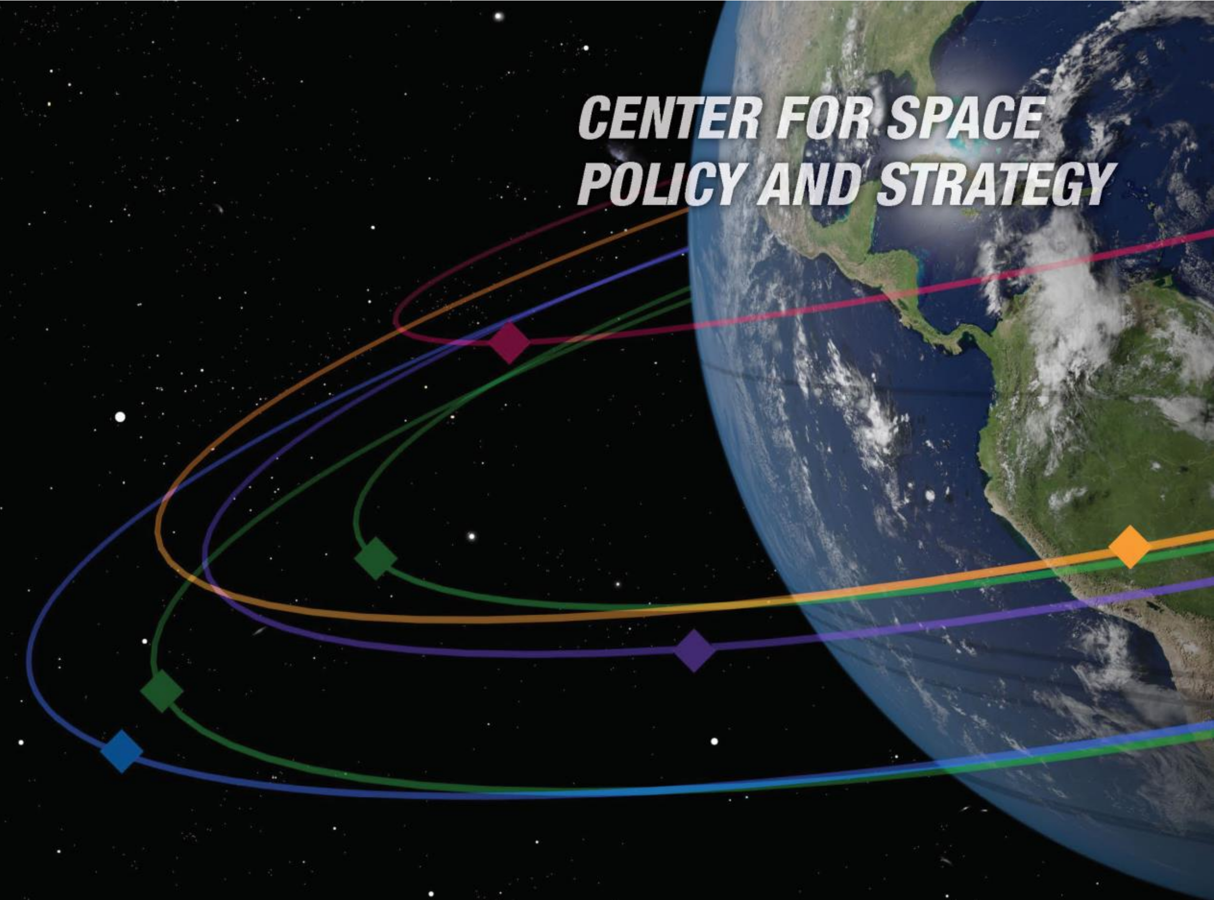

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U.S. SPACE TRAFFIC MANAGEMENT: BEST PRACTICES, GUIDELINES, STANDARDS, AND INTERNATIONAL CONSIDERATIONS

MICHAEL P. GLEASON
THE AEROSPACE CORPORATION

TRAVIS COTTOM
INDEPENDENT CONSULTANT

AEROSPACE

TRAVIS COTTOM

Travis Cottom is a space strategy consultant researching the changing space security environment for the Department of Defense. Previously, Cottom was a program associate for Defense and Space Policy at the George C. Marshall Institute where he researched space security, space exploration, cyber security policies, and other national security topics. Cottom worked for the Tauri Group as an aerospace analyst for NASA's Office of the Chief Financial Officer where he examined the planning and execution of NASA programs. Cottom earned a bachelor's degree in international relations with a concentration in conflict and security, and a master's degree in international science and technology policy with a concentration in national security space policy from the George Washington University.

MICHAEL P. GLEASON

Dr. Michael P. Gleason is a national security senior project engineer in The Aerospace Corporation's Center for Space Policy and Strategy. Prior to joining Aerospace, he supported the Office of the Secretary of Defense Office of Net Assessment as a senior strategic space analyst. He served 29 years in the Air Force and is an accomplished national security space expert with experience in space policy, strategy, satellite operations, and international affairs. While in the Air Force, he served for five years at the Pentagon and two years at the Department of State. A graduate of the U.S. Air Force Academy, he holds a Ph.D. in international relations from George Washington University.

For more information, go to www.aerospace.org/policy or email policy@aero.org.

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Summary

This paper describes current standards, best practices, and guidelines applicable to space traffic management. It is intended to provide a baseline for the Department of Commerce and other stakeholders as they work to develop additional standards, best practices, and guidelines in implementing Space Policy Directive-3 (SPD-3), National Space Traffic Management Policy. Department of Commerce space traffic management activities will factor into an international context as well. Therefore, this paper also assesses applicable treaties and non-legally-binding international agreements that may shape Commerce's space traffic management activities.

Introduction

SPD-3, National Space Traffic Management Policy, June 18, 2018, states that to maintain U.S. leadership in space the United States must develop a new approach to space traffic management (STM). The new approach includes designating the Department of Commerce as the lead civil agency responsible for the publicly releasable portion of the DOD space object catalogue; for administrating an open architecture data repository; and for on-orbit collision avoidance support services.

In addition, one of SPD-3's primary goals is the development of 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."[1] 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 behavioral norms, 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]

This paper describes current domestic standards, guidelines, and best practices applicable to space traffic management.[a] The paper also assesses the international context by describing the legally-binding and non-legally-binding international agreements that may shape Commerce's STM

[a] Note, this paper does not describe current statutory authorities and regulations that apply to space traffic management, which are spread among the Federal Communications Commission (FCC), the Department of Transportation (DOT), and the Department of Commerce.

activities. This survey provides a starting baseline, as various stakeholders implement SPD-3 and develop additional standards, guidelines, and best practices.

But what do we mean 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. Best practices are techniques or methodologies that have proven to reliably lead to a desired result through experience and research.[2] And guidelines are defined as a set of recommendations and advice provided by one or more organizations.

Standards, best practices, and guidelines for space activities matter for a number of reasons. First, they stimulate the development of rules for all actors to follow and help limit the amount of dangerous actions in space. Second, satellite operators can optimize their operating capabilities and improve their efficiency. Third, they will enable new space actors to be responsible space operators with a reduced learning curve. They also will make the Department of Commerce's STM tasks more likely to succeed, and ultimately, they will facilitate the growth of space commerce.

So which standards, best practices, and guidelines relevant to space traffic management already exist? While requirements for orbital debris mitigation and post-mission disposal exist, this analysis found that there are no widely embraced, compulsory, or integrated standards, best practices, or guidelines focused on mitigating collision risks in space. Instead, some un-codified best practices exist in the commercial space sector, but these are usually organizationally exclusive. Similarly, procedural standards and guidelines are organized uniquely throughout the DOD, NASA, and other agencies—although NASA and the DOD do utilize a common operating instruction for International Space Station (ISS) collision avoidance processes.[3]

The following section describes the landscape of current standards, guidelines and best practices that are relevant to STM, and will hopefully help Commerce's Office of Space Commerce (OSC) and other responsible stakeholders understand the scope of their task, prioritize their efforts, and contribute to the overall success of the STM mission.

Governmental Standards, Best Practices, And Guidelines Relevant to Space Traffic Management

Inter-Agency Space Debris Coordination Committee (IADC)

The first set of relevant best practices and guidelines for space are the U.S. Government Orbital Debris Mitigation Standard Practices (ODMSP) which aimed to limit the amount of orbital debris and the amount of time that debris and spacecraft can remain in orbit.[b] The standard practices include all spacecraft program phases, from concept development to space hardware disposal, and focus on four areas:

1. Control of the debris released during normal operations.
2. Minimize the debris generated by accidental explosions.
3. Select a safe flight profile and operational configuration.
4. Disposal of space structures following mission completion.

The standard practices apply to all U.S. Government organizations involved in space operations, including regulatory authorities. The standard

[b] Although "standard" is included in the name, these are not, strictly speaking, standards, but are more appropriately, "best practices".

practices serve as the U.S. Government's foundation for issuing specific orbital debris mitigation requirements and technical guidance. SPD-3 highlights the need to update the ODMSP "to enable more efficient and effective compliance, and establish standards that can be adopted internationally," and assigns the NASA Administrator primary responsibility for this task.[1]

The 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.[4] 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 developed through consensus and designed to mitigate the growth of the orbital debris population. The guidelines have three fundamental principles:

1. Preventing on-orbit break-ups.
2. Removing spacecraft and orbital stages that have reached the end of their mission operations from the useful and densely populated orbit regions no longer than 25 years after completion of mission.
3. Limiting the objects released during normal operations.[5]

For U.S. private spacecraft requiring FCC licensing, the FCC has implemented the ODMSP and IADC post-mission disposal guidelines and created rules that must be followed to obtain 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.[6]"

As noted above, SPD-3 directs updates to the ODMSP in the context of current space traffic forecasts and based on updated technical analysis.[c] For example, the 25-year orbital debris mitigation guideline may be out of date.[d] A variety of studies show statistically significant improvements in reducing collision risk when the re-entry time is less than 25 years.[7]

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.[8] SC13 members are Brazil, China, France, Germany, India, Italy, Israel, Japan, Kazakhstan, Russia, Ukraine, U.K.

[c] For example, see "Space Traffic Management in the Age of New Space," by Glenn Peterson, Marlon Sorge, William Ailor, Center for Space Policy and Strategy, The Aerospace Corporation, April 2018 https://aerospace.org/paper/space-traffic-management-age-new-space; and Marlon E. Sorge, "Commercial Space Activity and Its Impact on U.S. Space Debris Regulatory Structure," Crowded Space Series Paper #3, Center for Space Policy and Strategy, The Aerospace Corporation, November, 2017; and Glenn E. Peterson, A. B. Jenkin, M. E. Sorge, J. P. McVey, "Implications of Proposed Satellite Constellations on Space Traffic Management and Long Term Debris Growth in Near-Earth Environment," IAC-16,A6,7,8, x32389, 67th International Astronautical Conference, Guadalajara, Mexico, September 26–30, 2016.

[d] Sometimes referred to as the "25-year rule." But, this truly is not a "rule" in that compliance is not monitored nor enforced.

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, and Best Practices for Avoiding Collisions among Spacecraft which describes the operational processes for assessing collision probabilities and developing evasive maneuvers. The best practices created information requirements for warning operators and enabling cooperative avoidance, which is the basis for the 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.[9]

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 lifetrime.[10]

As of early 2018, 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, since they are standards, and Japan’s space agency (JAXA) imposes ISO 24113 on its contractors. As well, ISO 24113 is employed by European Space Agency (ESA) contractors.

NASA

NASA created the NASA Procedural Requirements (NPR) for Limiting Orbital Debris (NPR 8715.6). 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 leads the involvement and control. The NPR is also applicable for partial NASA involvement with control over design or operations via U.S. internal or international partnership agreements, including the launchvehicle.[11] Companion and lengthier NASA Standard (NASA-STD) 8719.14, Process for Limiting Orbital Debris, and the NASA-Handbook (NHBK) 8719.14, Handbook for Limiting Orbital Debris provide details on engineering processes to limit orbital debris.

NASA also created debris assessment software to assist NASA programs in performing orbital debris assessments. 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 into compliance.[12]

For ISS operations, flight rules provide specific operations practices to limit risk of collision. The criteria established are based on probability of collision and when a debris avoidance maneuver (DAM) should be considered and executed. The probability of collision thresholds range from 1 in 100,000 to 1 in 100. Along with the probability of collision data, various realtime mission-specific constraints are provided that must be considered prior to DAM execution, such as establishing if a visiting vehicle is approaching the ISS. Thus, DAM execution should not be based on the first notification of a threshold probability being crossed, but rather, DAM decisions "should be made as late as practical prior to the predicted time of closest approach.[13]"

Department of Defense

DOD issued Directive 3100.10 in October 2012 (revised in 2016), which promotes the responsible, peaceful, and safe use of space by following the USGODMSP to create a sustainable and stable space environment, which is vital to U.S. national interest. DOD also created Instruction 3100.12 in September 2000 with the goal of minimizing the creation of space debris. The instructions recommend DOD satellite operations consider following debris mitigation practices including removing debris within 25 years, minimizing debris by accidental explosions, and minimizing 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." Specific items of interest from the Instruction 91–217 include the following:

- Requires Air Force organizations controlling spacecraft to establish an "Orbital Safety Program."
- Establishes orbital debris mitigation considerations based on USGODMSP and NASA-STD-8719.14.
- Requires all Air Force spacecraft to implement a conjunction assessment and collision avoidance process using 18th Space Control Squadron's support.[14]

The Joint Space Operations Center (JSpOC) created the Spaceflight Safety Handbook for Satellite Operators, which provides a set of standards for reviewing SSA conjunctions, sending conjunction assessments to satellite operators, providing launch and early orbit conjunction assessments, and allowing satellite operators to provide ephemeris information to the JSpOC. The JSpOC has a standard for the conjunction assessment screening process, which reviews SSA conjunction assessments. The process begins with screening and updating the SSA catalog based on space surveillance network (SSN) sensor data. The JSpOC then performs an initial screening of all active satellites against the catalog to identify conjunction candidates. The candidates are then reevaluated by the JSpOC orbital safety analysts to ensure the most current observations are incorporated. The JSpOC then conducts a refinement screening to update the conjunction estimates of the conjunction candidates. If the parameters of the conjunction are within the criteria that identifies a close approach, the JSpOC will notify the owner/operator of the conjunction.[15]

The JSpOC also provides guidance and best practices for CubeSat operations to improve the tracking and operations of CubeSats.[16] The guidelines include:

- Passive or active identification markers on multi-payload launches.
- Some maneuver capability for conjunction avoidance.
- Design for controlled reentry or expedited uncontrolled reentry to minimize the threat to another on-orbit spacecraft.

- Orbit and mission parameters that include a satellite's operational lifetime greater than two thirds of the orbital life, deployment below or from the International Space Station to minimize risk, and placed into high inclinations to optimize tracking and identification.
- CubeSats should be deployed at multi-second intervals during burns of the launch vehicle to facilitate separation and JSpOC detection/identification/tracking or deployed in 60 second intervals during non-powered flight of the launch vehicle.
- Engagement with the JSpOC during CubeSat pre-mission planning, deployment, and during the operational phase.[17]

It may now be up to Commerce to maintain and update these guidelines.

FAA's Office of Commercial Space Transportation

The FAA's Office of Commercial Space Transportation created the Recommended Practices for Human Space Flight Occupant Safety document, which provides recommendations for the design, manufacturing and operations of a human space flight operation.[18] The document was created to identify subject areas that could benefit from industry consensus standards, but it is intended as a starting point to create dialogue, and perhaps gain consensus among government, industry, and the research community to improve the safety of human space flight vehicles.

Defense Advanced Research Projects Agency (DARPA)

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 U.S. Government has a great deal of experience in establishing mission-specific safety practices for rendezvous and proximity operations (RPO). Previous 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 are duly considered to avoid misinformed establishment of safety standards. With this in mind, DARPA created the Consortium for Execution of Rendezvous and Servicing Operations (CONFERS)[19] program, which has three initial goals that can be applied to the nascent robotic satellite servicing industry:

1. Developing non-binding industry consensus and standards for safe operational rendezvous and proximity and servicing techniques.
2. Serve as a forum to discuss related policy issues and simplifying U.S. government collaboration with industry.
3. Develop means to share data and experience between participants while protecting participants' financial and/or strategic advantages.

The Department of Commerce will likely be heavily involved in CONFERS or may have to establish similar processes.

Private Best Practices, Guidelines, and Standards for Space Traffic Management

With the exception of previously stated orbital debris guidelines, no specific, all encompassing, and/or codified private best practices, guidelines, and standards were found to exist for orbital operations. Each government or private organization creates and establishes best practices based on the context of their own specific risk tolerance and risk mitigation capabilities. As the examples below show, U.S. owner-operators are keenly aware of safety issues and they are working together more frequently in order to be more effective and efficient.

Space Data Association (SDA)

In 2009, the commercial space industry created the Space Data Association (SDA), which established a Space Data Center (SDC) to improve operations for conjunction assessments, RF interference and geo-location support, and contact information for a member's space object. SDA was formed due to the industry's inability to receive accurate and timely SSA information from the JSpOC, and the SDA wanted to coordinate activity and safeguard space-based infrastructure that had previously been handled in an ad hoc fashion. The SDA has an international membership composed of both private companies and governmental organizations. The members share spacecraft operation information and the SDC compiles the data to facilitate conjunction assessment and location information. The SDA and individual satellite operators use data sharing agreements to exchange data information with the government.[20] Nevertheless, the SDA does not have any codified standards, guidelines, or best practices for its satellite operators.

Commercial Spaceflight Federation (CSF)

Human suborbital launch activities are gaining traction in the private sector and will become a tourist attraction in the future. CSF has published only a few standards regarding human-rated suborbital launch vehicles. However, recently CSF has partnered with ASTM International, the international voluntary standards development body. ASTM established the Commercial Spaceflight (ASTM F47) Committee in an attempt to streamline the process of standards development and approval.[e] Established in October 2016, one purpose of the committee is to create human spaceflight safety standards.[21] The committee will also road-map the process to determine voluntary consensus standards in the areas of design, manufacturing and operational use of spaceflight vehicles.

Assessment

With the exception of guidelines for orbital debris mitigation and associated post-mission disposal plans, there are no regulations, standards, guidelines, and best practices focused on STM risk mitigation that are all encompassing or widely embraced, enforced, or integrated across the domestic space enterprise. Best practices beyond the U.S. Government ODMSP are satellite owner/operator specific because they each have unique needs and different operational concepts. The creation of a new STM approach will be vital in moving stakeholders to a more coordinated approach in development and codification of standards, best practices, and guidelines.

Assessing Treaties and International Agreements Relevant to Space Traffic Management

What treaties and other international obligations will the new U.S. STM approach need to operate within? There are 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). These three treaties may be interpreted to allow for domestic regulation of domestic space traffic. 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

[e] ASTM is not an acronym.

for space objects launched from their territory or launched by their nationals.

In addition, SPD-3 will facilitate U.S. 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. SPD-3 includes the goal of streamlining U.S. Governmental processes "to ensure accurate and timely registration submissions to the United Nations," in accordance with U.S. obligations under the Registration Convention.

Indeed, SPD-3 does not call for any changes to international law, instead calling for STM standards and best practices to be, as appropriate, adopted into U.S. domestic regulatory frameworks "and use them to inform and help shape international consensus practices and standards."[1]

Finally, the International Telecommunication Union (ITU) provides one potential, narrow model, for approaching STM internationally. 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.

Another alternative for the international development of STM may be the establishment of non-legally-binding, internationally accepted common standards and best practices, which can eventually be adopted into domestic law in each country. But what non-binding international arrangements relevant to potential STM standards and best practices already exist?

Non-Binding International Arrangements Relevant To STM

SPD-3 states "the United States should continue to develop and promote a range of norms of behavior, best practices and standards for safe operations in space to minimize the debris environment and promote data sharing and coordination of space activities."[1] Certainly, the growing need to protect the long-term sustainability of the space domain is driving the creation of non-binding international arrangements, for which Commerce will now have a significant responsibility.[f] The growing body of non-binding international arrangements concerning orbital debris shows that there is momentum behind a growing number of relevant, voluntary, non-legally-binding guidelines and internationally acknowledged best practices. In fact, the United States has been heavily involved in the development of these guidelines, and many of them are based upon U.S. experiences.

Over the past few years the United States has supported several multilateral initiatives promoting the long-term sustainability, safety, security and/or reliability of the space environment. U.S. diplomats in close coordination with the Department of Defense, NASA, NOAA, industry, and non-governmental organizations, and—going forward—now with the Department of Commerce, advocate

[f] Non-legally-binding international agreements can sometimes evolve into binding law in the form of a treaty, in the form of customary international law, or by being adopted into national laws and regulations.

for multilateral Transparency, and Confidence Building Measures (TCBMs). TCBMs are means by which governments can address challenges and share information with the aim of creating mutual understanding, mutual benefits, and reducing tensions.

One important effort was the United Nations Group of Governmental Experts (GGE) study of outer space transparency and confidence-building measures. The United States, China, Russia and other major countries, consented to the group's final report in 2013 which endorsed voluntary, non-legally-binding TCBMs to strengthen sustainability and security in space. With the United States Russia, and China co-sponsoring, the report was then endorsed by consensus by the UN General Assembly. The report recommended that states do several things in pursuit of TCBMs such as encouraging countries to publish their national space policies and strategies; conduct bilateral and multilateral thematic seminars on space security; implement the 2007 UN debris mitigation guidelines; improve international cooperation on space situational awareness; provide notifications on outer space activities aimed at risk reduction, and conduct visits to space launch sites and facilities.

Another on-going effort is led by the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) which leads multilateral efforts to protect the sustainability of the space environment. Building on the UN Debris Mitigation Guidelines, in 2010, UNCOPUOS began an effort to develop a broader set of voluntary guidelines and best-practices to enhance the long-term safety and sustainability of the outer space environment. Hence, the working group on the long-term sustainability (LTS) of outer space activities was established under the COPUOS Scientific and Technical Subcommittee to identify areas of concern for the long-term sustainability of outer space activities, propose measures that could enhance sustainability, and produce voluntary guidelines to reduce risks to the long-term sustainability of outer space activities. The working group and its expert groups focused on four broad areas including supporting sustainable development on Earth; space debris, space operations and tools to support collaborative space situational awareness; space weather; and regulatory regimes and guidance for actors in the space arena.

In 2016, the COPUOS LTS Working Group reached agreement on an initial set of 12 guidelines which represents a significant milestone in multilateral diplomatic efforts to preserve the outer space environment for current and future generations. Furthermore, in February 2018, COPUOS LTS Working Group reached consensus on nine additional guidelines for long-term sustainability of outer space activities. Like the debris mitigation guidelines, while not legally-binding internationally, the goal for the long-term sustainability guidelines is to have them incorporated into legally-binding national legislation by all responsible nations. The Department of Commerce is now a major stakeholder in this effort in addition to NASA, DOD, and others.

It is reasonable to judge that Commerce will need to engage the international community in the establishment of the U.S. STM process. Indeed, the international community will inform and contribute to the shape of Commerce's STM activities.

Conclusion

The Department of Commerce has been charged with the complex mission of establishing a new U.S. STM approach. The results of this effort will benefit the U.S. space sector and the international community as well. Hopefully this brief paper reveals significant features of the landscape into which Commerce is involved, and helps the Department of Commerce, and the Office of Space Commerce understand the scope of its task, prioritize its efforts, and contribute to the overall success of its STM mission.

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