learned, safety, and other industry incidents. | ASTM F-47, corresponds with CONFERS |
| F47.91 Terminology | ASTM F-47 |

| Table 3: Operations and Safety | |
|---|---|
| **Identified in Various Sources But Not in SPD-3** | |
| F47.92 Standards Roadmapping | ASTM F-47 |
| Safe use of nuclear power sources in outer space | UN General Assembly (UNGA) Resolution 47/68 |
| Monitoring integrity of terrestrial infrastructure | UN COPOUS LTS |

| Table 4: Debris Mitigation | |
|---|---|
| **Identified in SPD-3** | **Organizations Working to Some Extent on Corresponding Activities** |
| Orbital debris mitigation:<br>• Spacecraft and upper stages should be designed to eliminate or minimize debris released during normal operations.<br>• 25-year rule<br>• Limit risk due to breakups and accidental explosions<br>• Limit the probability of an operating space system becoming a source of debris by collision with man-made objects or meteoroids<br>• Plan for post-mission disposal of space structures<br>• Avoid intentional destruction and other harmful activities<br>• SPD-3 calls for establishing new guidelines for satellite design and operation | UN COPUOS Space Debris Mitigation Guidelines<br>IADC Space Debris Mitigation Guidelines<br>ISO TC20/SC14, Work Group 7* |
| Coordination of space activities to prevent collisions | Space Data Association (SDA), CONFERS |
| Coordination of orbit utilization to prevent conjunctions | International Telecommunications Union (ITU), CONFERS, IADC, GVF |
| Owner/operator (O/O) management of self-conjunctions | CONFERS, IADC |
| O/O notification of planned maneuvers | CONFERS |
| O/O sharing of satellite orbital location data | CONFERS, corresponds with GVF efforts |
| Actionable collision avoidance warning | SDA |

| Table 4: Debris Mitigation | |
|---|---|
| **Identified in SPD-3** | **Organizations Working to Some Extent on Corresponding Activities** |
| Minimizing the long-term effects of constellation operations with effective collision avoidance | Corresponds with GVF efforts |
| Minimizing the long-term effects of constellation operations with proper disposal | Corresponds with IADC Statement on Large Constellations of Satellites in Low Earth Orbit<br><br>Corresponds with GVF efforts |
| Self-disposal | Corresponds to IADC Space Debris Mitigation Guidelines |
| O/O provision of disposal using active debris removal methods | CONFERS |
| Disposal | Corresponds with GVF efforts |
| **Identified in Various Sources But Not in SPD-3** | |
| Determining orbit lifetime[35] | CSSI (with Germany, Japan, France), ISO |
| Determining collision probability (CSSI with Germany, Japan, U.K.) | CSSI (with Germany, Japan, U.K.), ISO |
| Disposal of satellites within LEO protected region | CSSI, ISO |
| Reentry safety control for unmanned spacecraft and launch vehicle orbital stages (CSSI with Japan) | CSSI (with Japan), ISO |
| Safety standards for debris removal | None found |
| Design for demise | None found |

* ISO standard 24113 is the second-most-requested SC14 standard and is imposed on industry in Japan and ESA member states. ISO SC14 has 168 published standards related to space.

| Table 5: SSA Data and Modeling | |
|---|---|
| **Identified in SPD-3** | **Organizations Working to Some Extent on Corresponding Activities** |
| Data integrity measures | None found |
| SSA data interoperability | CCSDS |
| • Standardized data formats | CCSDS |
| • O/O ephemerides | CCSDS |

| Table 5: SSA Data and Modeling | |
|---|---|
| **Identified in SPD-3** | **Organizations Working to Some Extent on Corresponding Activities** |
| Creation of an open architecture data repository | CCSDS |
| SSA data standards | CCSDS |
| Tracking | CONFERS |
| On-orbit tracking aids (e.g., beacons or sensing enhancements) | None found |
| Quality threshold for actionable collision avoidance warning | None found |
| Information data sharing | SDA, UN COPOUS LTS, CONFERS |
| Creation of an open architecture data repository | NSF (International Virtual Observatory) |
| Safeguarding propriety or sensitive data | SDA, CONFERS |
| Safeguarding national security information | Not applicable |
| Greater SSA data sharing | UN COPOUS LTS |
| **Identified in Various Sources But Not in SPD-3** | |
| SSA data models/layers | CCSDS |
| Data interoperability with IETF/ISO/CC | CCSDS |
| Data curation/management | CCSDS |
| Safeguarding data sources/provenance | CCSDS |
| Unique resident space object identification | AFRL |
| Precision SSA | AFRL |
| Predictive analytics | None found |
| Trade-space for disposal orbit options including super-sync | None found |
| Space traffic conflict resolution | None found |

| Table 6: Spectrum | |
|---|---|
| **Identified in SPD-3** | **Organizations Working to Some Extent on Corresponding Activities** |
| Spectrum use | SDA, FCC |
| Access to required spectrum for: | ITU, CCSDS |
| ◆ Inter-satellite safety communications | CONFERS |
| ◆ Active debris removal systems | CONFERS |

## Way Ahead

Tables 3 through 6 highlight the many issues facing the space community and the many organizations already grappling to solve them. However, more needs to be done. A first step may be increased investment in the organizations listed in the tables, with resources and experts' time. An increase in the tempo of the organizations' output may also be desired. Perhaps a "summit" meeting of the relevant standards organizations to discuss gaps, priorities, and a division of labor would be useful. Importantly, more public engagement and educational activities are critical for informing decisionmakers why internationally accepted, voluntary standards, guidelines, and best practices matter.

New organizations may also need to be established, like how CONFERS was established in the last few years to work on RPO and on-orbit servicing issues. Assuming it will take time to establish new organizational mechanisms, time for them to establish legitimacy, and time for them to agree upon a program of work, now is the time to start standing up new industry- and government-led, voluntary, consensus-based organizations to attack these looming issues. Perhaps a new organization to attack issues associated with large constellation standards, guidelines, and best practices should be a prioritized as per the "exemplar" prioritization strategy noted above.

**Way Ahead**

- Increase investment: more resources and more experts' time
- Increase tempo in standards development organizations' output (i.e., meet more often)
- Organize a summit meeting of relevant organizations
  - Discuss gaps, establish priorities, agree upon a division of labor
- Create new organizational mechanisms where needed (e.g., CONFERS model)
- Alternatives
  - Do nothing
  - Let governments take a lead through rules and regulations (i.e., default to a top-down approach)

The alternatives may not be appealing. First, doing nothing is not a good option. The sustainability of the space environment would be at risk if no changes are agreed upon. Moreover, in the presence of a vacuum, other countries may step in and take the lead internationally on these issues and the United States could forfeit its traditional leadership role in space, contrary to the intent of SPD-3. This is already happening to some extent. Second, U.S. government agencies are responsible for the safety and security of U.S. space activities and may take action to establish more top-down regulation, which may lack stakeholder buy in, potentially drive U.S. industry overseas, and stymie commercial space development.

Space community stakeholders hold the key to the future space age in their hands. Let’s turn the key and open the door to the establishment of more voluntary STM standards, guidelines, and best practices.

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