National Space Society

Position Paper:

United States Space Guard: A New Civil Entity to Protect Persons and Property per "Space Policy Directive-3"

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Executive Summary

Despite the growing threat of orbital debris, the number of Earth-orbiting satellites is on the verge of exponential growth. Most of these satellites will be commercial and launched into Low Earth Orbit (LEO). However, Medium Earth Orbit (MEO) will also face a sharp increase in commercial satellite numbers. The key to eliminating the orbital debris threat, while managing the space environment to foster safe, secure, and well-regulated commercial space activities, is a vigorous, worldwide Space Traffic Management (STM) system, which would take advantage of emerging technologies and techniques for Active Debris Removal (ADR) and enhanced Space Situational Awareness (SSA) to carry out effective traffic management on a worldwide scale.

Any effort to enhance the safety of navigation in space cannot succeed without the active involvement and support of our military, the commercial satellite industry, and space stakeholders worldwide. In a prior position paper, the National Space Society (NSS) identified the urgent need to control the growth of Earth orbiting debris.[1] In a 2017 follow up paper, NSS recommended the formation of a national "Space Guard" to orchestrate civil STM in collaboration with space-related national offices, including military sectors.[2] The National Space Council since then issued on 18 June 2018 "Space Policy Directive-3, National Space Traffic Management Policy" (SPD-3), which directs the Department of Commerce (DoC) to either manage or collaborate on aspects of STM heretofore left solely to other federal offices to foster "continued growth and innovation in the U.S. commercial space sector."[3]

In support of SPD-3, NSS reiterates its call for the legislature of the United States to demonstrate world leadership by creating a guardian management entity, evolving from industry standards and best practices, to enable and regulate the commercial space sector within a safe, sustainable, and secure space environment. In this paper, we offer concrete, practical suggestions as to how SPD-3 recommendations could be implemented in ways that

minimize turf battles and taxpayer expense. Our proposed guardian entity, housed in DoC in a manner analogous to NOAA within DoC, would also be able to promote and coordinate with analogous space entities internationally. In this paper, we shall call our proposed space entity the United States Space Guard (USSG).[4]

Effective STM Must Evolve from Industry Standards and Best Practices

SPD-3 recommends that the U.S. develop operational standards and best industry practices to promote safe and responsible behavior in outer space. SPD-3 spells out, as a crucial first step in this direction, for the U.S. to develop "minimum safety standards and best practices *to coordinate space traffic*."[5] (Emphasis ours.) Effective STM is therefore a major goal of SPD-3.

NSS defines STM broadly as activities taken to promote the safe use of outer space, including measures to lessen the negative impacts of the increasing physical congestion in space. Such safety of navigation (SoN) measures includes all systems, protocols, and procedures that assist spacecraft to safely orbit or travel beyond Earth, including orbital assignment, space situational awareness (SSA), launch and reentry licensing and regulation, safety approvals, frequency assignment, conjunction warnings, orbital debris mitigation, orbital debris remediation (cleanup) through Active Debris Removal (ADR),[6] and any other management practice that will facilitate safe and secure space travel. Although the broadest meaning of the term STM encompasses SSA, orbital debris mitigation and ADR, in this paper we will also speak of these and other comprehensive STM elements separately.

NSS strongly supports SPD-3's call for an STM regulatory framework to be built on industry best practices and safety standards.[7] Standards, best practices, guidelines, protocols, and safety norms, often called "soft law," are essential rungs on the ladder leading to an evolved regulatory STM framework, which in turn can lead to nationally legislated hard laws and regulations for STM. Soft and hard law, taken up and acted upon repeatedly by multiple national entities, can even evolve into "customary international law," which in turn can further evolve into codified international treaty law. This latter possibility is discussed further in the final section of this policy paper.

The urgency for better STM comes from the dramatic increase expected in trackable and untrackable objects in space within the next decade. There are about 1800 operating satellites in Earth orbit, sharing space with about 8,000 tons of orbital debris.[8] About 800 of these working satellites are in Low Earth Orbit (LEO)—200 to 2000 km altitude. Some altitude and inclination bands in LEO are already becoming perilously crowded with both functioning satellites and orbital debris. While most satellites currently in LEO are government owned and operated, commercial use of LEO will grow drastically within a few years because private companies are planning to launch over 20,000 new commercial satellites, mostly into LEO, even as baseline growth in satellite numbers continues.[9]

Beyond the planned exponential growth in commercial satellites, there are an estimated 750,000 untracked debris objects from 1 to 10 cm in Earth orbit, dangerous to spacecraft and people, but which cannot practically be shielded against.[10] These smaller objects are produced when larger spacecraft or debris break up or suffer collisions. Without active intervention, the multi-ton debris objects already in orbit will produce more orbital shrapnel *even if we never were to launch another spacecraft*.

SPD-3 pointedly recognizes small debris threat by calling for an enhancement of SSA technologies to the level where orbital shrapnel can be tracked and actively eliminated, along with multi-ton objects.[11] In this connection, ADR should make use of emerging public and private technologies[12] and commercial entities to clear away or re-purpose debris.[13] Moreover, enhanced SSA can also lead to actionable and timely conjunction reports for collision avoidance, also called for by SPD-3.[14]

In sum, orbital debris potentially threatens our modern way of life and our plans for future human spaceflight. The longer we ignore the 8000 tons of debris already in orbit, while making no new provisions to safely and securely manage the more than 20,000 new commercial satellites and upper stages to be launched in the next few years, the more vulnerable our modern society and space plans will become. It is now incumbent upon the United States to carry out the recommendations of SPD-3 through a reorganization and realignment of its various space offices, resulting in effective STM with the least cost and least amount of administrative disruption.

Reorganizing Federal Space Offices with Minimal Disruption and Cost

The United States Space Guard (USSG) should be an umbrella bureau, a coordinating and organizing superstructure, largely independent but connected, in line with SPD-3, to the Department of Commerce (DoC) and the Department of Transportation (DoT).[15] In this capacity, USSG would also have relevant connections to other U.S. government agencies and offices, the commercial satellite community, and international space stakeholders, and could provide an integrated "STM nexus" to secure the space environment for safe commercial and civil-government use.

To form this organizing superstructure with minimal cost and disruption, experienced personnel from Executive Branch offices dealing with space would be transferred into USSG, while at least in the beginning keeping administrative ties to their parent agencies.

Currently DoC's Office of Space Commerce (OSC) has only three Full-Time Employees (FTEs) and an annual budget of around $800,000. NOAA's Commercial Remote Sensing Regulatory Affairs Office within its Satellite and Information Services Office (DoC/NOAA/NESDIS/CRSRA) manages commercial Earth-observation satellites. NOAA/CRSRA has five FTEs and an annual budget of $1.2 million. DoT/FAA's Office of Commercial Space Transportation (DoT/FAA/AST) has about 100 FTEs and an annual budget of $20 million just to do licensing of commercial space launches

and re-entries.[16] These three offices currently provide licensing and oversight for nearly all commercial space activities.

FCC's Office of Engineering and Technology (FCC/OET) administers radio spectrum for non-Federal use. DoC's National Telecommunications and Information Administration (DoC/NTIA) administers radio spectrum for Federal use. NASA's Orbital Debris Program Office is administered out of Johnson Space Center. Incorporating personnel from these offices into USSG would also facilitate coordination among all sections of the bureau.

Maintaining administrative ties to parent departments and agencies would greatly reduce "turf wars" and taxpayer-funded reorganization costs, while retaining experienced personnel. NSS therefore recommends that the personnel of all the above offices be incorporated into the USSG to form the industry-enabling core of commercial space management, while maintaining administrative ties to their parent federal departments and agencies.

The State Department's Office of Space and Advanced Technology (DoS/OES/SAT), which works to ensure that U.S. space policies and multilateral science activities support U.S. foreign policy objectives and enhance U.S. technological competitiveness, would play a crucial role as a USSG liaison and advisor to international public and private space entities. In that capacity, when appropriate, SAT would also facilitate USSG coordination with the State Department's Directorate of Defense Trade Controls (DDTC) and its International Traffic in Arms Regulations (ITAR) Office, charged with controlling the export and temporary import of defense articles and defense services covered by the United States Munitions List (USML).

NSS believes that a legislative process to establish USSG, although slower than establishing by Executive Order, would lead to a more stable and durable space bureau. No matter how the NSS-proposed new federal entity is established, however, it should also coordinate closely with relevant non-government space stakeholders worldwide, including satellite companies, academia, NGOs, and the insurance industry.

Safety First

United States residents know they are safe taking routine commercial airline flights across the country because they also know that the aircraft has been properly certified and the pilots and mechanics properly trained and licensed.[17] The same should be true for persons traveling in space. The United States should set international space operating norms for spacecraft, orbital debris, and space-goers of all stripes, by putting its own house in order first.

DOT/FAA/AST already have the authority to issue a non-mandatory "safety approval" for one or more of the following safety of navigation (SoN) *elements*: a launch vehicle, a reentry vehicle, a safety system, process, service, or any identified component thereof, and qualified and trained personnel performing a process or function related to licensed launch activities.[18] Because safety approvals allow launch and reentry vehicle operators repeatedly to use an approved

safety *element*, without having to go through a re-examination of that element's fitness and suitability for a proposed launch or reentry operation, NSS recommends that SoN element approvals be continued to save time, effort, and money—even after safety licensing begins. Current federal law calls for the delay of formal safety regulation related to "spaceworthiness" to allow time for the industry to develop while allowing the FAA/AST to proactively ensure bystanders' safety and take corrective actions in response to specific problems and accidents. During this period passengers can fly on sub-orbital and orbital vehicles after signing a safety waiver. NSS supports this approach to regulation and believes that formal "spaceworthiness" regulations should be delayed until the nature and design of orbital vehicles has regularized. When regulations formally start, the logical approach is for FAA/AST to put forward regulations for vehicles that travel between the Earth's surface and orbit while the DOC is responsible for the regulation of vehicles that operate only in space and of installations on celestial bodies.

To ensure a level playing field and synch with evolving industry-enabling regulations for national entities, the USSG should coordinate with the State Department's Office of Space and Advanced Technology (DoS/OES/SAT) to lead the effort to standardize such requirements internationally as well. In all cases of evolved national requirements, NSS strongly recommends that they be instituted as hard regulations only after Russia, China, ESA, India, Japan and other relevant space actors also agree to the same regulatory requirements. NSS also recommends that space entities responsible for any spacecraft already in orbit be grandfathered under the policies and rules and enabling regulations in existence at the time of their design and construction, so that they are not penalized by any new STM policy, rule, or regulation.

Key Role for DoD Specified by SPD-3

Although other DoD entities have contributed to space development since the 1950s, the USAF has been the lead for military space activities.[19] Although the civilian USSG would organize the removal of orbital debris in coordination with personnel from other national space offices, the USAF would necessarily play a key role. The USAF already has the SSA capability to track assets and debris, operate communications globally, launch rockets, and operate assets in space. Thus, as specified by SPD-3, the USAF could contribute greatly to SSA enhancement, conjunction warnings, ADR, and other comprehensive STM capabilities by maintaining an authoritative catalog of space objects. To enhance data sharing, SPD-3 also directs DoC to be responsible for the "publicly releasable portion of the DoD catalog and for administering the open architecture data repository."[20] NSS therefore recommends that DoC carry out this directive as part of our proposed USSG superstructure.

NSS believes that non-sensitive DoD space resources and capabilities could eventually be integrated into the civilian USSG in cautious step-wise fashion. If carried out under the watchful eyes of DoD and civilian observers, such integration of DoD resources would accrue to the general benefit of the U.S. space effort. To assuage the fears of those who might suspect that a civilian USSG will only serve as cover for aggressive military plans,

safeguards for bringing DoD capabilities into USSG must be clear, transparent, and reassuring to outside national and international observers.

How to Pay for Comprehensive STM?

Currently, no single national or international entity exists to collect and allocate funds for safe and secure space operations. Yet the need for such funds will only grow as we face the task of safely managing the coming avalanche of new space traffic, plus financing public infrastructure in support of private and government activities in space.

Our financial situation is simple: pay now, or pay *(much more)* later. Even without launching another satellite, with time there will be more collisions between multi-ton bodies and more catastrophic breakups and cleaning up the mess will cost us all more.[21] It behooves us all to adequately fund comprehensive STM (including SSA and ADR) now to avoid this kind of situation.

As space commerce expands, a mechanism like the Oil Spill Liability Trust Fund, which pays for oil spill cleanup by the U.S. Coast Guard and Environmental Protection Agency, could emerge to cover the cost of cleaning up orbital debris by private contractors hired by USSG. A national trust fund, as part of USSG, could induce and then coordinate with an international version to collect and disburse funds via debris cleanup contracts, paid out only when private contractors reach milestones or provide actual cleanup or related services. In this way, the USSG may rise to become a potent fund-organizing entity. Although funds for cleanup could be raised from taxes, launch fees, or orbital parking fees, NSS notes that private satellite companies could take a leading role, in coordination with government, to proactively charge satellite service *end-user* fees at a low rate as a first step for accruing trust funds, first for technology development and demonstrations, and eventually for enhanced SSA, ADR, and other aspects of STM.[22]

In sum, NSS recommends that our Congress and Administration work diligently with private and public space stakeholders domestically and abroad to design and engage national and international collection and allocation mechanisms to finance comprehensive STM and space guardian services worldwide.

What about Planetary Defense?

NASA's Planetary Defense Coordination Office (PDCO), with a current budget of $50 million, is responsible for (1) ensuring the early detection of asteroids and comets deemed potentially hazardous objects (PHOs); (2) tracking and characterizing PHOs and issuing warnings about potential impacts; (3) providing timely and accurate communications about PHOs; and (4) leading the coordination of U.S. Government planning for response to an actual impact threat.[23] PDCO relies on data from projects supported by NASA's Near-Earth Object (NEO) Observations Program. PDCO also coordinates NEO observation efforts by ground-based

observatories sponsored by the National Science Foundation and space situational awareness facilities of the United States Air Force. Additionally, PDCO is developing defensive technologies under the Double Asteroid Redirection Test (DART) kinetic impact program.

De-spinning, grappling, deflection, and tugging technologies for moving large debris objects into salvage orbits could inform technologies for dealing with small NEOs and vice versa. Personnel in PDCO could therefore play a synergistic role with ADR personnel in USSG. Moreover, the very notion of a "space guard" logically entails the defense of persons and property from various threats, including NEOs. Therefore, NSS recommends that NASA's PDCO be incorporated into USSG with its current staffing and budget on a date deemed appropriate by the U.S. Administration. More information about planetary defense can be found in NSS's 2014 policy position paper, "Protecting Earth from Cosmic Impacts."[24]

Planetary defense against Near Earth Objects (NEOs), both asteroids and comets, should be a component in any proposed civil Space Guard.

International Coordination

SPD-3 calls on the United States to establish standards and best practices that can be adopted internationally.[25] As such, these standards and best practices will also require adherence to the 1967 Outer Space Treaty (OST), which requires the U.S. to track and keep custody of every object it launches from the time it is launched until it is deorbited, including objects launched by private companies. Article VI of the OST states:

> "States Parties to the Treaty shall **bear international responsibility** for national activities in outer space, including the Moon and other celestial bodies, whether such activities are carried on by governmental agencies or by non-governmental entities, and for assuring that national activities are carried out in conformity with the provisions set forth in the present Treaty. The **activities of non-governmental entities** in outer space, including the Moon and other celestial bodies, shall require **authorization and continuing supervision** by the appropriate State Party to the Treaty."[26] (Emphasis ours.)

A civil entity could ensure U.S. compliance with its obligations under Article VI of the OST. Both the House and Senate have legislative bills aimed at organizing comprehensive STM and facilitating commercial space, while adhering to the OST. However, the Senate bill differs with the House and SPD-3 in that it would give authority to DoT/FAA for authorizing so-called "non-traditional" commercial space activities, ranging from satellite servicing to lunar landers, that are not explicitly regulated today. The House bill, more in line with SPD-3, gives that authority to the Commerce Department.[27] Since it is not yet clear which view will prevail in legislation signed by the President, NSS emphasizes that it is vital that either DOC or DOT step up to this OST obligation as soon as possible to avoiding making the difficulty of

getting permission for new enterprises in space the primary obstacle to staring such enterprises.

Despite the long-standing need for worldwide coordination to deal with space traffic and cleanup, a perceived lack of urgency[28] and perceived dual use technologies within a tense geopolitical context thwart urgently needed space management actions. **International rivalries and the potential to interfere with others' satellites have led to a quagmire of geopolitical suspicion.**

Another quagmire to be avoided concerns international liability to launching states who are parties to the Outer Space Treaty (OST), such as the United States, Russia, Japan, China, and the European nation states. OST Article VI assigns international **responsibility** for activities carried out by State Parties in outer space, whether by government or non-government persons or entities (emphasis ours). "Liability" is translated as "responsibility" in Spanish, Italian, French, and other languages. In general, the term "responsibility" in Article VI represents a warning of possible liability claims because of persons or properties injured during a space mission.

Article VII of the OST, which identifies four different categories of State Party launching states, and Article V of the Convention on International Liability for Damage Caused by Space Objects (Liability Convention), taken together with OST Art. VI, also reveal liability risk to launching State Parties. Even Article VIII of the OST appears arguably to assign responsibility (and therefore liability risk) by stating that the "State Party to the Treaty on whose registry an object is launched into outer space is carried shall retain **jurisdiction and control** over such object, and over any personnel thereof…." (Emphasis ours.) The bottom line is that any OST State Party participating in almost any way with a space mission risks liability claims if persons or property are injured during a space mission, including missions to clean up orbital debris.[29]

Fortunately, the Liability Convention permits States to enter into bilateral and multilateral agreements to address issues of liability. The International Space Station Intergovernmental Agreement is a good example of States changing the nature of their liability to one another under specific circumstances. The cross-waiver of liability provision in Article 16 of that agreement also covers contractors and subcontractors as well as users and customers affiliated with the partner States.[30] Such international agreements and related consultations also fulfill the OST Article IX direction for States Parties to be guided by the "principle of cooperation" and to "undertake appropriate international consultations" to avoid harmful interference with each other's space activities.[31]

Bilateral and multilateral agreements containing liability waiver and/or assignment provisions to transparently carry out ADR on mutually selected non-sensitive debris targets, such as defunct upper stages, could greatly ease geopolitical tensions while advancing debris cleanup and other space technologies. At least equally important, such bilateral or multilateral debris remediation actions could establish new "customary international law" consistent with "due regard" concepts of the OST and aviation and maritime law. We foresee that the 8,000 tons of mostly aluminum and titanium alloy orbital debris will eventually be salvaged and reused for

on-orbit fabrication and construction. Maritime tradition for salvage operations, dating back thousands of years to the Phoenicians, Romans, and Greeks, offer lessons for space salvage, and more recent maritime law even allows for compensating commercial salvors who carry out cleanup operations.[32]

SPD-3, in outlining "Minimal Safety Standards and Best Practices" calls for "self-disposal upon the conclusion of operational lifetime, or owner-operator provision for disposal using active debris removal methods."[33] Indeed, abandoning uncontrollable spacecraft in orbit could be seen as a form of space "dumping," and the guideline for deorbiting a spacecraft after 25 years post-operations in the current U.S. Government Orbital Debris Mitigation Standard Practices, which SPD-3 calls "inadequate to control the growth of orbital debris,"[34] is hardly reassuring. Here again, maritime anti-dumping law might serve as a guide for U.S. best practices, which could eventually evolve into international best practices and finally into international treaty law.

The 1972 Convention on the Prevention of Marine Pollution by Dumping of Wastes and other Matter ("London Convention"), in force since 1975, is one of the first global conventions to protect the marine environment from human activities. In 2006, the "London Protocol" came into force to further modernize the Convention and eventually replace it. Under the Protocol, all dumping is prohibited, except for possibly acceptable wastes on the "reverse list."[35] A similar, acceptable waste "reverse list" could be established for spacecraft abandoned in orbits so low that they will deorbit almost immediately post-mission anyway, while the post-mission guideline for leaving uncontrolled spacecraft in higher orbits post-mission could be periodically shortened until it meets the SPD-3 goal of international "self-disposal [or ADR] upon the conclusion of operational lifetime."

Future USSG Operations

Although premature at this time, the USSG logically might over time evolve to provide services in space analogous to those provided by the U.S. Coast Guard, including but not limited to:

- Maintenance of navigation aids
- Deployment and maintenance of shelters and rescue gear
- In-space rescue operations
- Inspections and enforcement related to OST non-interference or safety zones for commercial operations in space

Conclusion

International aviation conferences led to the formation of the International Civil Aviation Organization (ICAO), which now publishes standards and recommendations widely adopted by civil air navigation authorities around the world. Similar maritime conferences have also led to

standards, recommendations, and even international law to facilitate safe and secure navigation in a maritime environment. However, the United States should not wait for international conferences or summits to formulate standards and recommendations to make the space environment safe and secure. NSS instead urges the United States to show leadership by leveraging its Space Policy Directive-3 into a civil and transparent United States Space Guard (USSG) to carry out safe, effective, and industry-enabling STM, thus inducing international consultation and cooperation by dint of example.

Acronyms and Abbreviations

ADR: Active Debris Removal
AST: Historical acronym for what is now the Office of Commercial Space Transportation within the Federal Aviation Administration
DoD: Department of Defense
DoC: Department of Commerce
DoC/NTIA: National Telecommunications and Information Administration within the Department of Commerce
DoC/NOAA: National Oceanic and Atmospheric Administration within the Department of Commerce
DoC/NOAA/NESDIS/CRSRA: Commercial Remote Sensing Activity Office within Satellite and Information Services Office within NOAA within Department of Commerce.
DoC/OSC: Office of Space Commerce in the Department of Commerce
DoS: Department of State
DoS/DDTC: Directorate of Defense Controls within the Department of State
DoS/OES/SAT: Department of State/Bureau of Oceans and International Environmental and Scientific Affairs/Office of Space and Advanced Technology
DoT: Department of Transportation
DoT/FAA/AST: Department of Transportation/Federal Aviation Administration/Office of Commercial Space Transportation EVAs: Extra-Vehicular Activities
EPA: Environmental Protection Agency
FAA: Federal Aviation Administration within the Department of Transportation
FCC: Federal Communications Commission
FCC/OET: Federal Communications Commission/Office of Engineering and Technology
GEO: Geostationary Earth Orbit
GPS: Global Positioning System
ICAO: International Civil Aviation Organization
ISS: International Space Station
LEO: Low Earth Orbit
MEO: Medium Earth Orbit
NASA: National Aeronautics and Space Administration
NOAA: National Oceanic and Atmospheric Administration in the U.S. Department of Commerce
NSS: National Space Society

NTIA: National Telecommunications and Information Administration within the Department of Commerce
OES: Bureau of Oceans and International Environmental and Scientific Affairs within the U.S. Department of State
OET: Office of Engineering and Technology within the Federal Communications Commission
OST: Outer Space Treaty (Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, 1967)
OOS: On-Orbit Servicing PPPs: Public-Private Partnerships SAA: Space Situational Awareness
PDCO: Planetary Defense Coordination Office, currently in NASA
RPO: Rendezvous and Proximity Operations
SAT: Space and Advanced Technology (Office of)
STM: Space Traffic Management USAF: United States Air Force
USML: United States Munitions List

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[1] National Space Society 2016 policy paper, "Orbital Debris: Overcoming Challenges," http://www.nss.org/legislative/positions/NSS_Position_Paper_Orbital_Debris_2016.pdf
[2] See NSS 2017 policy paper, "Space Guard: a New Organization to Facilitate Safe Space Activities," http://space.nss.org/media/NSS-Position-Paper-Space-Guard-2017.pdf
[3] See page 4/13 of "Space Policy Directive-3, National Space Traffic ManagementPolicy," 18 June 2018, https://www.whitehouse.gov/presidential-actions/space-policy-directive-3-national-space-traffic-management-policy/
[4] This name has been used by other authors, including USAF Lt. Col. Cynthia A. S. McKinley, James C. Bennett, and Anna Gunn-Golkin, in proposing various versions of a guardian space force.
[5] See page 5/13 of "Space Policy Directive-3, National Space Traffic Management Policy," 18 June 2018, https://www.whitehouse.gov/presidential-actions/space-policy-directive-3-national-space-traffic-management-policy/
[6] We are including On-Orbit Servicing (OOS) as another ADR method, which "removes" orbital debris via the rehabilitation of defunct spacecraft through repair, refueling, adding working parts, etc.
[7] See page 7/13 and 8/13 of "Space Policy Directive-3, National Space Traffic Management Policy," 18 June 2018, https://www.whitehouse.gov/presidential-actions/space-policy-directive-3-national-space-traffic-management-policy/
[8] https://www.esa.int/Our_Activities/Operations/Space_Debris/Space_debris_by_the_numbers
[9] Wang, Brian. "Total global satellite plans could have around 20,000 satellites in low and mid earth orbits in the 2020s." *Next Big Future*, 4 March 2017, https://www.nextbigfuture.com/2017/03/total-global-satellite-plans-could-have.html. Also see "Space X Wants to Launch 12,000 Satellites," *Parabolic Arc*, 3 March 2017, http://www.parabolicarc.com/tag/theia-holdings/
[10] https://www.esa.int/Our_Activities/Operations/Space_Debris/Space_debris_by_the_numbers
[11] See page 4/13, 7/13, & 8/13 of "Space Policy Directive-3, National Space Traffic Management Policy," 18 June 2018, https://www.whitehouse.gov/presidential-actions/space-policy-directive-3-national-space-traffic-management-policy/
[12] See the National Space Society 2016 policy paper, "Orbital Debris: Overcoming Challenges," pages 18-23 for information about ADR, which includes On-Orbit Servicing (OOS). http://www.nss.org/legislative/positions/NSS_Position_Paper_Orbital_Debris_2016.pdf
[13] For a description of "liability" salvage to clear away dangerous debris in a maritime context, see the National Space Society 2016 policy paper, "Orbital Debris: Overcoming Challenges," pages 23-24, http://www.nss.org/legislative/positions/NSS_Position_Paper_Orbital_Debris_2016.pdf
[14] See page 9/13 of "Space Policy Directive-3, National Space Traffic Management Policy," 18 June 2018, https://www.whitehouse.gov/presidential-actions/space-policy-directive-3-national-space-traffic-management-policy/

[15] See "Space Policy Directive-3, National Space Traffic Management Policy," 18 June 2018, https://www.whitehouse.gov/presidential-actions/space-policy-directive-3-national-space-traffic-management-policy/

[16] Faust, Jeff. "Space commerce traffic management," http://www.thespacereview.com/article/3485/1. See comment number 2 by Brian Weeden.

[17] Gunn-Golkin, Anna. "Space Guardians," *The Space Review*, 25 June 2018, http://www.thespacereview.com/article/3520/1

[18] See "Expected Casualty Calculations For Commercial Space Launch and Reentry Missions," *FAA Advisory Circular*, 30 August 2000, https://www.faa.gov/about/office_org/headquarters_offices/ast/licenses_permits/media/Ac4311fn.pdf

[19] Bennett, James C. "Proposing a 'Coast Guard' for Space, *The New Atlantis*, 2011, http://www.thenewatlantis.com/publications/proposing-a-coast-guard-for-space

[20] See page 7/13 of "Space Policy Directive-3, National Space Traffic Management Policy," 18 June 2018, https://www.whitehouse.gov/presidential-actions/space-policy-directive-3-national-space-traffic-management-policy/

[21] See NSS 2017 policy paper, "Space Guard: a New Organization to Facilitate Safe Space Activities," http://space.nss.org/media/NSS-Position-Paper-Space-Guard-2017.pdf

[22] A one cent per dollar satellite service end-user fee would already generate over a billion dollars a year. Many more billions of dollars would be generated annually when 20,000 new commercial satellites come on line. For a discussion of four different methods to finance comprehensive STM, including via end-user fees, see pages 8-9 of the NSS policy position paper, "Space Guard: An New Organization to Facilitate Safe Space Activities," http://space.nss.org/media/NSS-Position-Paper-Planetary-Defense-2014.pdf

[23] https://www.nasa.gov/planetarydefense/overview#neo

[24] http://space.nss.org/media/NSS-Position-Paper-Planetary-Defense-2014.pdf

[25] See page 4/13 and 5/13 of "Space Policy Directive-3, National Space Traffic Management Policy," 18 June 2018, https://www.whitehouse.gov/presidential-actions/space-policy-directive-3-national-space-traffic-management-policy/

[26] U.S. Department of State. "Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies," https://www.state.gov/t/isn/5181.htm

[27] https://spacenews.com/senate-introduces-bill-to-streamline-commercial-space-regulations/

[28] Dunstan, James E. "Space Trash: Lessons Learned (and Ignored) from Space Law and Government," 2013, http://www.spacelaw.olemiss.edu/jsl/back-issues/jsl-39-1.html

[29] For a complete compendium of international outer space treaties, see *International Space Law: United Nations Instruments* published by the United Nations Office for Outer Space Affairs, 2017.

[30] Anzaldua, Alfred. "A Pragmatic, Evolutionary Path to Orbital Debris Removal via Customary International Law," A technical presentation made during the 57th session of the UNCOPUOS Legal Subcommittee on 16 April 2018, http://www.unoosa.org/oosa/en/ourwork/copuos/lsc/technical-presentations.html

[31] U.S. Department of State. "Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies," https://www.state.gov/t/isn/5181.htm

[32] Anzaldua, Alfred & Michelle Hanlon, "Maritime tradition can inform policy and law for commercial active debris removal," *The Space Review*, 19 February 2018, http://www.thespacereview.com/article/3434/1

[33] See page 8/13 of "Space Policy Directive-3, National Space Traffic Management Policy," 18 June 2018, https://www.whitehouse.gov/presidential-actions/space-policy-directive-3-national-space-traffic-management-policy/

[34] See page 7/13 of "Space Policy Directive-3, National Space Traffic Management Policy," 18 June 2018, https://www.whitehouse.gov/presidential-actions/space-policy-directive-3-national-space-traffic-management-policy/

[33] http://www.imo.org/en/KnowledgeCentre/ReferencesAndArchives/IMO_Conferences_and_Meetings/London_Convention/Pages/default.aspx