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PRIORITIZING AND ESTABLISHING MECHANISMS FOR THE FORMATION OF SPACE TRAFFIC MANAGEMENT STANDARDS, GUIDELINES AND BEST PRACTICES

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ABSTRACT

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

A. INTRODUCTION

On June 18, 2018, the U.S. National Space Council released Space Policy Directive – 3, National Space Traffic Management Policy (SPD-3). One of SPD-3's primary goals is the development of Space Traffic Management (STM) standards 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 promote internationally 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 space traffic management (STM) related standards, best practices, and guidelines. Nevertheless, SPD-3 did not capture all the top-level standards, best practices, and guidelines that effective space traffic management will require. In addition, with the exception of updating the U.S government's Orbital Debris Mitigation Standard Practices first, SPD-3 did not identify which standards, guidelines, and best practices should receive priority in their development. This paper assesses the completeness of the list of standards, best practices, and guidelines called out in SPD-3 and identifies gaps. Next, the paper discusses different prioritization methods. Finally, the paper identifies existing standards development organizations and calls for increased investment, faster work, and new mechanisms to facilitate the formation and proliferation of necessary STM guidelines, best practices, and standards.

B. 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 ten years. Since the space age began over 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 or more 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 Communication Commission (FCC) released the "Notice of Proposed Rulemaking and Order on Reconsideration, IB Docket No. 18-313."[4] The Notice seeks 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 of more technical and operational requirements.

However, tension exists between the government's need to regulate 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 space traffic management 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 the term *Merchant* refers 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, sustainability, and security 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 off-shoring 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 off-shore 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, have the right of freedom of access to space, and 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.[†] 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 space traffic management, the risk to industry of overly burdensome regulation by the government, and the right of all states to freely access space and use space, leads to the idea that a promising first step for protecting the space environment is for commercial actors, in collaboration with governmental and international stakeholders, to develop internationally-accepted, voluntary standards, guidelines, best practices, and norms of behavior for space. 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 governmental 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, best practices, and guidelines. 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 and adhering to standards confers credibility for the user's products.[7] Best practices are techniques or methodologies that have proven to reliably lead to a desired result through experience and research. And guidelines are defined as a set of recommendations and advice that are provided by one or more organizations.[8]

Voluntary standards, best practices, and guidelines for space activities matter for several additional reasons. First, *merchants* and *guardians*, so to speak, working together to develop consensus-based standards, guidelines, best practices, and norms of behavior for space foster the legitimacy critical to successfully manage space traffic and protect the sustainability of the space environment. As such, they stimulate a predictable and supportive environment for all actors and help limit the amount of dangerous actions in space. In addition, ideally the legitimacy of the standards and practices will reduce incentives for commercial stakeholders to off-shore their

[†] Some may argue that the 1979 Moon Treaty "Agreement Governing the Activities of States on the Moon and Other Celestial Bodies" constrains the exploration and uses of the moon and its natural resources. However, the Russia, China, the United States, and other spacefaring powers have not joined the Moon Treaty and it is generally considered a failed treaty.

activities. Satellite operators should also be better able to optimize their operating capabilities and improve their efficiency with settled standards and best practices. As well, new space actors will be able to learn more quickly how to be responsible space operators. Ultimately, voluntary standards, best practices, guidelines, and international norms of behavior for outer space will facilitate the growth of space commerce.[9]

Provide broad-based legitimacy
Protect the sustainability of the space environment
Stimulate predictable and supportive space governance
Reduce dangerous actions in space
Reduce off-shoring incentives
Improve efficiency of operations
Guide new space actors in responsible space operations
Facilitate the growth of space commerce

Figure 1: Why Standards, Best Practices, and Guidelines Matter

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, 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.

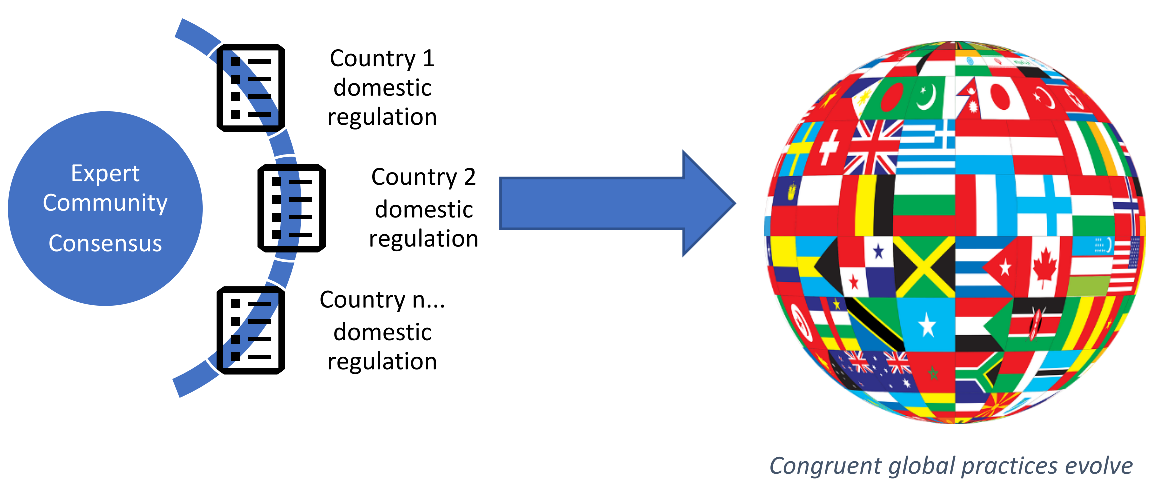

Figure 2: The Bottom Up Process

Using this road map, 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 Orbital Debris Mitigation Standard Practices (ODMSP) in 1998 and mandated U.S. private spacecraft companies' compliance in order to obtain FCC licensing. [10] 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 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.[11] SPD-3 endorses this game plan for development of a new international Space Traffic Management approach, although other countries have not necessarily agreed to the United States taking a leadership role.

C. GAPS AND PRIORITIZATION

The space community has identified a broad assortment of standards, best practices, and guidelines related to managing orbital activities, as identified in the tables below. The tables indicate that development of STM standards, guidelines, best practices and norms is lagging in a few critical areas. For example, issues associated with large constellation operations and identifying an organization devoted to appropriate standards development appears 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, best practices, and guidelines in a variety of rational ways. For example, analysts may determine priorities by identifying the chronological order in which standards must be set, i.e. some standards must be set before other standards can be agreed upon and set. Everything cannot be done in parallel. Alternatively, if making quick progress is the top priority, then working toward adoption of well understood, non-controversial, standards may focus efforts. With this prioritization strategy in mind, Space Policy Directive – 3 prioritized updates to the U.S. Orbital Debris Mitigation Standard Practices.

Chronological order
Well understood, non-controversial
Exemplar case
National security
Economic/commercial profit maximizing
National preferences

Figure 3: Prioritization Strategies

Another prioritization strategy may be to pick one difficult, exemplar case that drives development of standards, best practices and guidelines across a wide swath of space traffic management issues.[12] 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 the Execution of Rendezvous and Servicing Operation (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.[13] Finally, the national security community may drive priorities that are in tension with other stakeholder priorities. Likewise, the commercial space sector may favor prioritizing areas that lower costs and maximize profit. As well stakeholders in the international community will have their own national preferences which may diverge from other nations' stakeholders' preferences.

The tensions among these different prioritization schemes makes 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 and best practices difficult. Hence, the domestic and international space standards development community may end up relying on a "muddling through" strategy, which is not ideal.[14]

D. MECHANISMS/ORGANIZATIONS

The following key organization are leading in the development of various STM-related standards, best practices and guidelines, as outlined in the tables below. The organizations often agree upon similar standards and the standards are sometimes used and published concomitantly across organizations.

International Organization for Standardization (ISO):[15]

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. 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 and those that relate specifically to STM include ISO TR 16158, Best Practices for Avoiding Collisions among Spacecraft, 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 DOD to provide conjunction warnings.

In 2011, ISO released ISO 24113, the 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. The Orbital Debris working group at ISO is in the process of consolidating some of these standards. The updated ISO 24113 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 together.

The ISO standard duplicates many practices employed by the space agencies that belong to IADC; hence, most space agencies do not employ it specifically. However, the requirements in ISO 24113 are more specific and measurable than the IADC guidelines and two major space agencies do use it. Japan's space agency (JAXA) imposes ISO 24113 on its contractors, and it also is employed by ESA member state space agencies.[16]

Inter-Agency Space Debris Coordination Committee (IADC)[17]

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:

- 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 no longer than 25 years after completion of mission.
- Limiting the objects released during normal operations.

***Consultative Committee for Space Data Systems* (CCSDS)**[18]

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

***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[19]

In February 2019 CONFERS published “Recommended Design and Operational Practices” which cover a broad swath of lessons learned from prior government servicing operations. The numerous practices described are categorized as I) Design for Mission Success, II) Design satellites to facilitate safe and effective satellite servicing, III) Design serving operations to minimize the risk and consequence of mishaps, IV) Avoid physical or electro-magnetic interference during all phases of operations, V) Share information on resolution of spacecraft anomalies/failures and related root cause analysis, VI) Promote the long-term sustainability of space activities.[20]

ASTM‡ 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.[21]

International Association for Space Safety (IAASS)

The Association 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

‡ ASTM is not an acronym

public, ground personnel, crews and flight participants. The Association also advocates for the sustainability of the space environment to enable access to space for future generations.[22]

The IAASS is 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.[23]

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 the formation of comprehensive best practices for the sustainability of space operations. 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.[24] GVF also endorses the COPUOS Long-term Sustainability Guidelines.

United Nations Committee on the Peaceful Uses of Outer Space (UN 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: Policy and regulatory framework for space activities; safety of space operations; international cooperation, capacity-building, and awareness; and scientific and technical research and development. 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, best practices and guidelines and may be added with future research.

E. TABLES

The tables below illustrate the wide variety of entities working on various pieces of the space traffic management puzzle and 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, best practices and norms. The tables identify a variety of needed STM-related standards, guidelines, best practices and norms. Table 1 and Table 2 are categorized as "Operations" standards, best practices, and guidelines. Table 1 highlights those identified in SPD-3 while Table 2 highlights those gathered from other sources. The standards and practices identified are not in priority order. Table 3 and Table 4 are categorized as "Technical" standards, best practices, and guidelines. Table 3 highlights those identified in SPD-3 while Table 4 highlights those identified by other experts. Although this is not a perfectly clean categorization and not comprehensive, the tables help identify which standards, best practices and guidelines the U.S. government prioritized in SPD-3, and help identify which type of organizations and experts will need to be engaged in the development of appropriate standards, best practices and guidelines.

Where possible the tables attempt to identify where existing consensus-based, voluntary standards organizations currently exist and are working to some extent on developing corresponding standards, guidelines, best practices.[3] The ultimate purpose of the tables is to 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, best practices and norms. Once these gaps are identified, prioritization of implementation efforts may occur and a strategy formulated. It is not possible to comprehensively list every organization and important standard, best practice or guideline under development in this short paper. However, future research will expand these findings.

Table 1: Operations

Identified in SPD-3 Operations-Related	Standards Development Organizations (SDOs) Working to Some Extent on Corresponding Activities
Orbital Debris Mitigation: ❖ Spacecraft and upper stages should be designed to eliminate or minimize debris released during normal operations. ❖ 25 years rule ❖ Limit risk due to breakups and accidental explosions ❖ Limit the probability of operating space system becoming a source or debris by collision with man-made objects, or meteoroids ❖ Plan for post-mission disposal of space structures ❖ Avoid intentional destruction and other harmful activities ❖ SPD-3 calls for establishing new guidelines for satellite design and operation.	❖ UN Committee on the Peaceful uses of Outer Space (COPUOS) Space Debris Mitigation Guidelines ❖ IADC Space Debris Mitigation Guidelines ❖ ISO Technical Committee 20, Subcommittee 14, 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 Global VSAT Forum efforts
Actionable collision avoidance warning	SDA
Large Constellation operations	Corresponds with IADC, GVF
Rendezvous and proximity operations	CONFERS

Table 1: Operations	
Identified in SPD-3 Operations-Related	**Standards Development Organizations (SDOs) Working to Some Extent on Corresponding Activities**
Small Satellite operations	Secure World Foundation
Minimizing the long-term effects of constellation operations with effective collision avoidance	Corresponds with Global VSAT Forum 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. Corresponds with Global VSAT Forum efforts
Self-disposal	Corresponds to IADC Space Debris Mitigation Guidelines
O/O provision of disposal using active debris removal methods	CONFERS
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
Establish a common process by which individual spacecraft may transit volumes used by existing satellites or constellations	UN COPOUS LTS
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	
Greater SSA data sharing	UN COPOUS LTS
Spectrum use	SDA, FCC
*(ISO standard 24113, is the second-most requested SC14 standard and is imposed on industry in Japan and ESA Member States. ISO Subcommittee 14 has 168 published standards related to space.	

Table 2: Operations (Not included in SPD-3)	
Possible Additional Operations-Related Standards, Best Practices, Guidelines and Norms of Behavior Procedures for:	**Standards Development Organizations (SDOs) Working to Some Extent on Corresponding Activities**
Data curation/management	CCSDS

Table 2: Operations (Not included in SPD-3)	
Possible Additional Operations-Related Standards, Best Practices, Guidelines and Norms of Behavior Procedures for:	**Standards Development Organizations (SDOs) Working to Some Extent on Corresponding Activities**
Safeguarding data sources/provenance	CCSDS
Safety standards for debris removal	
On-orbit Servicing	CONFERS
Operations insured to reasonably cover 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
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
Space traffic conflict resolution	
Monitoring integrity of terrestrial infrastructure	UN COPOUS LTS
Safe use of nuclear power sources in outer space	UNGA Resolution 47/68
Commercial Spaceflight Safety Standards[25]	ASTM International F-47 in partnership with Commercial Spaceflight Federation (CSF) 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	ASTM F-47
❖ WK61254 New Classification for Spacecraft vehicle types.	

Table 2: Operations (Not included in SPD-3)	
Possible Additional Operations-Related Standards, Best Practices, Guidelines and Norms of Behavior Procedures for:	**Standards Development Organizations (SDOs) Working to Some Extent on Corresponding Activities**
Scope: Collate information that sets definitions for spacecraft vehicle types. ❖ WK64814 New Guide for Flight Controller Training Scope: this guide is focused on vehicle operations and that any maintenance and ground ops would be contained in other guides or standards.	
F47.05 Cross-cutting	ASTM F-47
WK65152 Reportable safety events Scope: Reportable Incidents (public, proprietary, anonymous) what is reportable? Taxonomy of what is to be reported. List of all things that should be voluntary reported. Includes a guide on ***formats and templates*** to accept as outputs of data entries that are useful for lessons learn, safety and other industry incidents.	Corresponds with CONFERS
F47.91 Terminology	ASTM F-47
F47.92 Standards Road mapping	ASTM F-47
Determining orbit lifetime[26]	CSSI (w/Germany, Japan, France), ISO
Determining collision probability (CSSI w/Germany, Japan, U.K.)	CSSI (w/Germany, Japan, U.K.), ISO
Disposal of Satellites w/in LEO protected region	CSSI, ISO
Reentry safety control for unmanned spacecraft and launch vehicle orbital stages (CSSI w/Japan)	CSSI (w/Japan), ISO

SPD – 3 Calls for standards, best Practice, guidelines and norms for the following technical design:

Table 3: Technical	
Identified in SPD-3 Technical	**Standards Development Organizations (SDOs) Working on Corresponding Activities**
Safety through all stages of satellite operation from design through end-of-life	UN COPOUS LTS, CONFERS, Corresponds with Global VSAT Forum efforts
Reliability	CONFERS
❖ Minimum reliability based on type of mission	Corresponds with IADC Statement on Large Constellations of Satellites in Low Earth Orbit
❖ Minimum reliability based on phase of operation	Corresponds with IADC

Table 3: Technical	
Identified in SPD-3 Technical	Standards Development Organizations (SDOs) Working on Corresponding Activities
❖ Reliability standards to minimize the long-term effects of constellation operations	Corresponds with IADC
Quality threshold for actionable collision avoidance warning	
Maneuverability	
Tracking	CONFERS
On-orbit tracking aids, e.g. beacons or sensing enhancements	The Aerospace Corporation
Disposal	Corresponds with Global VSAT Forum efforts
Data protection measures for ground site operations	CCSDS. Corresponds with ISO Technical Committee 20, Subcommittee 13, "Space Data and Information Transfer Systems". There is significant standards "co-use" between CCSDS and ISO TC20/SC13.
Encryption of TT&C links	CCSDS
Creation of an open architecture data repository	CCSDS
SSA data standards	CCSDS
Data Standards	
Data integrity measures	
SSA data interoperability	CCSDS
❖ Standardized data formats	CCSDS
❖ O/O ephemerides	CCSDS
Access to required spectrum for:	
❖ Inter-satellite safety communications	ITU, CCSDS CONFERS
❖ Active debris removal systems	CONFERS

Table 4: Technical (Not included in SPD-3)	
Possible Additional Technical Standards, Best Practices, Guidelines and Norms of Behavior for Technical Design for:	**Standards Development Organizations (SDOs) Working on Corresponding Activities**
SSA Data Models/Layers	CCSDS
Data interoperability with IETF/ISO/CC	CCSDS
Predictive analytics	
Trade-space for disposal orbit options including super-sync	
Design for demise	
Unique resident space object identification	AFRL
Precision SSA	AFRL

F. WAY AHEAD

The tables above 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 above, with resources and experts' time. An increase in the tempo of the organization's 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 decision-makers why internationally accepted, voluntary standards, best practices, and guidelines matter.

New organizations may also need to be established, much as 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 their 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, best practices and guidelines should be a prioritized as per the "exemplar" prioritization strategy noted above.

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 hand. Let's turn the key and open the door to the development of more voluntary space traffic management standards, best practices, guidelines and norms.

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