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A SHORT GUIDE FOR UNDERSTANDING AND ASSESSING U.S. SPACE SUSTAINABILITY INITIATIVES

Michael P. Gleason

In the last few years, the United States has taken significant steps forward in establishing a framework for protecting the sustainability of the space domain and in demonstrating U.S. leadership and commitment to preserving the safety, stability, security, and long-term sustainability of space activities. The framework is implicit in the first ever U.S. National Space Traffic Management Policy, Space Policy Directive-3 (SPD-3),[1] which is re-emphasized and promoted in the December 2020 U.S. National Space Policy (NSP).[2] This paper identifies key lines of effort, extrapolated from SPD-3 and reinforced in the 2020 NSP, to guide understanding and assessment of recent efforts, and provides insights into where new and continuing efforts should be focused.

Population Explosion in Space

Since the Space Age began more than 60 years ago, about 9,800 satellites have been placed in orbit with about 6,700 still there, and as of March 2021 about 3,100 of those are still operating.[3] In 2019, several commercial companies proposed satellite constellations ranging from potentially 1,000 to 30,000 satellites each, totaling 75,000 or more new satellites in orbit for a single generation. The number of proposed satellites changes nearly every day with some recent estimates reaching more than 100,000 additional satellites in orbit by 2030. This anticipated rise in the number of satellites in such a short period of time will lead to a significant increase in collision risk. The resulting space debris, along with the new vehicles themselves, will challenge the overall sustainability of the space environment. While it is unlikely that all of the planned satellites will be launched, the graph below illustrates that almost 2,000 new commercial satellites have been placed in non-geostationary orbits (NGSO) since 2012 and the upward trend continues to accelerate.* The United States is beginning to address the fundamental changes occurring in the space environment.

U.S. Government Orbital Debris Mitigation Standard Practices. Among its top priorities, SPD-3 called for an update to the U.S. Government Orbital Debris Mitigation Standard Practices (USG ODMSP) from the year 2000. The standard practices apply to all U.S. government organizations involved in space operations and serve as the U.S. government's foundation for issuing specific orbital debris mitigation requirements and technical guidance. Furthermore, the Federal Communications

* See the annex, "Proposed, Approved, and Deployed Satellite Constellations," for more detailed numbers.

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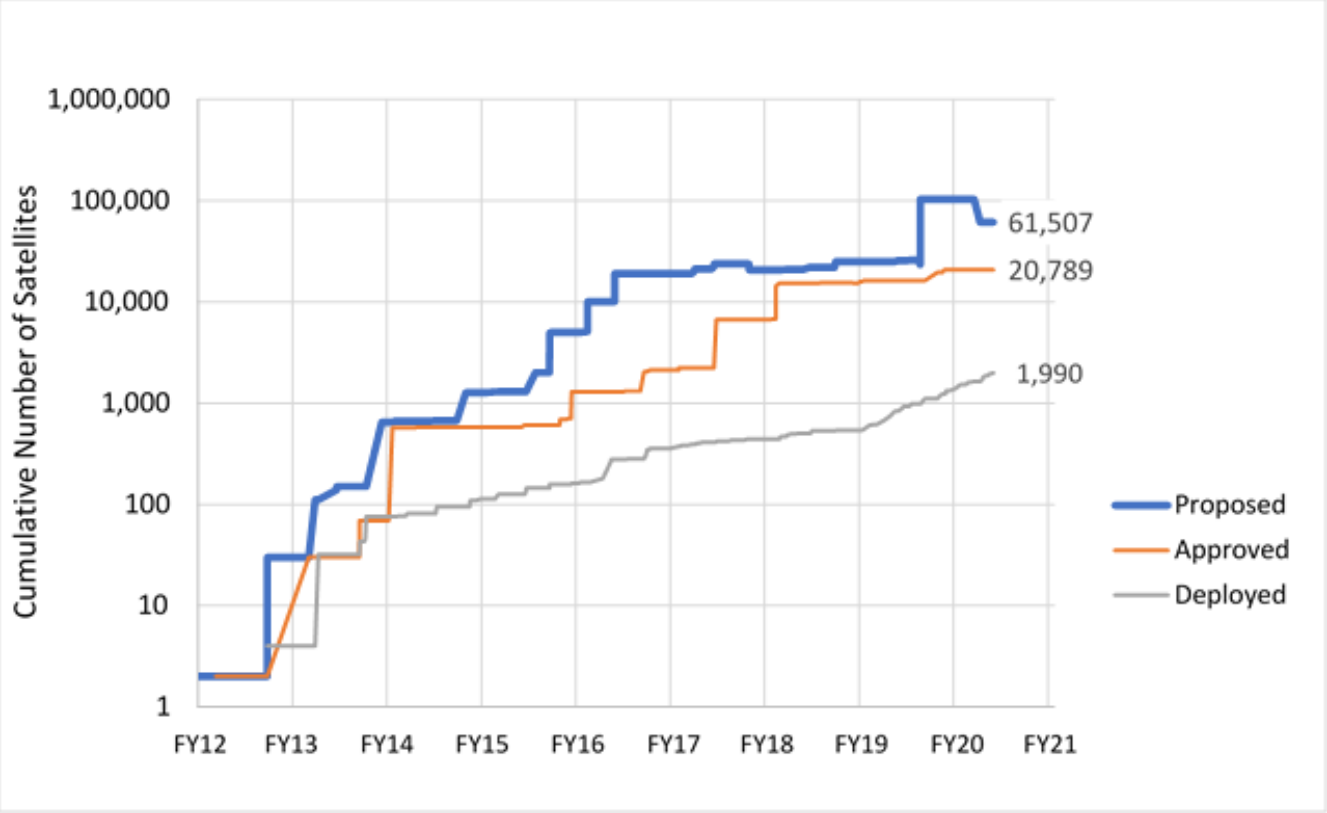

Figure 1: Growth in commercial GS constellations – number of satellites per FCC filings since October 2012 (logarithmic scale).

Commission (FCC), Federal Aviation Administration (FAA), and National Oceanic and Atmospheric Administration (NOAA), three U.S. space regulatory agencies, mandated the compliance of U.S. private spacecraft companies with agency or commission regulations based on USG ODMSP. The 2000 USG ODMSP aimed to limit the amount of orbital debris and the amount of time that such debris and spacecraft could remain in orbit. The standard practices include all spacecraft program phases, from concept development to space hardware disposal.

SPD-3 highlighted the need to update the USG ODMSP "to enable more efficient and effective compliance and establish standards that can be adopted internationally." In December 2019, eighteen months after SPD-3 was published, the U.S. government released its new Orbital Debris Mitigation Standard Practices.[4] The 2019 update, a U.S. whole-of-government effort led by the National Aeronautics and Space Administration (NASA), introduced operating practices for emerging space activities—including large constellations and small satellite (including CubeSat) operations, rendezvous and proximity operations (RPO), active debris removal operations (ADR), and satellite servicing. It also introduced quantitative limits on debris released during normal operations, probability limits on accidental explosions and collisions with large and small debris, and a reliability threshold for post-mission disposal. In addition, the new ODMSP includes preferred and new end-of-mission-life disposal and storage options for structures in low Earth orbit (LEO), medium Earth orbit (MEO), geosynchronous orbit (GEO), inclined GEO orbits, highly elliptical orbits (HEO), and other orbits to minimize the impact on future space operations.

Nevertheless, many observers viewed the update as modest given the dramatic rise in the number of satellites projected to be placed in orbit.[5] Many were disappointed that the 2019 USG ODMSP did not change the previous ODMSP guideline recommending that satellite operators remove spacecraft and orbital stages from useful and densely populated orbit regions no longer than 25 years after mission completion, colloquially referred to as the

"25-year rule." Many observers advocate for reducing the time frame to *under* 25 years, even though compliance rates with the current 25-year standard are poor.[6] These observers argue that the current approach will not scale to the expected increases from satellite constellations consisting of hundreds or thousands of satellites.[7] Nor does the current approach account for the short mission lives of CubeSats, which represent a growing sector of the satellite industry. Other observers argue that the effect on the debris environment of shorter lifetimes is relatively small, and the new USG ODMSP's addition of a 90 percent or better post-mission disposal requirement addresses the lack-of-compliance issue by making the success rate an active consideration. The 2020 NSP states that the United States shall periodically update the USG ODMSP, but it is unclear how often that will occur. Given the rapidly changing space environment, the debates surrounding the 25-year rule and measures for managing large numbers of satellites are likely to continue and ideally the USG ODMSP will be updated more frequently than the previous 20 years between updates.

U.S. International Leadership. The coming few years will also show if the 2019 USG ODMSP follows a similar path as the 2000 USG ODMSP to wide international acceptance. The 2000 USG ODMSP influenced the development of the 2002 Inter-Agency Space Debris Coordination Committee (IADC) Space Debris Mitigation Guidelines, which in turn influenced the United Nations (UN) Committee on the Peaceful Uses of Outer Space (COPUOS) Space Debris Mitigation Guidelines.[8] Today, the 13 IADC-member agencies have, to various extents, incorporated these debris mitigation standards into their domestic regulation and law.[†]

SPD-3 endorsed development of congruent international approaches to minimize debris and called for the United States to promote the USG ODMSP as a model for consideration in international forums such as IADC, International Organization for Standardization (ISO), and COPUOS. The 2020 NSP establishes policy consistent with this approach as well. The United States was successful in following this approach and could continue to lead the rest of the world forward along this proven path. And with an increased sense of urgency, the United States could benefit by promoting the 2019 USG ODSMP in the IADC and in COPUOS.

In addition, the 2020 National Space Policy and SPD-3 call for U.S. leadership in the development of international and industry standards that will help preserve the space environment through organizations such as the ISO. As the most important of the ISO space debris mitigation standards, ISO Standard 24113 represents another line of effort in which momentum should be maintained. ISO Standard 24113 was updated in July 2019, with several revisions including important updates to the probability of successful post-mission disposal.[9] The probability is now calculated from the beginning of the mission rather than from just before disposal. Also, the required success rate is at least 90 percent, which is in line with the 2019 ODMSP, which was taken from NASA Standard 8719.14 and AFI 91-217 (now in AFI 91-202). While ISO 24113 remains the primary debris mitigation standard, two additional standards—ISO 20893, which was completed in March 2021, and ISO 23312, which is under development—will be new supporting standards for 24113. It is likely that revisions to ISO 24113 will begin well before the standard review cycle with a goal of synchronizing development of the related debris mitigation standards.[10] The United States could benefit by continuing to encourage development of these new standards on an accelerated timeline.

SPD-3 and the NSP also encourage the international adoption of guidelines and best practices for safe space operations through U.S. participation in COPUOS. In June 2019, COPUOS achieved consensus among 92 countries (including Russia and China) and adopted a set of 21 voluntary "Guidelines for the Long-term Sustainability of Outer Space Activities" (also known as LTS guidelines).[11] In adopting the guidelines, the committee agreed to establish a follow-on working group for 2020 through 2024 to examine issues associated with implementation, capacity building, and possible new guidelines. However, the formation of this "LTS 2.0" working group has been slowed by COVID-19 and continued efforts by Russia to inject disarmament-motivated proposals (such as a guideline for non-

[†] IADC member agencies include ASI (Agenzia Spaziale Italiana), CNES (Centre National d'Etudes Spatiales), CNSA (China National Space Administration), CSA (Canadian Space Agency), DLR (German Aerospace Center), ESA (European Space Agency), ISRO (Indian Space Research Organisation), JAXA (Japan Aerospace Exploration Agency) KARI (Korea Aerospace Research Institute), NASA (National Aeronautics and Space Administration), ROSCOSMOS (State Space Corporation), SSAU (State Space Agency of Ukraine), and the UK Space Agency.

cooperative rendezvous and proximity operations) which exceed COPUOS's longstanding mandate to address "bottom up" measures for spaceflight safety. The United States and like-minded nations continue to encourage Russia in COPUOS to agree to the follow-on LTS working group or at least not stand in its way.

Space Traffic Management. Perhaps the most ambitious line of effort in SPD-3, and reinforced in the NSP, is transitioning civil space situational awareness (SSA) and space traffic management (STM) service responsibilities from the Department of Defense (DOD) to the Department of Commerce (DOC). In December 2020, Congress approved this course of action in law, and directed the DOC Office of Space Commerce (OSC) to initiate a STM pilot program and an open architecture data repository (OADR) pilot project. Congress provided increased appropriations to the DOC/OSC in fiscal year 2021, marking a significant increase in funding compared to the appropriations OSC received in previous years. Despite its constrained budget, however, DOC/OSC has been making progress since 2018 in establishing the OADR.

SPD-3 also calls for research and development to support such SSA and STM capabilities and applications saying, "These activities include improving fundamental knowledge of the space environment, such as the characterization of small debris, advancing the science and technology of critical SSA inputs such as observational data, algorithms, and models necessary to improve SSA capabilities, and developing new hardware and software to support data processing and observations."[12] The January 2021 National Orbital Debris Research and Development (R&D) Plan answers that call by providing a national plan to coordinate and prioritize research and development into managing the risk posed by orbital debris. The plan calls for continued coordination and discussion among the interagency, private industry, academia, and international partners. As the national space debris R&D plan evolves, it will help close critical technical gaps in understanding the debris environment and the capabilities needed to protect space sustainability.[13]

Rules and Regulations. Separate and distinct from the NSP and SPD-3 mandates, on October 25, 2018, the FCC released the "Notice of Proposed Rulemaking and Order on Reconsideration, IB Docket No. 18-313." Importantly, the FCC is an independent agency, not under the authority of the executive branch of the U.S. government as DOC is. The notice sought comments from the public on proposed updates to the orbital debris mitigation rules for all FCC-authorized satellites. As noted above, the FCC mandates that U.S. private spacecraft companies comply with debris mitigation rules that are based on the USG ODMSP in order to obtain FCC licensing. The proposed update offered many potential new regulations—for example, new rules regarding space object trackability, information sharing requirements, orbit selection, post-mission disposal reliability, and dozens of other technical and operational requirements.

However, this FCC rulemaking effort highlighted the natural tension that exists between the government's need for regulation to protect the safety, security, and sustainability of the space environment and industry's desire for 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.

On April 2, 2020, the FCC released a draft of revised orbital debris mitigation regulations and the tensions noted above came to the forefront. The draft rules included stringent new requirements for operators applying for an FCC license and U.S. market access to indemnify the government for damage their satellites might cause; to be bonded for up to $100 million, which would be forfeited if operators did not properly dispose of the satellites; and to design spacecraft flying above 400 kilometers to be maneuverable in order to avoid collisions above that altitude. These strict new rules were opposed by industry, Congress, and others as being detrimental to U.S. space companies and for putting the U.S. space industry at a competitive disadvantage compared to other countries.[14] On April 23, 2020, in the face of this opposition, the FCC voted unanimously in favor of requiring satellite operators to quantify their collision risk, probability of successfully disposing spacecraft, and the casualty risk associated with spacecraft that reenter Earth's atmosphere, but deferred consideration of the more controversial draft rules until they could be studied further.[15] Soon thereafter the FCC issued a "Further Notice of Proposed Rulemaking"

(FNPRM) and began a new round of public comment on the unresolved issues. Final public comments on this new FNPRM were due to the FCC in October 2020. An additional set of draft rules will be generated based on consideration of the additional comments from industry and government. Congress and other stakeholders could benefit from following the development of these draft FCC rules and evaluate their alignment with the other lines of effort outlined above.

These various lines of effort toward establishing a new framework for protecting the sustainability of the space environment, as directed in SPD-3 and reemphasized in the NSP, and through the independent initiatives of the FCC, show progress is being made in response to the rapid changes in space activities. Observers should expect to see continued momentum by the United States along these lines of effort.

Table 1: Understanding and Assessing U.S. Space Sustainability Initiatives

Lines of Effort	Status	Moving Forward
USG ODMSP updates	Last updated December 2019	Periodic updates: To be determined
IADC (regarding 2019 ODMSP update)	Last updated March 2020	Not informed by 2019 USG ODMSP yet
COPUOS (regarding ODMSP update)	Last updated January 2010	Not informed by 2019 USG ODMSP yet
ISO standards	ISO Standard 24113 last updated July 2019	ISO 20893 published March 2021 ISO 23312 in development ISO 24113 accelerated development
DOC SSA and STM mission	Congressional approval. December 2020 Congressional funding. December 2020 STM pilot program OADR development	STM pilot program: To be determined OADR operation: To be determined
COPUOS LTS guidelines	21 guidelines approved, June 2019	LTS 2.0 workgroup approval: To be determined
Orbital debris (R&D)	Plan released January 2021	Prioritization and funding: To be determined
FCC rules, orbital debris mitigation regulations	New regulations being drafted	New regulation alignment with NSP/SPD-3: To be determined

Conclusion

SPD-3 drove steady, incremental progress over the last few years toward establishment of a new framework for protecting the sustainability of the space domain, and the U.S. government has outlined the way ahead domestically and internationally as reflected in Table 1.

As the new U.S. administration and Congress chart the course for U.S. space leadership, they should find that the 2019 USG ODMSP is now in place to help the United States promote new approaches for orbital debris mitigation in international forums like the IADC and COPUOS, and to inform future revisions to ISO 24113. In addition, the COPUOS follow-on working group for LTS guidelines indicates that multilateral efforts to promote sustainability guidelines hold promise but may need a push to overcome the obstacles presented by Russia.

While the DOC space traffic management line of effort matures, expect to see lessons learned from its STM pilot program. Likewise, as orbital debris R&D becomes better coordinated and prioritized, improved knowledge of orbital debris should lead to new understanding and advanced capabilities. And as new FCC rules emerge, stakeholders may evaluate their alignment with the NSP and SPD-3.

Assessing these lines of effort, extrapolated from SPD-3 and the 2020 NSP, provides insight into where efforts going forward could focus in order for the United States to demonstrate and maintain global leadership and protect the sustainability of space activities.

Annex: Proposed, Approved, and Deployed Satellite Constellations as of March 2021

Call Signs	NGSO Constellations	Proposed	Approved	Deployed
S3069	SpaceX Starlink Gen2	30,000	0	0
S2992	SpaceX Starlink VLEO	7,518	7,518	0
S2963	OneWeb LEO	7,088	720	110
S2983 & S3018	SpaceX Starlink LEO	4,409	4,409	1,143
S3051	Amazon Kuiper	3,236	3,236	0
S2976	Telesat	1,671	117	0
S2994	Oneweb MEO	1,280	1,280	0
S2912	Planet Labs Flocks of Doves	1,156	1,156	424
S2946	Spire Global	1,000	1,000	84
S3045	Spire Global MINAS	872	636	12
S3068	Magnata	791	0	0
S3064	SWARM Astrobiene	450	0	0
S3070	Kepler	360	0	0
S3041	SWARM	300	150	81
S2985	Viasat	288	20	0
S3065	AST	243	0	0
S2993	Boeing	147	0	0
S2981	Kepler	140	140	8
S2986	Theia Holdings A	120	120	0
S2935	O3b	112	38	20
S2110	Iridium NEXT	81	81	75
S3042	Hawkeye	80	80	3
S3014	Astro Digital U.S.	30	5	1
S3057	Myriota	26	26	0
S3054	Keneis	25	0	0
S2862	Planet Labs Skysat	21	21	21
S3019	New Spectrum Satellite	18	0	0
S3032	Blacksky Global	16	16	6
S2980	Karousel	12	12	0
S3067	R2 Space	8	0	0
S2982	Audacy	3	3	0
S3073	Capella Space	3	3	2
S2978	Space Norway	2	2	0
S3052	LOFT	1	0	0
34 Constellations	**Totals:**	**61,507**	**20,789**	**1,990**

These numbers are estimates based upon analysis of FCC filings and public records of launches from various sources such as *SpaceNews* and *SpaceflightNow*. The FCC does not publish these types of summary statistics. (Courtesy of Grant Cates, The Aerospace Corporation.)

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[3] Interviews with Marlon Sorge and Grant Cates, The Aerospace Corporation, March 2020.

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[7] Rebecca Reesman et al, *Slash the Trash: Incentivizing Deorbit*, April 2020 (https://aerospace.org/paper/slash-trash-incentivizing-deorbit).

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About the Author

Dr. Michael P. Gleason is a national security senior project engineer in The Aerospace Corporation's Center for Space Policy and Strategy and is a well-regarded author on space policy subjects, including international cooperation, space traffic management, national security, and deterrence. He has presented his research on critical space policy issues at conferences in Canada, Europe, Japan, and across the United States. A graduate of the U.S. Air Force Academy, Gleason served 29 years active in the Air Force space career field, including stints in spacecraft operations, on the Air Force Academy faculty, at the Pentagon, and at the Department of State. He holds a Ph.D. in International Relations from George Washington University (GWU) and is an alumnus of the GWU Space Policy Institute. Gleason is the recipient of the Defense Superior Service Medal and the Department of State Superior Honor Award.

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