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Key Points

The United States and the growing list of global space actors currently are participants in a fundamental reordering of many tenets and assumptions that have been long-standing attributes of US national space policy and international agreements.

The United States should lead by example. Part of this leadership is creating a path that does more than react to the technical evolution, programmatic developments, or perceived intentions of other countries. The path should serve US national interests by expanding capabilities that enhance security, the economy, and science.

The United States should embrace emerging technologies and services rather than try to restrain them. US entities can be competitive or even dominant in the world market if the US government encourages and facilitates new space applications. The US government should learn to live with the proliferation of space capabilities, even in the face of potential threats, in order to maximize their potential benefits.

Major Policy Issues in Evolving Global Space Operations

A collaboration with The Aerospace Corporation's Center for Space Policy and Strategy

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Abstract

This paper is designed to inform decision-makers and other interested parties on how the United States may develop national space policy to address the dynamic space environment, based on input from a variety of experts. The issues addressed here, such as space traffic management, small satellites, proximity operations, orbital debris, counterspace threats, and norms of behavior, were chosen because they are likely to demand the attention of decision-makers in the near future. In addition to highlighting the issues, the report presents an overview of options for addressing them.

Despite the diversity of the participants surveyed for this paper, important areas of consensus emerged on preferred approaches to addressing the changing strategic space environment. The most important of these are the following: 1) the United States should lead by example; 2) roles need to be clarified among the government, commercial, and international sectors of activity; 3) emerging technologies should be embraced, not obstructed, even if their proliferation carries some risk; 4) classification of space operations could be reduced to facilitate international and cross-sector collaboration; and 5) reform of international agreements should be approached with caution and patience to ensure that important provisions and understandings are not lost.

Introduction

The field of play in space activities is shifting, with new players continuing to enter the arena and space technology advancing and proliferating. The commercial sector—from traditional aerospace companies, to entrepreneurs, to space-advocate billionaires and venture capitalists—is driving a larger share of space development, and expanding into new applications, proving itself indispensable for satisfying the US government’s present and future space-related needs. Meanwhile, the current US administration is working to formulate its space objectives and determine its approach to achieving them. As always, deliberate strategy and policy formulation activities compete for limited time with the need to make important near-term decisions.

The United States and other global space actors are participants in a fundamental reordering of many tenets and assumptions that have been long-standing attributes of US national space policy and international agreements. While the precise character and magnitude of these changes remain to be seen, it is clear that the world is experiencing a transition in space development that has many moving parts.

This complicates decision-making as multiple interdependent factors must be considered:

- The number and diversity of space actors has been growing for decades and now consists of a wide array of national and subnational organizations. For example, business investment is now the driver of most space applications, and “smallsats” (small satellites or miniaturized satellites) are being deployed on orbit on behalf of universities, high schools, and even middle schools. This has been called the “democratization” of space.
- Around the world, government and industry researchers are pursuing next-generation capabilities, in some cases with unfriendly or unpredictable intentions. They recognize the advantages and vulnerabilities of space-enabled business and warfare. As a result, the perception of space as a superpower-dominated (or even government-dominated)

domain has faded, as has the notion that space is a sanctuary shielded from the warfighting domain. How can the US and its allies avoid conflict in this contested space environment?

- As participation in space activities grows and diversifies, hazards and limits become more evident. Key natural assets (e.g., the electromagnetic spectrum and useful Earth orbits) are threatened with crowding in a domain once thought to be too vast for such concerns. Human-driven pollution undermines the utility of the most prized orbital regimes. How can these crowded space limits be addressed in a manner that is fair, economically viable, and not overly constraining on technical and operational advances?
- Spacefaring ambitions include the building of enduring space infrastructure and the means to maintain it, leading to far-reaching exploration and in-space industries that could someday add substantial value to Earth’s economy—just one of multiple potential game changers in the space domain. To achieve these ambitions, how should the United States cultivate collaboration? Stated differently, how should the United States build and maintain trust in its capabilities, reliability, and intentions? How should it respond to competition? How will norms on sovereignty and property rights need to change?

In an environment of constantly shifting geopolitical relationships and economic conditions, where the drivers, threats, and potential long-term benefits of space activities are all evolving, the new Trump Administration must decide how it will balance opportunity costs. In the search for solutions, how should the United States apply limited resources across various space investments—and their non-space substitutes? This paper seeks to enrich the dialogue and assist the decision process by surveying experts in the field, and analyzing the areas of concurrence and discord on issues that are appearing on the horizon.

This paper is designed to inform decision-makers and other interested parties on how the United States may develop national space policy to address the current dynamic space environment.

The United States and other global space actors are participants in a fundamental reordering of many tenets and assumptions that have been long-standing attributes of US national space policy and international agreements.

A collaboration of The Aerospace Corporation's Center for Space Policy and Strategy and the Mitchell Institute for Aerospace Studies, this paper draws on insights obtained from more than 30 subject matter experts consulted between August and September 2017, and from comments by a panel of senior reviewers in November 2017. Their comments and insights appear throughout the sections of this paper.

The issues addressed here were chosen because they are likely to demand the attention of decision-makers in the near future. While this report is not intended to advocate for any specific solutions, our intention is to go beyond just highlighting the issues, and to present current thinking on specific options for addressing these issues. We hope this effort will provide a concise overview and analysis of the views of diverse experts, and will enable better-informed decision-making.

Space Tracking Roles in an Era of Increasing Activity

The increasing number and variety of space actors, along with the many proposals for very large low-Earth orbit (LEO) constellations, will challenge the tracking, analysis, and reporting resources of the Department of Defense (DOD) and call into question the appropriateness of DOD providing services to commercial and foreign entities. As these responsibilities grow, what are the most appropriate and efficient roles of the US government, the private sector, and non-profit organizations?

Background

Developing consistent, enduring, and effective policies regarding the provision of tracking data for space objects has proved to be one of the most difficult, complex, and controversial elements of US national space policy. Experts disagree about foundational aspects surrounding the goals, rationale, organizations, and processes for providing this data, and the United States, along with other major spacefaring actors, lacks consensus on a clear path forward.

The term space situational awareness (SSA) is often used, particularly by the US military, to describe space tracking data. US Strategic Command (USSTRATCOM) provides a catalogue of the more than 21,000 objects on orbit it is currently tracking.¹ Today there are approximately 1,500 active satellites, about 20,000 tracked debris objects, and most analysts believe there are millions of debris objects too small to track but, fortunately, mostly pose less risk of causing catastrophic damage from collision with satellites. Many analysts believe that the United States and other major spacefaring actors should move towards a more active role in managing the increasing number of satellites and debris objects. Instead of SSA, these experts prefer the term “space traffic management” (or STM). Additional objectives for STM are to enhance, facilitate, and support continued development of the commercial space industry, ensure safe commercial space operations, minimize false alarms, and foster development and sharing of norms of behavior and best practices.

For decades, the United States has played the leading role in providing free space tracking data worldwide, but the organization responsible for providing this data has evolved over time from the National Aeronautics and Space Administration (NASA), to Air Force Space Command (AFSPC), to the current process in which USSTRATCOM provides this data through its Joint Space Operations Center (JSpOC) at Vandenberg Air Force Base, California. The SSA mission is jointly supported by DOD and the Intelligence Community (IC) and it includes four functional areas outlined in *Joint Publication 3-14: Space Operations*.² These four functional areas are: Detect/Track/Identification; Characterization; Threat Warning & Assessment; and Data Integration and Exploitation. DOD recently completed a capabilities-based assessment for SSA that identified and prioritized the gaps in an initial capabilities document validated by the Joint Chiefs of Staff in 2012.

As the value and volume of commercial space activity has grown, the largest commercial actors including Intelsat, SES, and Inmarsat have developed processes that enable sharing more data with other satellite owners and operators. These firms and actors created the Space Data Association (SDA) in 2009 to facilitate providing more comprehensive and

Despite a majority of respondents advocating significant changes for the organizational structures responsible for STM, almost all strongly supported the need for continuing US leadership in this area.

higher fidelity data to members. It is expected that commercially provided tracking data will continue to improve with time, and several companies including Analytical Graphics Incorporated (AGI), with its Commercial Space Operations Center (COMSpOC), are leaders in providing these fee-based improved commercial services. In 2015, the Commercial Space Launch Competitiveness Act (CSLCA) tasked the Secretary of Transportation, in concurrence with the Secretary of Defense and in consultation with the heads of other relevant federal agencies, to submit to Congress a report on the feasibility of releasing safety-related SSA information to any entity consistent with national security interests and public safety obligations to the United States. The CSLCA report lays out a rationale for developing a pilot civil space traffic management program by 2019 and achieving initial operational capability by 2020.

Findings

Most respondents favored moving away from a space situational awareness model towards a STM model, and away from the Department of Defense (DOD) towards a civil agency such as the Federal Aviation Administration (FAA) as the lead for providing this data. Before exploring the rationale behind these proposed changes, it is worthwhile to review arguments for maintaining the status quo.

Benefits of the current approach. While most would admit that DOD has been hamstrung in making needed incremental improvements by the 2012 Budget Control Act (BCA; also known as sequestration), supporters of the current approach maintain that providing spaceflight safety information is an inherently governmental function. They also note that continuing and accelerating growth in commercial space activity should not change this governmental responsibility, and that serious security issues would arise from any entity other than DOD having the lead for providing this data. Proponents of change strongly challenge each of these rationales and argue that current processes will become increasingly incapable of dealing with the challenges of exponential growth in commercial actors, active satellites, and debris.

Benefits of greater transparency. Proponents of change cite a number of what they believe would be significant benefits flowing from moving towards a space traffic management model, away from DOD organizationally, and towards greater transparency. These proponents believe that unless the United States moves towards a different model with greater transparency and makes more progress on STM, there are risks of slowing growth and losing US leadership in the commercial space sector. A number of other transparency concerns are closely interrelated with space tracking data and procedures including: classified processes for excluding certain satellites from the catalogue; the role of tracking data in “naming and shaming” irresponsible behavior; classification impediments both to sharing data internationally with coalition partners and domestically for building better informed constituencies; and for supporting space control operations, particularly for temporary and reversible effects. Transparency concerns are often multi-dimensional and require balancing of different interests; the US government and commercial actors may desire greater transparency about the space activities of others but be reluctant to provide the same level of transparency about their own space activities due to national security and proprietary concerns.

Alternative organizational structures. Despite a majority of respondents advocating significant changes for the organizational structures responsible for STM, almost all strongly supported the need for continuing US leadership in this area. The rationale for focus on US leadership included a desire to avoid greater disarray during a period of explosive growth, a perceived need for the US government to continue having the best SSA data, and a desire for strong, experienced leadership to help the international community move towards a more effective and efficient structure that includes active debris removal (ADR).

Some respondents believe that the best STM model would be to shift from the DOD to the not-for-profit sector—preferably a science-driven organization. President Trump has proposed that a private, non-profit company be established to handle air traffic control in the United States, an approach already chosen by Canada, the UK, France, Germany, New Zealand, Australia and

Switzerland. For STM, there are concerns that a government agency, such as the FAA, could become too bogged down in bureaucracy and expectations that a non-profit (or possibly a Federally-Funded Research and Development Center, also known as an FFRDC) would face less bureaucratic entanglement. This approach could also help to reduce the purchase and use of software or other services that are either not optimal or unnecessary. Parallel commercial services (such as the Space Data Association) should be encouraged, and can provide useful data.

Most respondents agree that ultimate responsibility and oversight of STM should remain with the government. Likewise, while the US government can and should buy fee-for-service STM data as needed, it should avoid directly funding commercial STM operations. Other analysts believe that the importance of space and its inherently global nature mandate creation of a formal intergovernmental organization that could be modeled after the structure for air traffic, which is administered by the International Civil Aviation Organization (ICAO), a specialized UN agency. In addition, some respondents emphasized that as we pass the tipping point where commercial space activity becomes increasingly dominant, the rules and processes that were developed for nation-state actors will become increasingly ineffective and a larger, more comprehensive move away from legacy approaches will be needed.

As part of these larger and more comprehensive changes, the United States should consider ways to share real-time data such as operational status, location (perhaps through Global Positioning System (GPS) transponders), active and passive sensor information from on-board systems, and even require prior coordination of plans to deconflict automated and manual satellite maneuvering.

Selected Quotes on Space Tracking from Subject Matter Experts

“Two distinct arguments arise, one on whether safety of flight in space should be a government mission (parallel to the FAA debates about privatization), and second, if the first is answered affirmatively, on whether DOD is the best government agency to provide the service.”

“Air Force and DOD leaders want to be space warriors, not space traffic cops. DOD is not a regulatory organization.”

“It is problematic for the DOD to look at this problem principally from a warfighting focus. The DOD needs to consider a net assessment approach and consider what persistent advantages exist as the global provider of such services. Whoever is the global provider of STM and ADR services gains significant advantages, as it creates incentives for others to be ‘free-riders’ on our system and not to develop their own capabilities to compete. As the global provider, we have differential access to the data and the ability to withhold information we feel creates information asymmetries that provide advantage to the United States and its allies.”

“I am concerned that SSA information will turn into just a service for those who can pay; as a matter of public safety, it would behoove some branch of the US government to take on data-sharing, at least enough so that collisions can be avoided as much as possible.”

“SSA is undergoing a very similar shift in public/private roles and merchant/guardian tensions that other space sectors such as remote sensing have gone through. I think it’s important to look for lessons from the experiences in those other sectors so we don’t make some of the same mistakes with SSA.”

Fulfillment of Launch Requirements

In an era of increasing international space cooperation (including military) and shifting launch markets, does it still make sense to require US government payloads to use US launchers (unless exempted at the highest levels)? How do we define a US launcher? How should the US government balance the development of new launch systems with efforts to enable satellite servicing capabilities (which may affect launch demand), while not unduly interfering with global space market forces?

Background

The two national policies currently governing space launch, *National Space Policy of the United States of America* (PPD-4), dated June 28, 2010, and *National Space Transportation Policy* (PPD-26), dated November 21, 2013, direct that US government payloads should be launched on US vehicles.^{3,4} The intent is to ensure the security of the payloads and their missions, and to maintain a strong US space industrial base. Relevant agency policies, particularly at DOD and NASA, incorporate this national-level guidance.

Despite their protectionist aspect, both policies permit foreign content in US vehicles.

Neither policy specifies a limit to foreign content that would disqualify vehicles from eligibility to carry US government payloads. The 2010 National Space Policy directs that “United States Government payloads shall be launched on vehicles manufactured in the United States unless exempted by the National Security Advisor and the Assistant to the President for Science and Technology.”⁵ PPD-26 permits use of foreign components “on a case-by-case basis.” The “manufactured in the US” standard consequently has not been

a barrier to the inclusion of a variety of foreign components in launchers as the number and quality of foreign space hardware products on the world market has grown. As a result, the de facto interpretation of “manufactured in the US” appears to be “integration and assembly in the US.”

Current policy does not recognize a vehicle as a US launcher based on a specific corporate ownership formula, the location of its launch facilities, or its eligibility for an FAA commercial launch license. If the US continues to follow current practice, it is reasonable to consider the possibility that a foreign launch provider from an allied country could set up rocket manufacturing facilities in the US—perhaps to get closer to an important customer base and take advantage of US spaceports and the skilled workforce—and thereby qualify to bid on US government payloads.

This would prompt reconsideration of how to define a US launcher, or perhaps abandonment of attempts to distinguish between US and foreign vehicles in a globalized launch market. The Air Force’s solution for the next generation of the Evolved Expendable Launch Vehicle (EELV) program is to use the definition in the Buy American Act of 1933, which specifies not only manufacture in the US, but also that the cost of an item’s domestic components must exceed 50 percent of the cost of all of its components.⁶

Findings

Support for current policy. The prevailing expert opinion on this survey question is that the US should continue its policy of requiring US government payloads to use US launch vehicles. Several years ago, when a single domestic provider dominated government launches and the prospects for viable homegrown competition were unclear, concerns about pricing, schedule, capacity, and the risk of single-point failure made foreign options look attractive, at least as a backup. But those concerns have been alleviated by several factors, including the continued success of United Launch Alliance (ULA) launches, the demonstrated capabilities of the SpaceX Falcon 9, and the outlook for other competitors such as Orbital ATK, Blue Origin, and others. With multiple domestic providers offering competitive pricing and adequate capacity, the pressure to shop elsewhere is reduced. Additionally, the motivation to ensure security and maintain the industrial base has not gone away.

Respondents also believe that the ability to seek a waiver to use a foreign launcher should be retained to allow flexibility, especially for small payloads but also for larger cooperative opportunities like the Ariane 5 launch of NASA’s James Webb Space Telescope. It was suggested that any government launch on a foreign rocket should remain subject to review and approval, and must demonstrate a good-faith attempt to secure a US launch at competitive pricing.

On the other hand, some respondents expressed concern that protecting the US government launch market for domestic providers would take away incentive for those providers to be competitive on the global market. Also,

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...future consolidation or contraction of domestic industry could put the US government back into a monopoly provider situation, increasing risks to pricing, schedule, and capacity. To prepare for contingencies, the US could exercise the capability to launch a classified payload using the launcher of an ally such as France or Japan where US security standards can be met.

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Definition of US launch vehicle. Some expert responses indicate a desire to tighten up the definition of what constitutes a US launch vehicle. As noted earlier, national policies simply say that the launcher must be manufactured in the US, but one suggestion would add the requirement that the vehicle be owned and operated by a US corporation. If this change were to be made, it should be accompanied by a definition of a US corporation for purposes of this policy, as has been done for shipping, airlines, mining, energy, banking, and other industries.⁷ For example, the definition could require that the launch provider be incorporated in the US and be majority owned by US citizens.

Another suggestion for defining a US launch vehicle would mandate that a majority of the launch system be based on US-made components and software; and key mission critical elements (propulsion systems, avionics, etc.) should also be domestically sourced. This definition would seemingly eliminate the ULA Atlas 5 and the Orbital ATK Antares rockets due to their use of Russian engines for first stage propulsion, as well as other foreign-sourced components. Such a definition would need to be backed up by a consistent methodology that accommodates measurement challenges, in general. For example, a policy requiring at least 50 percent of components be of US origin would need to specify whether the 50 percent is measured by weight, by dollar value, or by the number of components.⁸ Adherence to the Buy American Act resolves this question by focusing on the cost of components; however,

dollar values are a moving target because of changing market conditions and foreign exchange rates. Government agencies purchasing rides into space may need to monitor large proprietary databases of components and their valuations for each potential provider.

On-orbit developments affecting launch demand. Most expert respondents on launch issues chose not to comment on the potential effect of new on-orbit applications (e.g., satellite servicing) on launch demand. Those who did comment generally felt that on-orbit servicing would be mostly limited to large, expensive geostationary Earth orbit (GEO) satellites and would be infrequent. Large low-Earth orbit infrastructure, such as the International Space Station, could generate some activity, but the predominance of smaller, cheaper satellites and the challenges of maneuvering in that environment would undermine the viability of business plans for LEO servicing.

Addressing what the US government could or should do in this area, there was no consensus. Some felt that on-orbit servicing is a low-consequence activity that does not have a compelling role for the government to play in its development, at least in the near term. One respondent stated that it is more important for the government to “maintain a sufficiently robust satellite manufacturing and launch industrial base” and allow commercial interests to make the investments in new on-orbit applications. In a contrasting viewpoint, space robotics and servicing were identified as critical investments. No expert recommended that the government become an anchor tenant in commercial on-orbit servicing, although there was a suggestion that the government should make “small bets” on commercial systems.

One respondent called for “transforming the architecture” to enable the logistics train for “permanent presence.” The long-term challenge is determining the most efficient transportation architecture to serve future needs that can only be guessed at today. Low-cost launch from Earth to LEO will always be an important goal, but new traffic throughout cislunar space (the volume within the Moon’s orbit) and beyond will stimulate the need for more transportation options and other infrastructure elements such as fueling stations.

Selected Quotes on Launch Requirements from Subject Matter Experts

“The United States has strong, longstanding national security and economic reasons for developing and nurturing its launch industry; those reasons are not affected by increasing international space cooperation or shifting launch markets.”

“Given the increase in US commercial launch capacity from SpaceX and perhaps Blue Origin in addition to traditional providers such as ULA, there should be enough future domestic capacity for USG payloads.”

“The US certainly should be unapologetic about creating a protectionist market for space launch... However, an overly protectionist approach is going to also slow innovation of our private sector and even defense.”

“Every launch that the US Government uses a foreign launcher for is one less opportunity to solidify our own independent launch capability... the US Government should continue to launch on US launchers [more frequently] to maintain our industrial complex than for safety or reliability issues.”

“As a matter of trade policy, the US Government should not permit US payloads to be launched with foreign launchers if the other country does not extend the same terms to US launchers for that country’s payloads.”

“We should want to avoid where at all possible being trapped by a single supplier of whatever nationality, especially an adversary supplier.”

“The best way to be certain the US possesses an independent and robust space launch capability is to provide a US Government base volume of launch business for US private sector capabilities.”

“As a NATO [North Atlantic Treaty Organization] country, the US should also envisage to have a classified payload launched by an allied country, or group of countries.”

“While [buy American] should be the preference, other alternatives should be available, such as with our allies and partners.”

“We can either have a strong US smallsat market or we can have a strong US smallsat launch market. We can’t do both, and the former is really champing at the bit for launch opportunities now, while the latter is something that in theory might exist in a couple of years.”

“[The US government] should move towards the CRAF [Civil Reserve Air Fleet] model in all space mission areas where it could make sense and be economically viable.”

A critical factor for launch mission assurance is “the pace at which launch vehicles are built and launched—at too low of a pace, launch vehicle manufacturing and operations could suffer because critical skills and expertise could atrophy.”

“Space launch capabilities will continue to be developed and exercised for reasons well beyond cost and flexibility. Those reasons include national pride and prestige; national security and independence; and economic growth and high-tech industry development.”

“We should be transforming [space] architecture... low cost launch to LEO, multiple space propulsion systems tailored from LEO to multiple destinations, and robotics and servicing are all critical investments.”

Tracking Smallsats As They Multiply

The small satellite (or “smallsat”) revolution has opened up new possibilities for satisfying government, business, and academic needs. But it adds to orbital congestion and complicates tracking. Is there a need to expand international debris mitigation guidelines to require active and/or passive tracking aids on smallsats, perhaps varying the requirements based on orbital altitude and inclination zones?

Background

The ability to put useful capabilities into a small, relatively inexpensive, space-worthy package has opened a door that has allowed the entry of dozens of US and foreign companies, universities, and even high schools into the space arena. The

breakout year for smallsat proliferation was 2013, which saw a 269 percent increase in the launch of one kilogram-to-50 kilogram smallsats over the previous year. Substantial annual growth in numbers of these satellites is projected to continue, based on existing programs and announced plans of developers. By one estimate, nearly 2,400 smallsats of this size are expected to be launched from 2017 to 2023.⁹ Already evident is the increasing number of smallsats in the one-to-10 kilogram range—the most difficult to track, the most likely to fail early, and also the most unlikely to have maneuvering capability or trackable emitters.

A tiny spacecraft can be difficult or impossible to track with current technology, and even when detected, custody may not be maintained. In other words, once detected the object may be lost on a subsequent orbit. Inconsistencies such as these degrade collision assessment, threatening the safety of flight for space assets of all types. Attempts to overcome these inconsistencies carry an opportunity cost—they divert resources from other tasks.

A single launch vehicle can carry dozens of smallsats, and the International Space Station has the ability to deploy small payloads routinely. New launch services, intended to be operational before the end of this decade, are being developed to orbit smallsats in increasing numbers and at decreasing cost.

The so-called “mega-constellations” of satellites are another aspect of the challenge. These spacecraft tend to be bigger than those discussed above, and therefore are more easily trackable. But they are proposed to be deployed in very large numbers. At one time, “large” referred to a constellation the size of Globalstar (40) or Iridium (72). Today we see numerous plans for much larger deployments, including OneWeb (720) and SpaceX (4425). Not all plans will come to fruition, and some that do reach initial operational capability may never launch as many spacecraft as originally proposed. But the rate of growth is still likely to raise concerns.

Smallsats challenge current and future space operations in four ways: their large numbers add to the burden of tracking and characterizing

space objects; their small size and general lack of identification devices compound the tracking problem; their short operational life, but continued presence on orbit, makes them a significant contributor to orbital debris; and, from a national security perspective, their growing capabilities may enable their use in a threatening manner (but also offer significant potential to augment government capabilities and create more resilient architectures). The proliferating population of smallsats in various orbits includes many that lack maneuverability and rely on natural decay for end-of-life disposal, which adds risk of collision as they transit lower during their orbital decay. Commercial enterprises in some cases contribute to orbital safety efforts, for example in services provided by the Space Data Association and LEO Labs for tracking and collision avoidance.

Little has been said in international agreements about in-space operations other than the general message that nations should not take actions that interfere with other nations’ space assets or prevent their access to or use of space. These agreements were not intended to prescribe best practices for satellite design or govern routine activities.

In the United States, the regulation of on-orbit activities is an incomplete patchwork. The Federal Communications Commission (FCC) handles radio frequency use and GEO orbital slot assignments, and acts as the conduit to the International Telecommunication Union (ITU) process. The National Oceanic and Atmospheric Administration (NOAA) does licensing and regulation of US commercial remote sensing from space. The Federal Aviation Administration (FAA) is responsible for licensing and regulation of commercial launch and reentry. All of these agencies include language on orbital debris mitigation in the licenses they issue, but none have regulations specifically designed to address smallsat operations in space.

Findings

Advancements in spaceflight safety practices can be ground-based or space-based. The former includes improved tracking systems and—just as important—better communication among operators who share substantial information on the position of their orbiting assets and their plans for maneuvers. This interaction helps to ease the

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National and international debris mitigation guidelines should be strengthened for all satellites regardless of size or altitude. The most frequently mentioned recommendation was that the 25-year rule for post-mission disposal should be shortened dramatically.

job of tracking and feeds into the planning and maintenance of every operator's space systems. However, information flows on the ground may not always be comprehensive and timely, reinforcing the need for space-based safety enhancements as well.

In establishing US guidelines and standards for smallsats, no single approach is likely to fulfill the requirements for a more secure and safe orbital environment. Additionally, the needs and ambitions of emerging operators, researchers, and educational efforts must be considered. Extraordinary security and safety measures that create significant technical or financial barriers to entry could be counterproductive, creating roadblocks for US developers that would not affect their competition elsewhere in the world. As with other types of regulation, operators prefer that specific technical solutions not be imposed on them; rather, they would like to choose their own means of achieving a specified standard of performance.

Most experts who offered opinions on this issue are in general agreement on the following points:

- The current compliance rate for existing debris mitigation and end-of-life disposal guidelines is not good enough. Strong enforcement is needed.
- National and international debris mitigation guidelines should be strengthened for all satellites regardless of size or altitude. The most frequently mentioned recommendation was that the 25-year rule for post-mission disposal should be shortened dramatically.
- Tracking aids should be required on all satellites, and ground-based tracking capabilities need to keep improving. (However, one respondent suggested that the soon-to-be-operational Air Force "Space Fence," which will dramatically increase the number of trackable space objects, will "at least postpone the need for active or passive smallsat tracking aids.")

There were some differences of opinion among experts on the relative importance and desirability of active versus passive tracking aids. While some

respondents favored using (even requiring) both types of aids, others pointed out the downside of active devices. Active devices need power, which taps into the satellite's resources and may not be available once the operational lifetime ends, unless they have an independent power supply. Depending on the particular technology employed, active emitters may cause electromagnetic interference or light pollution, require an antenna and precise attitude control, and impose significant integration costs. One respondent suggested that the national security community may have concerns regarding transmission of what is essentially a homing signal. Despite these drawbacks, active tracking aids are seen as valuable, comparable to automatic identification systems (AIS) on ships or transponder squawking on aircraft.

Passive tracking aids, on the other hand, are promising because they are relatively cheap and easy to integrate into small satellite systems. They do not require power, so they may function beyond the operational life of the spacecraft. They are also reflectors rather than emitters, so they may not cause frequency interference or require attitude control—although they could contribute to light pollution that affects ground-based astronomy.

Respondents generally acknowledged that the requirement to include active and/or passive tracking aids on small satellites would be an important step forward, but some emphasized that this is only a partial solution. It cannot be applied retroactively to debris already in orbit, and will be ineffective in the case of a satellite breakup.

One respondent noted that no single US government organization has been given the responsibility to "authorize and continually supervise" non-governmental activities in space, a set of functions identified but not defined in the Outer Space Treaty. This situation may need to be rectified soon, alongside efforts to greatly expand cooperation among countries and organizations having SSA capabilities. As part of these efforts, exercises could be run to develop cooperative efforts to respond to collision and deorbit mishaps and recover from them.

Active debris removal, which is addressed in more detail in the next section, was briefly noted as a future objective, recognizing the dual use technology issues that arise from deployment

and routine use of systems that could be used destructively. One contributor noted that tracking aids should be a high priority for spacecraft performing rendezvous and proximity operations “to simplify identification and lessen the risk of these systems being identified as threats to nearby spacecraft.”

Selected Quotes on Tracking Smallsats from Subject Matter Experts

“It is important to realize that the space industry is currently witnessing the very early stages of the smallsat revolution, and we have likely only scratched the surface of what this technology is capable of accomplishing. Therefore, prudence is required when regulating to ensure that this new technology is not stifled, or overregulated, in a manner that will inhibit continued technological advancement.”

“International guidelines for smallsats are far too lenient... the 25-year de-orbiting guideline (which is widely ignored, according to some studies) needs to be cut to five years and enforced through licensing and fines at the domestic level and possible sanctioning of companies at the international level.”

“The latest reports from the IADC [Inter-Agency Space Debris Coordination Committee] and UNOOSA [United Nations Office of Outer Space Affairs] suggest that implementation of space debris mitigation guidelines in both LEO and GEO is currently insufficient. Moreover, proposals for large constellations of satellites dramatically increase the risk of collisions in outer space.”

“All satellites should have transponders and things that enable easier radar and optical tracking.”

“Small satellites, especially those that cannot adequately maneuver, should be outfitted both with active and passive tracking measures.”

“[The United States] should require tracking aids on all satellites, not just smallsats. But [we] need to work to level the playing field so US operators aren’t put at a disadvantage.”

“Passive approaches that will provide information, even if the space vehicle is no longer operating, should be preferred.”

“Small satellites at any altitude or inclination could be required to have simple reflective surfaces which would not significantly affect their payload mass.”

“Passive tracking aids show more promise, as there are potentially multiple technologies to accomplish this, which could allow industry to develop the best solutions. However, government sensors will still be key to tracking so the government should provide some requirements for what passive tracking aids should meet to be effective.”

“All operators need to minimize their time in space, and should pursue active deorbit. While on orbit, they should perform active collision avoidance with other objects. This level of sophistication may be beyond many cubesat operators, but standards, guidelines, and norms of behavior should be established to make this the goal and the norm.”

“There needs to be significant discussions about ‘rules of the road’ for constellation design, deployment, operations, replenishment, conjunction management within/between constellations and the background environment, emergency response, and retiring.”

“The dual use technology issues that arise from debris mitigation and removal can create dangerous physical and political environments that can lead to unnecessary conflict and instability.”

“Those who would complain about over-regulation in space need to recognize that sometimes there are serious costs that are external to private decision-making but nonetheless impose tangible costs on the larger economy and society. We don’t need regulation for regulation’s sake, but we do need to ensure that these very real external costs get internalized into private, and governmental, decision-making.”

“Because there are relatively few launching states, they have the ability (and I would argue the vested interest and responsibility) to require [both active and passive tracking measures] of any satellite that they launch.”

It is important to realize that the space industry is currently witnessing the very early stages of the smallsat revolution, and we have likely only scratched the surface of what this technology is capable of accomplishing.

“Voluntary guidelines on best practices for space and space launch operations are superior to any legal vehicle (such as a treaty) that mandates compliance.”

“Commercial enterprise should have the freedom to choose the specific way they plan to meet such standards, such as with active and/or passive tracking devices, smallsat end-of-life and disposal, and data sharing to ensure safety on the part of US operations.”

Orbital Debris Mitigation and Preparing for Active Remediation

As new capabilities become available in on-orbit inspection, servicing, and active debris removal, global space operators will need to find an effective balance between orbital debris mitigation and active remediation. To prepare for this new environment, how should the international community efficiently direct resources toward greater enforcement of existing guidelines, development and implementation of new guidelines, and development and deployment of debris clean-up technologies? Are voluntary debris mitigation standards sufficient or should the international space community move towards more mandatory standards and perhaps sanctions? What should the US government do to incentivize commercial space debris removal in LEO?

Background

The current US guidelines on orbital debris mitigation were developed in the late 1990s in a collaborative effort between the Department of Defense (DOD) and NASA, and adopted by the National Security Council as national guidelines in December 2000.¹⁰ Immediately thereafter, the United States began the long process of gaining international acceptance of the guidelines to encourage existing and emerging spacefaring nations to use best practices that would help control the growing debris problem. This effort was eventually successful in establishing voluntary international guidelines very similar to those followed by the United States.

Global adoption of best practices for mitigation is an ongoing challenge, but even broad success in this area would not provide a complete solution to the debris problem. The next step, removal of debris, has been discussed for decades without advancing to the implementation stage due to technical limitations, affordability issues, and political concerns. These challenges pushed the testing and deployment of remediation systems well into the future.

Operational debris removal systems may no longer be such a distant prospect. Advances in robotics, satellite bus design, automated rendezvous and docking, and low-mass orbital maneuvering systems, coupled with efforts to reduce launch costs, may make debris remediation practical in the next 10 to 15 years. In a related development, commercial space companies using similar technologies plan to initiate satellite servicing operations in a comparable (or even shorter) timeframe.^{11,12} Meanwhile, NASA has conducted risk-reduction demonstrations for satellite refueling aboard the International Space Station starting in 2011 and in December 2016 awarded a contract for a satellite servicing demonstration spacecraft, Restore-L, to be flown in 2020.^{13,14} With technological solutions applicable to active debris removal appearing on the horizon, it is not too early to give attention to hurdles in policy and international law that need to be surmounted if remediation efforts are to become reality. Two significant hurdles are: 1) remediation technologies and operations could double as anti-satellite (ASAT) systems, and 2) international law treats salvage in space differently from salvage at sea. Regarding the latter, the Outer Space Treaty (OST) of 1967 grants perpetual ownership of space objects to their launching state, even after the objects are deactivated and become uncontrolled junk. This is an obstacle to effective cleanup efforts, but most active spacefaring nations (including the United States) are reluctant to open up the OST for revision.¹⁵ In addition, efforts should be initiated to review whether there are legally supportable theories that would permit the removal of unattributed orbital debris without the permission of the launching state—an alternative to the current salvage model.

Findings

Debris mitigation. The previous section on smallsats noted the general impression that there is inadequate compliance with existing orbital debris mitigation standard practices. Most respondents for this section reinforced the importance of enforcing mitigation standards, since it is less risky and more economical to refrain from creating debris than it is to retrieve it from orbit. But even in this area of general agreement, there was some discord.

Some commenters feel that current guidelines are not sufficient to get control of the debris problem and should be strengthened and made mandatory. A few suggested that the UN Committee on the Peaceful Uses of Outer Space (COPUOS) is the right venue to pursue this path. Wherever it is devised, a system of mandatory regulations would need an enforcement mechanism that specifies sanctions for violators. It was suggested that sanctions could take the form of revocation of GEO slots and frequencies, or a “do not launch” list that would block access to orbit for entities that flaunt guidelines. Another suggestion was to impose fines for debris-generating activities, or unsafe on-orbit operations more generally, under some conditions. Sanctions could be imposed on individual operators or at the nation-state level—but according to one respondent, should be reserved for circumstances that could actually result in dangerous outcomes.

On the other hand, some see mandatory guidelines as unrealistic because they lack flexibility and would be difficult to enforce. Instead, the United States should lead by example and share its knowledge and experience regarding best practices. One respondent put it this way: *The US government may be best served if it were to simply publish its own version of best practices unilaterally, state its intent to abide with those practices (except in extraordinary circumstances), and its intent to review the practices of others for consistency with our own understanding of best practices.*

If leading by example is to be at the forefront of US strategy, however, we must recognize that “Too many in the US national security space

community want others to follow rules that it has no intention of following,” according to one expert. Many waivers are granted, so the United States could use some improvement in its own adherence to the guidelines. Although in many cases the United States follows international treaty requirements while adversaries covertly ignore them, the US can be more influential in this area with allies and others if we do a better job of following the rules that we helped to create, this expert believes.

If the global space community stays with a strictly voluntary approach, the private sector could devise its own methods for meeting standards, which could be set and updated through government/industry collaboration. One participant suggested that insurance companies have a role to play by reflecting debris mitigation and end-of-life removal practices in their underwriting of policies.

One industry observer pointed out that the European Space Agency and the French government’s space agency (CNES, the *Centre National d’Etudes Spatiales*) both generate annual reports reviewing worldwide compliance with debris mitigation guidelines for both GEO and LEO satellites. This, and compliance discussions at the IADC, have been an effective way of improving compliance rates without regulations, according to this commenter.

Debris removal. Active debris removal (ADR) as a mission (or market) changes the space operational environment significantly, prompting suggestions for a variety of developmental approaches. Governments are seen as appropriate providers of incentives for advancing ADR, but there is no consensus on what manner of incentives the US government should employ.

The United States is “late in the game” according to one respondent, and should already be executing remediation efforts. This expert suggests that “current spaceflight safety is a more relevant objective than long-term environment stability.” In other words, “if short-term spaceflight safety is assured by preventing the most significant collision events, then environment stability will in turn be assured.”

Commenters preferring a hands-on approach look to familiar solutions to boost ADR

...some see mandatory guidelines as unrealistic because they lack flexibility and would be difficult to enforce. Instead, the United States should lead by example and share its knowledge and experience regarding best practices.

The growing use of small satellites and very large constellations should provoke an increase in the responsibilities of space operators, according to some respondents.

such as federally funded research programs, demonstrations, and sharing of the technologies for removal of space debris, particularly in low-Earth orbit. This will buy down the risk and open the door for the private sector to take over.

In general, governments could encourage the development, deployment, and safe operations of ADR systems by removing barriers to satellite salvage and reuse. Suggested methods for doing this include the following:

- Initiate a prize challenge with an award for removal of a specific debris object or objects, with permission obtained in advance from the launching state(s).
 - Establish a mechanism at the international level through which objects can be designated as eligible for salvage.¹⁶ The US government can take a leadership position in this effort by designating expired US assets for active debris cleanup.
 - As on-orbit servicing companies establish themselves, offer them contracts to use idle resources to remove large debris.
 - Companies specifically targeting debris removal in their business plan could be offered a guaranteed minimum contract over a specified time period.

One respondent illustrated the possible evolution of ADR by outlining an incremental approach that links on-orbit servicing with active remediation:

1. Rendezvous and interact with a satellite under active attitude control.
2. Rendezvous and interact with an object that has no active attitude control.
3. Tow a dead satellite to a graveyard orbit.
4. Tow an inert stage to a graveyard orbit or reentry path.

The growing use of small satellites and very large constellations should provoke an increase in the responsibilities of space operators, according to some respondents. For example, large deployments (from dozens to thousands of satellites) lead to frequent replenishment missions as satellites fail, and accumulation of expired hardware that needs to be removed from traffic lanes. The industries involved could be held responsible for developing or acquiring systems for repair and disposal of their hardware. When the necessary technologies

become available, such responsibilities could become a standard component of national licensing and regulation regimes.

Another licensing issue for large constellations could be the specification of a cap on the expected failure rate to qualify for a license. Governments and the insurance industry have shared interests in encouraging liability and safety standards for on-orbit service providers.

Selected Quotes on Debris Mitigation and Remediation from Subject Matter Experts _____

“It is clear that voluntary debris mitigation standards are insufficient to minimize the risk of a catastrophic event in space.”

“There is no way that voluntary debris mitigation is going to be adequate [for] future commercial development.”

“Continuing with voluntary and incentivized approaches might be best given the challenge of enforcing sanctions,” but “mandatory standards such as including passive de-orbiting capabilities on smallsats could be a good approach.”

“[Regarding debris remediation] it might be worth applying a mandatory fee toward this process for all launches, similar to the mandatory recycling fee paid when purchasing tires, for example.”

“Voluntary compliance with best practices provides the best path forward in areas such as debris prevention and mitigation. The US is best served if its government is the judge of its own compliance with these standards as well as the compliance of others.”

“If the international community is to get serious about the issue of space debris, the leading space nations—the US, Russia, and China—will need to develop a way forward through discussions at the highest level.”

“Smallsat operators have been pretty explicit that they want to follow the rules—they just need to know what the rules are.”

“The US should be a good actor first, establish norms, then model ideas to others.”

“In the spirit of establishing a culture of safety, it is imperative to monitor, characterize, and share information about these individual [debris] events in order to motivate responsible action.”

“The first priority in debris mitigation is compliance with the existing guidelines, particularly post-mission disposal... Retrieval should be considered primarily for reducing the effects of past debris objects and for removing failed objects.”

“There is a need to begin now on creating a regime for active debris removal.”

“[Active debris removal] will likely need actions by governments to create a rule set, at least for anything involving foreign satellites. For domestic satellites, it is not clear that new rules are needed.”

“International community can aim to reduce barriers to cleanup efforts... Each country can set a good example and contribute to development of best practices.”

“Set up a governmental program that demonstrates the capability to remove space debris in LEO. The private sector will then follow up.”

On-Orbit Liability

The Liability Convention of 1972 specifies definitions and procedures for international mishaps related to space activities. But its implementation in on-orbit incidents remains largely untested. In an environment that includes commercial human spaceflight and proximity operations, what issues need to be clarified? What gaps need to be filled?

Background

Ratified by 94 countries and signed by another 23, the 1972 Convention on International Liability for Damage Caused by Space Objects (the Liability Convention) sets the minimum standards of liability for spacefaring nations whose activities could cause health, property, or environmental damage outside their own borders.¹⁷ Traditionally,

the probability of such incidents occurring has been very low, but the magnitude of any consequences has the potential to be high.

The treaty declares that “a launching state shall be absolutely liable” for any damage on Earth or to an aircraft in flight caused by a space object. This means that the launching state is completely responsible regardless of the circumstances of the incident. For damage to objects in space, on the other hand, a fault standard is used, so that liability is assigned based on the determination of negligence or malicious intent. Determining fault, however, could prove difficult or impossible in many situations, since space tracking is not precise and hands-on examination of the physical evidence is unlikely.

The treaty attempts to limit damage claims, but does so in vague terms that may be subject to dispute. Damaged property, for example, must be restored to “prior condition.” Settlements must be made “in accordance with international law and the principles of justice and equity.” No incidents to date have been sufficient to provide clarity or enduring guidance. Even the Cosmos 954 incident in January 1978, in which a Soviet nuclear-powered satellite crashed in Canada, did not prove to be a useful model. Canada received a settlement a few years later and sees this as an example of successful implementation of the Liability Convention. Russia, on the other hand, takes the position that the convention never came into play.

The Liability Convention states that international disputes should first go through diplomatic channels, and if no resolution can be achieved, a claims commission can be formed. This arbitration technique has never been used, so its effectiveness is yet to be determined.

Also, it remains to be seen how well a convention that went into force in 1972 can function in a 21st century environment that features unprecedented levels of commercial space activity, including human spaceflight and satellite constellations numbering in the hundreds or thousands.

Findings

Respondents were nearly unanimous in the following observations about the Liability Convention: The 45-year-old treaty doesn’t have

The Liability Convention is seen as a general principles document that should be built upon, not amended or replaced in the current geopolitical environment.

all the answers for today's and tomorrow's space operations; it doesn't have strong enforcement mechanisms, but most significantly, it should be left in place because it is the best set of guidelines the US and spacefaring nations are likely to have for the foreseeable future.

The Liability Convention is seen as a general principles document that should be built upon, not amended or replaced in the current geopolitical environment. That building process could take the form of separate bilateral or multilateral agreements to create what one commenter described as "a common understanding of what constitutes dangerous interference and encroachment" and to clarify definitions, standards, and procedures to accommodate modern circumstances.

Respondents offered several examples of items in need of clarification to sort out differences in interpretation. The meaning of "launching state" is an obvious choice. The Liability Convention defines this as:

- a state which launches or procures the launching of a space object, or
- a state from whose territory or facility a space object is launched.

Many space missions today involve payloads launching from foreign sites, and launch vehicles carrying multiple payloads from different countries. This is part of the natural evolution of the global launch services industry. The traditional interpretation of the definition above treats this industry differently than terrestrial trucking or shipping, which typically do not continue to have risk exposure for their cargo after delivery is complete. But under the convention, the launch provider's host country continues to have launching state responsibility after the rocket has done its job and no trace of it is left—even if the satellite operator has maneuvered or otherwise altered the payload since deployment. An active launch sector in an era of increasingly congested orbits may have an interest in revisiting and clarifying the launching state definition to assess its effects on the industry's future risk exposure.

The Iridium-Cosmos collision of 2009 presents a relevant case highlighted by multiple respondents: Russia clearly had jurisdiction over the derelict Cosmos satellite, but it was also the

launching state of the Iridium satellite. Should Russia have been held liable for the collision because it was the launching state for both parties?

Another aspect of the determination-of-fault problem illustrated in the Iridium-Cosmos case relates to the operational status of the satellites. Were the Russians negligent because they left a piece of junk in a traffic lane, or was Iridium at fault because it had the ability to maneuver but didn't get out of the way? This question was never resolved in a satisfactory manner that would set precedent. One commenter suggested that if the maneuverable object is always held responsible for collision avoidance in similar situations, this would create an incentive for future satellite operators to forgo maneuverability. But it seems unlikely that a satellite operator would sacrifice a function that supports the mission and end-of-life disposal.

Several consulted experts emphasized the importance of establishing STM standards and procedures as a means to avoid mishaps and to assign responsibility for mishaps that do occur. Air traffic analogies are common, such as the filing of flight plans; the determination of right-of-way, especially during maneuvers; and the incorporation of collision avoidance systems. One respondent suggested that "an international liability organization is needed" as part of this process. However, others believe "it is too soon" to start regulating space traffic because this "runs the risk of putting rules in place that do not fit the circumstances."

The debate continues as to whether evolving space operations are better served by bilateral or multilateral agreements. Each approach has advantages and disadvantages. Lessons learned from the maritime and aviation industries tell us that a system built on a patchwork of conflicting regulations and case-by-case arrangements can significantly hinder the industry's global development. However, multilateral agreements that attempt to cover business plans (e.g., routes, flight frequencies, fares) and politics (e.g., landing rights, competition with state-owned transportation enterprises) fail to garner widespread support, limiting or undermining their ability to promote a global industry and enable its safe operation. The experiences of the International Civil Aviation Organization (ICAO)

and the International Maritime Organization (IMO) demonstrate that multilateral agreements focused on technical standards and safety issues have proven successful as technologies and markets have matured.^{18,19} Bilateral agreements—for example, hundreds of them in international aviation—have continued to be the instrument of choice for economic and politically sensitive issues. This bifurcated approach could serve the needs of the spaceflight community as well as it has served other sectors of international activity.

Selected Quotes on On-Orbit Liability from Subject Matter Experts

“New treaties or conventions are probably not in the cards.”

“No change is needed to the Liability Convention... It’s more important to get technology improvements to space tracking and collision avoidance.”

“It’s possible that the right answer is to repudiate the convention as un-enforceable. However, it’s just about the only thing we actually have right now, and a replacement is unlikely to be easily negotiated.”

“The current convention lacks a solid enforcement mechanism... This needs to be fixed in some manner, possibly through incentives and/or sanctions that could be applied by the ITU or other international licensing bodies. National sanctions on offending countries and corporations could be another mechanism. But more study is needed here.”

“Liability law is ubiquitous and common to most nations. However, the details are not.”

“Commercial space or not, the launching state liability will prevail.”

“It would reduce tensions if a civil agency (versus the DOD or IC) had leadership within USG and internationally” to address next-generation space liability issues.

“The US should continue bilateral space security dialogues with Russia, China, and other nations to discuss the potential for mishaps... Discussions on observed behavior, national perceptions of the event,

and processes for communicating on such matters may facilitate development of processes for preventing mishaps and de-escalating situations... The FAA and the National Transportation Safety Board have processes that could be adapted to prevention of mishaps in space operations, and shared with the international arena.”

Authorization and Supervision of Space Activities in an Increasingly Congested Space Environment

How can the international space community best deal with increasing congestion in the electromagnetic (EM) spectrum and purposeful interference? What are the most effective and efficient emerging or existing technologies and domestic and international EM regulatory and governance structures? What are inherently governmental functions for dealing with increasingly congested space and what should be accomplished by public-private partnerships or perhaps by the private sector? What would be benefits and drawbacks of moving toward the “permissionless” authorization advocated by some legislators?

Background

Article VI of the OST creates an obligation that “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.” As with almost all other aspects of the OST, there is very little specific content to this obligation for signatories, including whether the launching state is always the appropriate party for continuing supervision of space activities. With ongoing large growth in space activity, the United States faces more complex and controversial challenges in finding ways to effectively and efficiently authorize and supervise non-governmental space activity.

Today there is increasing congestion and pressures on the radio frequency (RF) spectrum required for satellite operations, as well as on

the orbital locations where satellites operate. Congestion has been a long-standing issue in GEO where most communications satellites operate and will be an increasing challenge for all of the proposed very large constellations in LEO, particularly since this is also the region of space with the most orbital debris.

The RF spectrum is regulated domestically by the Federal Communications Commission (FCC) and National Telecommunications and Information Administration (NTIA). Internationally, the RF spectrum is regulated by the International Telecommunication Union (ITU), a specialized agency of the United Nations (UN). Satellite operators must obtain

permission from these regulators to use allocations of the RF spectrum for the up- and down-links needed to control satellites and transmit their mission data. In the past, contentious debates within the ITU and at its periodic World Radiocommunication Conferences (WRCs), the normal venue for setting and deconflicting standards for using the RF spectrum for various space applications, were between the developed and developing world over use of the GEO orbit/spectrum resource. These debates were at least partially assuaged by adoption of an equitable access plan for GEO orbit/spectrum allotments at the 1985 WRC. More recently, the focus of contention has shifted to the developed world and has increasingly

centered on efforts to find more bandwidth for explosive growth in the Internet, wireless networking, and mobile applications. At the next WRC in 2019, there will likely be pressure on RF spectrum currently allocated to space applications in order to find more bandwidth for 5G use (that includes significantly faster mobile broadband speeds), more extensive mobile data usage, and to enable the full potential of the so-called “Internet of Things.”

Since 1994, the FCC has sometimes auctioned off parts of the spectrum for use by the highest commercial bidders; the last major auction

(Advanced Wireless Services-3) was completed in January 2015 and resulted in 1611 licenses awarded for almost \$45 billion in bids. By contrast, the ITU considers the RF spectrum a limited natural resource, has plans in place that are designed to equitably allocate at least a small segment of the GEO orbit/spectrum to every state in the ITU, and has never seriously considered developing processes for international RF spectrum auctions. In addition to obtaining international and domestic licenses for RF spectrum use, US satellite operators must also obtain domestic licenses for launch (from the FAA) and for operation of remote sensing capabilities (from the National Oceanic and Atmospheric Administration (NOAA) in the Department of Commerce). A less formalized regulatory framework for minimizing debris provides an important foundation for this objective and consists of both domestic and international elements: the US Government Orbital Debris Mitigation Standard Practices and the voluntary guidelines developed by the Inter-Agency Debris Coordination Committee (IADC).

The United States, like most other countries, also has export control regulations. Many analysts believe that the stringent International Traffic in Arms Regulations (ITAR) that Congress imposed on space technology exports in the late 1990s significantly contributed to steep reductions in US satellite exports and incentivized strong growth in indigenous foreign space technology development. Many of the most restrictive export controls have recently been relaxed and the process for obtaining export control licenses has transitioned away from the State Department’s ITAR system to the US Department of Commerce’s Commerce Control List (CCL). Nonetheless, many space entrepreneurs, particularly those interested in obtaining a license to operate systems for tasks such as satellite servicing, non-Earth imaging, active debris removal, or other novel and potentially emerging commercial markets, still believe they face a slow and opaque space regulatory environment in the United States; they characterize the US process as one that tells you no slowly but can’t tell you why.

In 2015, the Commercial Space Launch Competitiveness Act tasked the US Office of Science and Technology Policy (OSTP)—in consultation with the Secretary of State, the Secretary of

Many analysts believe that the stringent International Traffic in Arms Regulations (ITAR) that Congress imposed on space technology exports in the late 1990s significantly contributed to steep reductions in US satellite exports and incentivized strong growth in indigenous foreign space technology development.

Most respondents believe the current regulatory approaches are working well enough that they should form the foundation for advancing a more effective and efficient regulatory regime...

Transportation, the Administrator of the National Aeronautics and Space Administration, the heads of other relevant federal agencies, and the commercial space sector—to (1) assess current, and proposed near-term, commercial non-governmental activities conducted in space; (2) identify appropriate authorization and supervision authorities for space activities; and (3) recommend an authorization and supervision approach that would prioritize safety, utilize existing authorities,

minimize burdens to the industry, promote the US commercial space sector, and meet the United States obligations under international treaties. In response, OSTP found that while “existing licensing frameworks provide clear means to address certain aspects of these activities, they do not, by themselves, provide the United States Government with a straightforward means to fulfill its treaty obligation to ensure the conformity of these activities with the provisions of the Outer Space Treaty.”²⁰ At the first meeting of the revitalized National Space Council (NSpC) on October 5, 2017, Vice President Mike Pence tasked the Department of Commerce and the Office of Management and Budget to identify major regulatory impediments to increased US commercial space activity within 45 days.

Findings

Benefits of current approach. Most respondents believe the current regulatory approaches are working well enough that they should form the foundation for advancing a more effective and efficient regulatory regime; current processes may need some modifications but they provide an adequate basis for balancing a range of sometimes conflicting values. There was also strong agreement that these regulatory actions are inherently governmental functions that should be carefully considered and vetted across multiple stakeholders and other constituencies in order to work towards: enhancing the safety of space operations; preserving the space environment; negotiating with other governments; and facilitating the development of norms, standards, guidelines, and best practices. Some respondents

believe that our regulatory structure must find better ways of valuing and supporting the public good aspects the RF spectrum that enables space-based telecommunications, remote sensing, and positioning, navigation, and timing (PNT) services since this spectrum is often under great pressure both domestically and internationally from actors demanding more spectrum for various commercial applications and for wireless mobile networks in particular.

Our respondents voiced little support for permissionless authorization and minimal continuous supervision for operations in an inherently global, complex, expensive, and hazardous environment that includes large national security considerations and noted that few, if any, major US space actors have publicly supported such an approach. More specifically, respondents emphasized that the American Space Commerce Free Enterprise Act (ASCFEA) of 2017 could inadvertently harm the development of new space enterprises by mandating that a new Department of Commerce entity respond to an application for a proposed space activity within 90 days or it would be automatically approved. They noted that 90 days might not allow enough time for the responsible authorities to make an informed decision and believe the proposed process could reward applicants for “running out the clock,” and only slowly responding to questions from the government.

Alternative approaches. For addressing RF spectrum congestion, respondents recommended that the international community should set out challenges related to bandwidth and pursue an innovation prize model to develop ideas for technology, policy, and allocation; they also noted that laser communications could enable further high bandwidth growth and potentially provide alternate means of in-space and space-to-Earth transmissions. A few respondents emphasized that while permissionless access to space has advocates in Congress, the new licensing process proposed in the ASCFEA calls for “presumed approval,” not permissionless access. Presumed approval might lower regulatory barriers while retaining governmental control of space access and allow for significant national security concerns to be addressed in a more transparent fashion within

the industry. Presumed approval could also lessen the regulatory strain on government and allow limited resources to be focused where they are most needed.

More broadly, some respondents believe the specific controversy on the management of commercial space provides an opportunity for the US government to encourage a continuous dialogue on industry best standards that potentially inform regulatory matters. Industry practices considered or developed across a range of companies proposing or performing similar commercial space functions might serve as an excellent source of practical regulatory input to government decisions. While it is reasonable for government to justify restrictions on nongovernmental space activities, some experts emphasize that other large enterprises such as the Internet developed in a relatively permissionless environment and believe that regulation of commercial space would benefit by following that path.

Selected Quotes on Authorization and Supervision of Space Activities from Subject Matter Experts

“Satellites face growing pressure from the demands of the mobile wireless industry. Wireless industry believes its use of bandwidth is more important because it can generate large near-term revenues, but this undervalues the public good aspects of satellite services for communications, navigation, and remote sensing.”

“Space traffic management is a natural monopoly. Whoever controls the monopoly has superior knowledge. Our first choice would be for this to be a ‘Space Guard’ capability (a constabulary uniformed service). Second choices would be a federal civilian or commercial agency with embedded military personnel exercising shutter control.”

“I am confident that the World Radio Conference is not an optimal structure for governing this function internationally. The idea of ‘one nation, one vote’ that puts Vanuatu on equal legal footing with Washington is inherently irrational and unfair, and potentially jeopardizes US security.”

“I don’t believe that the international community will be able to do much to inhibit purposeful interference.”

“The international community has proven itself both untrustworthy and incapable of performing [authorization and supervision of space activities].”

“In the case of deliberate jamming, it is of utmost importance that ITU again can play a greater role in ‘naming and shaming’ strategies by reinforcing its role as a neutral expert center that can attribute responsibilities.”

“We need to start having public conversations now about Laws of Armed Conflict (LOAC) for purposeful interference, as that is the type of space warfare that is a) the most likely to happen... and which b) we have no idea how to handle.”

“Having a permissionless authorization to operate in an expensive and hazardous environment is absurd.”

Formulating and Enforcing Norms of Behavior

The recent European-led effort to establish an International Code of Conduct for Outer Space has not proved successful. How can the US government best improve compliance with existing international obligations and foster development of more robust norms of responsible space behavior? What are the complementary roles for the US government and the commercial space sector in shaping international perceptions on what is acceptable or “normal” behavior in space?

Background

There is a good deal of discouragement across the international space diplomatic community following the failure to establish an International Code of Conduct (ICoC) in 2015. Fortunately, there are also a number of recent or ongoing efforts that have been more successful or hold significant promise for advancing other work to develop space norms. One of the most important and successful efforts is the technical work undertaken by the IADC, a group that began work in the late 1990s and is now comprised of 13 national space agencies. This group has developed a comprehensive set of

Most analysts believe that movement towards consensus on implementing actual debris removal processes is unlikely to be fast or easy as there are a number of highly complex, multidimensional challenges that cut across multiple political, security, technical, financial, commercial, and legal considerations.

voluntary debris mitigation guidelines that were endorsed by the United Nations General Assembly (UNGA) in December 2007.²¹ More recent work by the IADC has focused on a number of technical approaches for ADR but the Committee has not yet reached consensus on the most promising approaches or advanced specific ADR guidelines for consideration by policymakers. Most analysts believe that movement towards consensus on implementing actual debris removal processes is unlikely to be fast or easy as there are a number of highly complex, multidimensional challenges that cut across multiple political, security, technical, financial, commercial, and legal considerations. Security-related concerns about ADR are focused by considering that one group's ADR system can easily and objectively be viewed as an ASAT capability by others; this reality indicates ADR approaches are best advanced in multilateral ways, rather than unilaterally.

The three recently concluded and ongoing major diplomatic efforts to develop more robust space norms have met mixed results so far. As noted above, the 2015 collapse of the ICoC (which began in the mid-2000s as the European Union (EU) Code of Conduct) represents a significant diplomatic setback, especially since the ICoC was the leading diplomatic effort for more than a decade, and because there is no consensus on ways to build from or reinstate work that led to the ICoC. Perhaps even more disappointing is the fact that most objections to the ICoC center on the process for its development rather than on its substance, although this might also prove to be a silver lining if the work is to be reinstated. A second major diplomatic initiative includes the proposals for Transparency and Confidence Building Measures (TCBMs) set out in the 2013 consensus report of the UN Group of Governmental Experts (GGE) on TCBMs in Outer Space. Many analysts initially characterized the TCBMs proposed by the governmental experts report as modest, but may

now see them as more significant given the failure of the ICoC. Finally, there is the ongoing program of work at the UN Committee on the Peaceful Uses of Outer Space (UNCOPUOS) to develop a comprehensive set of guidelines for the long-term sustainability of space activities (LTSSA). The UN's committee on the peaceful use of Outer Space did reach consensus on a number of guidelines which were presented to the General Assembly in June 2016, and the program of work to complete the remaining guidelines was extended to June 2018. While hopeful, many analysts believe the end game of finalizing and reaching consensus on the LTSSA guidelines may prove to be challenging. This illustrates not only some fundamental disagreements among major COPUOS actors about the object and scope of these negotiations but also some of the deep-seated divisions on space security that have thwarted effective work on space security at the UN's Conference on Disarmament (CD) for more than a decade.

Findings

Redouble diplomatic efforts. Noting that many impediments to progress on developing norms stem from procedural rather than substantive issues, several respondents emphasized the need for greater effort and leadership in advancing diplomatic work, particularly on the part of the United States. To advance the transparency and confidence building measures from the UN's GGE report, the grouping recommends that a major space actor, group of states, or a state-private sector partnership convene a meeting to discuss the potential for implementation of these or similar TCBMs in practice in the near term. Some of the respondents even believe this could be more important than the UNCOPUOS long term sustainability of space activities work. Several respondents emphasized that leadership would be essential for any effort to reinstate work on an International Code of Conduct but noted that both the EU and United States seem leery of taking on this leadership role. The 50th anniversary of the Outer Space Treaty and the June 2018 UNISPACE+50 conference also present opportunities to tie code of conduct work to the OST and ongoing UN efforts to advance the OST regime. Although a redoubling of diplomatic effort seems unlikely during a Trump Administration,

Some aspects of norms development are likely to remain inherently governmental activities, but these respondents argue that industry can help point government toward more productive approaches for norms development and implementation.

these respondents argue that US leadership in space diplomacy has been weak or missing for decades and that this approach is shortsighted since the United States faces disproportionate dangers from a space arms race due to its reliance on space capabilities.

Advance civil space traffic management as the leading norms development effort. Other respondents take a more pragmatic approach and see US leadership in implementing a civil STM system as the best way to develop, refine, practice, and enforce enhanced norms. These analysts believe that the mixed results from recent “top-down” diplomatic efforts indicate that US leadership in developing and practicing “bottom-up” steps leading to a civil STM system are more important than ever. As the world’s leader in all sectors of space activity, the United States has a window of opportunity to lead by example and be more intentional in pursuing these objectives.

Several respondents advocated use of GPS transponders on satellites, active position reporting, and pre-notification of manual and automatic maneuvers as potential approaches for improving spaceflight safety and providing a baseline for developing metrics that could help to define and measure responsible behavior. Metrics might then be used in domestic, and perhaps international, licensing decisions. Trust is a key aspect in advancing any comprehensive civil STM system and major space actors will not voluntarily join or support such a system unless they believe it will provide better spaceflight safety and more clearly identify responsible and irresponsible behavior in space. There are obvious overlaps and dependencies between creating and disseminating high-fidelity tracking data and advancing a more transparent civil STM system. Respondents advocated finding ways to synergize these highly related efforts. From a security perspective, important outcomes from this work would be providing better clarity and consensus on what constitutes hostile intent in space as well as acceptable measures for self-defense in space, concepts the United States has been struggling with internally for a number of years.

A final group of respondents also advocates US leadership in creating a civil STM system but believes the US commercial space sector, rather than the government, should lead this effort. The rationales for this approach include the credibility the US industry enjoys as the world’s leader in almost all aspects of commercial space activity; the pragmatic need for industry to continue leading efforts to advance best practices, particularly as commercial space and novel commercial applications grow; and the faster, more transparent, and more collaborative approaches industry is likely to favor in contrast to government approaches. Some aspects of norms development are likely to remain inherently governmental activities, but these respondents argue that industry can help point government toward more productive approaches for norms development and implementation. Several respondents emphasized that the US government has clear opportunities to leverage the effort of commercial space actors to enhance and develop more comprehensive norms because commercial actors have motivations and incentives to move in this direction that are at least as strong as the motivations for the US government.

Selected Quotes on Formulating and Enforcing Norms of Behavior from Subject Matter Experts —

“Behavioral norms will have a better chance of being accepted and sustained if they’re bottom-up rather than top-down.”

“Very likely the best chances are if this conversation [on international norms] begins not with arms control and security people, but rather with private operators who desire a stable environment.”

“[The ICoC] was a huge missed opportunity. Even if the code would have been a just a modest step, the failure to bring it across the finish line makes it harder to garner support for other such initiatives. US leadership on this is essential.”

“The Code of Conduct was unsuccessful because the US administration and Congress were uncertain about the ultimate utility of such a code. ‘More robust norms’ will likely not be possible until key decision makers in the administration and Congress determine that they are necessary.”

The US government should set the example and encourage a coalition of the willing. This regime could ostracize non-compliance and irresponsible space behavior. The United States and European Union are in the best position to advance this approach.

“The ICoC has failed, not because of its content—it’s probably the best set of guidelines and TCBMs put together so far—but because of the demarche followed to address various fora and being promoted outside of the UN format. It should be relaunched under a different name and format, keeping its excellent principles, supported by a group of UN member states to start a discussion within the COPUOS and then be moved to the UNGA. The United States, European countries, Japan, India, and some Latin America and African countries can support such an initiative.”

“The ICoC was not successful in getting a final product signed and agreed, true. But it was successful in that it demonstrated that the international community recognized the importance of norms of behavior and that one could try to explicitly state what a responsible space actor did/not do. It also showed that non-legally-

binding responses were a possibility. The work with the long-term sustainability guidelines in COPUOS is an example of non-legally-binding norms that the international community is coming together to work on and should continue to be strongly supported by the US government.”

“The US government may be best served if it were to simply publish its own version of best practices unilaterally, state its intent to abide with those practices (except in extraordinary circumstances), its intent to review the practices of others for consistency with our own understanding of best practices, and serve as the judge of its own compliance with these standards as well as the compliance of others.”

“The US government should set the example and encourage a coalition of the willing. This regime could ostracize non-compliance and irresponsible space behavior. The United States and European Union are in the best position to advance this approach. The Chicago Convention and the regime created for air traffic control under the ICAO will not be completely appropriate for space but provides the best model. I have seen the People’s Republic of China and Russian Federation repeatedly and disingenuously subvert progress—don’t work with them.”

“The United States should absolutely work to implement the Transparency- and Confidence-Building Measures (TCBMs) devised by the UN Group of Governmental Experts and the UN Committee on the Peaceful Uses of Outer Space (COPUOS) Long-term Sustainability Guidelines by pushing them to be adopted in the United Nations General Assembly (UNGA) and to build them into domestic policy and regulations. This will only get so far, as these tend to skirt the most difficult issues dealing with military uses of space and competing security interests. While the major spacefaring countries have seemed to disagree on the substance and approach to security issues (see Prevention of Placement of Weapons in Space Treaty (PPWT)), in reality there have not been substantive discussions to identify what common ground on space security issues might exist.”

“The United States should, in concert with other major spacefaring states, move to convene an OST review conference or meeting. This could be focused on providing clarifying discussions about how different states view the balancing of concepts of freedom to use space for peaceful purposes, due regard to other actors, and the use of space to benefit all humankind.”

“The United States should continue to participate in forums like the UNCOPUOS Working Group on the long-term sustainability of outer space and ICAO’s space learning group, involving both established and emerging spacefaring nations. Specifically, US participation should be from both government AND industry—including industry in the US delegations to these meetings where possible, and developing US positions and statements with industry beforehand.”

“The US government should support the development of best practices by following the lead of US commercial corporations, which have great sway internationally. For example, in human spaceflight, it is likely that US companies will lead the way in sub-orbital and orbital flights at least over the next decade. Coordination is already taking place among these companies in this regard. Similarly, asteroid mining companies are already coordinating informally on norms. The US Government could endorse these processes and begin to support these norms through its policy statements (such as the National Space Policy),

enlisting other governments and their corporations to support them as well. Over time, if the bulk of Western governments and their corporations adopt such standards, China, Russia, and other possible outliers will likely find it beneficial to eventually join them. This may be easier than a straight political process.”

“The only basis [for norms development] should be safety and [technology] based. Otherwise the United States looks manipulative and dictatorial.”

“Recognize that future space operations will not be primarily governmental in nature, and empower an office to work on it. The dual mandate of public safety and ‘encourage, facilitate, and promote’ that the FAA Office of Commercial Space Transportation (AST) has provides an excellent example of how government can enable industry to be both safe and successful.”

“As industry works on its own efforts to develop standards and best practices, it is important that those efforts continue to be international as well. The US Government should encourage industry efforts and support them where appropriate.”

Preparing for Ubiquitous Proximity Operations and Non-Earth Imaging

The next generation of space development is expected to include proliferation of rendezvous and proximity operations (RPO). What does the US national security community need to do to accommodate this potentially threatening environment—and possibly gain advantage from it?

In addition to RPO, non-Earth imaging will also proliferate, since it is essential to many space operations and business models. How could the US government adjust its architectures, operations, classification guides, and public affairs approach to keep this from becoming a problem, or even turn it into a benefit?

Background

All space sectors—civil, commercial, and national security—are exploring expanded operational concepts based on the physical manipulation of space objects and the gathering of information on space objects. These activities require two capabilities that have great potential but also present security concerns: proximity operations and non-Earth imaging.

Rendezvous and proximity operations (RPO) could include on-orbit repair, refueling, repositioning, and end-of-life disposal/recycling, as well as active debris removal. Advances in guidance, navigation, control, and propulsion systems make the necessary technologies more widely available, which enables more rapid space development but also increases concerns about intended and unintended interference with space systems.

Proximity operations commonly have been associated with piloted missions (such as the Apollo Program, the space shuttle, and the International Space Station) performed infrequently by a small cadre of experts working on high-profile government programs. But this is changing. There have been robotic proximity ops demonstrations (by NASA and the Defense Advanced Research Projects Agency (DARPA) for example), which are likely to become much more frequent. Multiple private-sector entities are planning to offer on-orbit servicing and are working on active debris removal concepts, including seasoned space companies such as Orbital ATK, MacDonald, Dettwiler, & Associates, and Airbus.²² Space insurance companies, anticipating a new line of business, also have shown interest in business plans based on proximity operations.

Non-Earth imaging is required for satellite inspection, rendezvous and docking maneuvers, debris tracking, and asteroid searches by companies interested in extraterrestrial resources. In space surveillance and imaging, the diffusion of observation technology and know-how has curtailed the ability to maintain secrecy in areas once thought to be invisible to public view. For many years, independent actors such as amateur astronomers have been routinely detecting, tracking, and identifying satellites. The hardware and software to support this activity has become

widely available and affordable. Global networks of amateurs linked by the Internet share findings and coordinate follow-up sightings to increase accuracy.

To perform their missions, RPO systems require automated and/or tele-operated imaging systems capable of pointing in all directions to aid in navigation and interaction with other space objects, so proximity ops and non-Earth imaging are linked. The global community can be expected to pursue these capabilities regardless of what the US does, especially if they are perceived as key elements on a path to technological and economic advancement. Other nations may assess the net benefits differently than the US does, perhaps with less emphasis on the threat aspects since they have fewer on-orbit assets directly at stake.

An oft-repeated axiom tells us that technology is neutral; how we use it determines whether it produces good or ill. The participants in this project appear to recognize this, as well as the tendency of useful technologies to spread rapidly in the modern world.

Findings

An oft-repeated axiom tells us that technology is neutral; how we use it determines whether it produces good or ill. The participants in this project appear to recognize this, as well as the tendency of useful technologies to spread rapidly in the modern world.

The questionnaire submitted to experts consulted for this paper asked separate questions on proximity operations and non-Earth imaging, but most respondents addressed them as two components of a single issue: space technology proliferation and what to do about it. As one expert put it: the opening assumption should be that everything about your satellites can be seen and that rendezvous is a routine event. In that situation, what policies, technologies, and designs will make this a non-problem and still accomplish the mission?

Demonstrating strong concurrence on this issue, respondents made points that can be summarized as follows:

- The US government must plan for the coming era in which proximity ops and non-Earth imaging are widespread.
- The US should take a leadership role in establishing norms of behavior for RPO and non-Earth imaging that keep the space environment safe, secure, and sustainable for all.

- Do not try to fight these developments. Prohibition or excessive restriction of these capabilities could stifle an entire class of emerging commercial space activity—for US companies, but not for their foreign competitors.
- As the number of players with satellite inspection and interaction capabilities increases, devoting resources to countermeasures will have an opportunity cost.

On the last point, there was not complete agreement on how to manage the opportunity cost. Many respondents felt that limited resources could be more productively applied to keeping the US and its space industrial base at the forefront of these capabilities. But not everyone was reluctant to invest in countermeasures. Suggestions for denial of unwanted orbital interaction included dazzling, jamming, bumping, spraying, or destruction by directed energy. Some favor a strong declaration of policy by the US stating the limits of its tolerance for intrusions and the defensive and retaliatory actions that the US is prepared to take. The technologies, architectures, and tactics supporting this course of action are elements of the drive for resilience in space systems. Rapid replenishment—through flexible, responsive launch and accelerated manufacturing—was suggested as a key element of this approach.

Rendezvous and proximity operations.

The dominant view of the respondents on RPO is clearly articulated in this comment from one of them:

The US national security community needs to accept that rendezvous and proximity operations (RPO) is an inevitable feature of the future space environment: not the distant future, the near future. It is in the strategic interest of the United States to ensure that our space technology remains on par with, or ahead of, that of our strategic peers.

Widespread use of rendezvous and proximity operations is a concern for the national security community because the technologies and operational techniques are essentially the same as those needed for anti-satellite (ASAT) operations. This allows the possibility that ASAT development, testing, and deployment could masquerade as seemingly non-threatening orbital applications. But as some respondents pointed out, this concern

... today's spacecraft do not have the ability to monitor their surroundings and defend themselves from hazards and threats which, unlike their maritime counterparts, would not necessarily approach in observable steps.

must be weighed against the potential of this capability to enable safety and security benefits by inspecting and servicing satellites and by improving space-based situational awareness. For example, one participant described a proposed on-orbit servicing plan that positions repair vehicles in popular orbits and assigns them an SSA mission during idle times between service calls.

The increase in space traffic generally, and close-approach activities specifically, will compel monitors on Earth to improve SSA capabilities for orbital regimes as high as GEO. Ambiguous activities such as unannounced maneuvers, especially in the vicinity of other space systems, need to be analyzed to determine if they are benign or potentially hostile. Some commenters speculated that as an STM system takes shape, it may include filing “flight plans” for maneuvers, and may issue the space equivalent of Notices to Mariners and Notices to Airmen. Respondents suggested that this could be aided by the sensors on an assortment of RPO vehicles in popular orbits. Rather than be wary of such developments, the US national security community should encourage and facilitate them, including helping to establish standards, in an effort to take full advantage of the benefits they could provide, according to several respondents.

A few participants suggested consideration of self-defense or keep-out zones, judging that any questionable movements in or near the zones could provide a useful warning of potential trouble. Safety perimeters and exclusive economic zones on celestial bodies or in orbital space have been discussed for many years, but important details and significant challenges need to be worked out.

Protected zones have been used in the maritime domain, where nations can declare sovereignty in territorial waters up to 12 nautical miles from shore.²³ Similarly, ships at sea may derive benefit from keeping a protective bubble around them. Like satellites in orbit, ships on the high seas are operating outside of sovereign territory and must consider the potential threats from environmental hazards, intentional attack,

and unintentional interference. There is no internationally recognized keep-away distance, so the size of a ship's or fleet's protective zone is no bigger than what they can enforce.

However, today's spacecraft do not have the ability to monitor their surroundings and defend themselves from hazards and threats which, unlike their maritime counterparts, would not necessarily approach in observable steps. Even if they did, there still may not be time to react to them. With rare exceptions (e.g., the International Space Station and human transport vehicles), lives are not in danger, so the legitimacy of protective zones of arbitrary size likely would be questioned by other spacefarers. Another challenge to legitimacy could come as a result of the OST's prohibition on declarations of national sovereignty in space.

Non-Earth imaging. Similar to proximity ops, the view on this topic from participants is that the US government should embrace non-Earth imaging and use it to advantage, not suppress it. As one respondent noted:

Our international peer competitors are pursuing this technology, and it is naïve to assume that they will not use it, to some extent, for intelligence purposes. Therefore, limiting US commercial companies to limited pixels and low resolution only serves to constrain the American industry without providing additional safeguards for American government systems.

Current restrictions on US systems allow for imaging of consenting spacecraft with no resolution limit, upon obtaining written approval and providing a notice to the government 90 days prior to the operation. Imagery of non-consenting spacecraft is limited to a 3x3 pixel size and resolution no better than half a meter. A commenter suggested an alternative approach that could be more productive: no pixel or resolution restrictions, just restrictions on public dissemination of the imagery. Commercial missions could be carried out freely with consenting spacecraft, while the US government could act as the sole purchaser of sensitive imagery of non-consenting spacecraft, or of US government spacecraft. In addition to the obvious intelligence benefits, the government can use these systems to maintain and monitor its own on-orbit systems.

US leadership in setting norms of behavior.

The proliferation of increasingly capable RPO and non-Earth imaging technologies without accompanying rules or norms of behavior presents a security challenge as the increasing tempo of activity could spark or escalate a crisis. Several respondents believe that the risks of misinterpretation and miscalculation could be mitigated by norms such as passive or active tracking aids, routine sharing of tracking information, and possibly keep-out zones.

Respondents believe the US government is well positioned to take the lead in developing best-practice guidelines through an international regime. They remind us that the collective US interests in space operations are the largest in the world, which would seem to call for an effort to seek a dominant role in guiding global space operations.

Selected Quotes on Proximity Operations from Subject Matter Experts

“Accept the proliferation of [proximity operations]. It’s going to happen, so don’t fight it. The USG has to be transparent with allies and partners about what it’s doing in [proximity operations], and they have to reciprocate.”

“Accept the proliferation of [proximity operations]. It’s going to happen, so don’t fight it. The USG has to be transparent with allies and partners about what it’s doing in [proximity operations], and they have to reciprocate.”

“The US can be a leader in this area if we focus on enabling industry to be successful, rather than trying to control and restrict capabilities.”

“Creative government partnerships with the commercial space industry will ensure US global leadership in RPO.”

“If the national security community relies only on government systems for capabilities such as Earth imaging, space situational awareness, or RPO, they will be playing a continuous game of catch-up to international competitors.”

“The national security community needs to support and to be involved with the emerging [commercial STM] system and be assured that they will receive the best and most current information available on all orbiting objects and planned maneuvers.”

“The US national security community needs to accelerate the development efforts for a joint DOD & IC space tracking system to combine all sources of sensor data.”

“The US must remain fully engaged in the process to establish new international standards and norms.”

“It’s the intention, not the capability, which is the most destabilizing.”

Selected Quotes on Non-Earth Imaging from Subject Matter Experts

“Accept that non-Earth imaging is a routine element of future operations.”

“Start with the assumption that it’s going to happen. Many are still focused on how to prevent it from happening. It’s too late for that.”

“The US national security systems have operated with a certain, tacit assumption of privacy. This will no longer be the case in the near future.”

“Current US Government approach is a counterproductive holding pattern... withholding licenses from US companies hurts US national security and [the space industrial base].”

“By overly regulating [non-Earth imaging], we only harm US companies and capabilities, much like we did with [the International Traffic in Arms Regulations]. The remote sensing regulations need to more accurately reflect the current state of EO [electro-optical] capabilities around the world, and not forbid efforts that are already pervasive globally.”

“The current commercial space environment calls for US government anticipation of the kinds of capabilities that will be requested for licensing in the future. Rather than wish that some of these ideas go away, the US government should proactively think about the strategic, government, and economic consequences of the commercialization of new space functions.”

“The US Government needs to strike the right balance in setting guidelines for the commercial space sector that allows both the Government and companies to benefit from developed non-Earth imaging (NEI) capabilities without imposing unnecessary restrictions

that apply only to US companies, and thereby have little practical effect.”

“If we have a great new capability, but we don’t allow anyone to use it, [others] will go try and develop their own system. [The] default position of [the] US Government is too often to hide/protect new capabilities. If we focus on being the best, and then [allow] US industry to market the products and services (maybe with some delay in time or capability), it can be a huge scientific and economic benefit for the US”

“The US Government should review the purpose and degree of classification of certain orbital data with the goal of improving common awareness throughout the space operations community, as long as this would serve national interests.”

“There is great potential to use [non-Earth imaging] capability as a means of enforcing good behavior in space, and perhaps providing an option toward verification for arms control purposes.”

“We should encourage private groups to publish open-source data.”

“Given that we cannot control foreign systems, we need to consider what restrictions actually make sense for US-licensed systems... we may just have to get used to the idea that we cannot maintain secrecy for some systems, and adjust our plans, operations, and security policies accordingly.”

“[The] exclusion list [of items from the space tracking catalog] is counterproductive—it creates incentives to track excluded objects... Some satellites are truly secret and better ways must be found to keep them that way.”

“By defining a protection volume around space objects, [unwanted] imaging could be limited. This should be commonly agreed by spacefaring nations. Entering such a protective volume would expose the intruder to possible retaliation.”

“An overall approach to improve survivability and resilience (larger constellations, smaller satellites, flexibility in launch and so on) will be the most important aspect of reducing the significance of non-Earth imaging.”

Countering Counterspace

How can the US government best deal with the accelerating pace of Chinese and Russian counterspace capability development and testing, ensure freedom of action in space, and improve space system resilience?

Background

Perhaps no national space policy issue has seen more change, and requires more focus, than addressing the accelerating pace of Chinese and Russian counterspace capability development and testing, ensuring freedom of action in space, and improving space system resilience. As the strategic space environment becomes increasingly contested, all aspects of US national space policy must adjust and adapt to this new reality. On January 11, 2007 China conducted a test of a ground-based, direct-ascent anti-satellite (ASAT) system that destroyed an aging Chinese weather satellite. The kinetic impact from this test was most notorious for creating large amounts of long-lived space debris; it initially increased the amount of debris in LEO by 25 percent, and much of this debris will remain in orbit for decades. From a strategic perspective, the 2007 ASAT test also marked the end of an era when the United States could plausibly consider that its satellites, even those in LEO, were operating in a benign or permissive environment and did not require strong efforts to ensure their safety and effectiveness.

Any vestiges of a space sanctuary mindset were removed following a May 2013 Chinese test of a ground-based, direct-ascent system all the way to GEO, a capability the United States and Soviet Union did not develop even in the depths of the Cold War. The Chinese are also developing a wide range of multi-dimensional and comprehensive ground- and space-based counterspace capabilities in addition to these most prominent ground-based, direct ascent ASAT systems. In 2015 China created the People’s Liberation Army Strategic Support Force to synergize space, cyber, and electronic warfare capabilities within a single command and advance its ability to conduct informationized warfare.

Senior officials in the Trump Administration are working to build on this momentum in addressing counterspace developments and, marking a break with previous administrations, have not been reticent in discussing counterspace and space control issues.

Meanwhile, as overall US-Russia relations become increasingly hostile, the Russians are building off of a long-standing and deep space technology base to pursue a wide range of increasingly effective and worrisome ground-based, airborne, and space-based counterspace capabilities. The Russians have been more overt about their counterspace objectives but their programs and testing are often more difficult to track and understand. Director of National Intelligence (DNI) Dan Coats summarized the situation in the 2017 Worldwide Threat Assessment: *...despite ongoing US and allied diplomatic efforts to dissuade expansion of threats to the peaceful use of space, including international engagements through the UN... Russia and China perceive a need to offset*

*any US military advantage derived from military, civil, or commercial space systems and are increasingly considering attacks against satellite systems as part of their future warfare doctrine. Both will continue to pursue a full range of anti-satellite (ASAT) weapons as a means to reduce US military effectiveness.*²⁴

The United States has been carefully studying these developments and moving towards greater space mission assurance but many analysts question whether it has moved far enough or fast enough. Much of the data surrounding counterspace developments remains highly classified and there are also serious debates about the value of keeping so much data so highly classified given the accelerating pace of both open and covert counterspace capability developments. The 2011 *National Security Space Strategy* (NSSS) was the first public document to emphasize these changes and it was followed by a classified National Intelligence Estimate (NIE) in 2012, an update to the NIE in 2014; a Space Strategic Portfolio Review (SPR) in 2014; the 2015 Office of the Secretary of Defense (OSD) White Paper on Space Domain Mission Assurance: A Resilience Taxonomy; creation of the Principal Department of Defense (DOD) Space Advisor (PDSA) position in 2015; and direction in the House Armed Service Committee (HASC) version of the Fiscal Year 2018

National Defense Authorization Act (NDAA) for the Secretary of the Air Force to create a space corps within the US Air Force by the beginning of 2019 and direction in the Senate Armed Services Committee (SASC) version of the FY18 NDAA for DOD to create a new Chief Information Warfare Officer (CIWO) within OSD that would oversee the DOD's principal space advisor.

Senior officials in the Trump Administration are working to build on this momentum in addressing counterspace developments and, marking a break with previous administrations, have not been reticent in discussing counterspace and space control issues. The top priority of Secretary of Defense James Mattis is to increase the lethality of DOD across the board, and he has included space as one of his focus areas: "And whether it be safe guarding our nuclear deterrent, or air combat, mobility to space, to personnel management processes and policies and everything in between, your actions must meet one standard. And that is to make the US Air Force more lethal every day that you serve; to turn the US Air Force over to your successors as more lethal than you inherited it here today," he told a gathering of Air Force officials in September 2017.²⁵ For her part, Secretary of the Air Force (and PDSA) Heather Wilson has been even more explicit: "And a third thing with respect to normalizing space is the ability to create effects. We have to be able to defend ourselves. We also have to be able, if we are to deter the malevolent actions of others, to take offensive action, if needed. So we're going to have to develop those capabilities in space."²⁶ At the first meeting of the revitalized National Space Council on October 5, 2017, the National Security Advisor, Army Lt Gen H.R. McMaster, announced that the National Security Council (NSC) is developing a classified Space Strategic Framework that will focus on measures to address counterspace developments including strengthening the resilience, safety, stability, and sustainability of space activities; as well as on ways to deter and, when necessary, defeat adversaries' space and counterspace threats that are hostile to the United States and our allies. Vice President Pence, chair of the NSpC, tasked the council to develop implementation actions for the Space Strategic Framework within 45 days.

Findings

Almost all respondents believe the United States needs to do more to address counterspace developments but there are several disagreements about whether our efforts should focus on diplomatic, commercial, or governmental approaches and the most appropriate ways to synergize or separate these efforts.

Increased US focus and leadership on diplomatic approaches. Although a few respondents indicated counterspace issues simply cannot be usefully addressed via diplomatic means, a larger number believe that diplomatic approaches hold the best prospects for success. One simple approach is for the United States to more widely, comprehensively, and effectively publicize its own space best practices in the hope that other space actors will choose to emulate these practices. Another proposal is for the United States to sponsor some sort of specific dialogue on counterspace issues with China and Russia, either through formal, or more likely informal channels. The main goals of this private dialogue would be to have a frank exchange about attribution, hostile intent, self-defense, and other counterspace issues as well as to discuss other space activities such as rendezvous and proximity operations (RPO) that are closely related to counterspace capabilities. Other specific informal dialogue opportunities the United States should consider supporting (and or leveraging) more effectively

The United States should also look beyond just space-focused and traditional diplomatic tools when considering a range of economic and financial means to dissuade development of counterspace capabilities or punish actors for their testing or use.

include discussions on limiting space-based missile defenses, civil space traffic management, and talks on the Manual on International Law Applicable to Military Uses of Outer Space (MILAMOS). The United States should also look beyond just space-focused and traditional diplomatic tools when considering a range of economic and financial means to dissuade development of counterspace capabilities or punish actors for their testing or use. Almost all diplomatic approaches require improved attribution capabilities, greater transparency, and lower classification of relevant counterspace data in order to aid in building domestic and international support as well as in naming and shaming bad

behavior. In pursuing this approach, the United States would need to be mindful of the adage that “those who live in glass houses shouldn’t throw stones” when balancing the value of greater transparency against the exposure of its own activities and loss of some freedom of action.

Leveraging commercial capabilities. Most respondents advocated finding ways to leverage the burgeoning commercial space sector to improve the resilience of space capabilities that support national security. Noting that developing commercial space capabilities can often be three to five times less expensive than developing an equivalent government space system and anticipating near-term explosive growth in commercial space capabilities, particularly in LEO, many respondents emphasized that these commercial developments will create some of the most exciting and potentially game-changing opportunities ever seen for advancing space capabilities. There are many ways this explosive commercial space growth has great potential to augment and enhance space mission assurance and to create agile, resilient, and distributed architectures including:

- increasing the number of nodes in the overall architecture by orders of magnitude, thereby reducing the value of attacking individual nodes;
- expanding opportunities for deception, multiple types of various SSA and mission sensors, and perhaps even offensive and defensive counterspace capabilities built into each large constellation;
- providing new reconstitution opportunities from responsive launch of small satellites constellations at time and places advantageous to the United States and its deployed warfighters; and
- creating new ways to use persistent coverage and big data analytics to understand and predict activity on Earth and in space.

Several respondents emphasized that growing commercial capabilities seem to represent one of the only ways the United States can get ahead of the cost curve or the “Nitze criteria” (the basic requirements for successful ballistic missile defense) and make incremental investments in space defenses cost less than America’s adversaries’ incremental offensive investments. Others believe

that proliferation of space situational awareness sensors and communications pathways with large commercial constellations represent the best opportunity to improve US space command and control and attribution capabilities, as well as being essential for safety of flight as LEO becomes increasingly congested.

DOD leadership and space acquisition professionals must prepare for the novel and non-traditional acquisition opportunities that growth in commercial and allied space capabilities will present. The US government will need clear and well understood criteria for what space mission areas can be completely performed by commercial and allied systems, where commercial and allied

DOD leadership and space acquisition professionals must prepare for the novel and non-traditional acquisition opportunities that growth in commercial and allied space capabilities will present.

augmentation is appropriate, and what functions will remain completely governmental. The most careful consideration should focus on ways to create incentives for DOD, the Air Force, and all other major US government space acquisition and operations entities to move as far as possible towards commercial systems. Since this approach would not be business as usual, this will result in less direct control and likely lower individual system capabilities, and may even be more expensive initially or require funding from non-traditional sources or budget categories.

Accelerating governmental efforts. A final approach favored by several respondents is to embrace space as a warfighting domain and take more traditional measures to ensure the success of military operations in space. Experts espousing this approach believe the United States is already in a space arms race, that this is a race the US cannot afford to lose, and that being prepared to prevail in a war that begins or extends to space is the best way to dissuade adversaries from further developing dedicated counterspace capabilities, and to deter them from using such capabilities. Other options include preferential defense of high-value assets, changing US approaches toward disposal or continuing use of satellites nearing end of life, and moving towards more resilient and distributed US government space capabilities. Many of these approaches would mirror commercial approaches discussed above,

except that the constellations would be owned and operated by the US government and it would again be important to find appropriate incentives to advance government, mixed, and commercial constellations and capabilities.

Some respondents emphasized that the DOD spending caps in the Budget Control Act have significantly reduced America's ability to respond to growing threats, and believe additional funding for space capabilities is an essential first step towards addressing adversary counterspace capabilities.

Selected Quotes on Countering Counterspace from Subject Matter Experts

"The United States should fully leverage our commercial space industry to provide a distributed, resilient capability to rapidly reconstitute small satellites enabling a persistent communications and data infrastructure for joint force operations... Rapid and flexible small satellite launch minimizes the vulnerability of our current space and land-based command and control assets by ensuring rapid reconstitution at a time and place advantageous to the United States."

"Keep pace in an arms race and have the ability to threaten tit-for-tat symmetrically."

"A vigorous research and development (R&D) program with a highly multi-nodal architecture is a necessity. It also would be useful to engage in more, not less, dialogue with Russia and China on these issues. We'll hardly convince them, but dialogue can be useful and provide an important communications channel if times get difficult."

"First, let the Chinese and Russians know that the United States has the means to know in detail what they are about, which necessitates development of new tracking means and close approach maneuver capability. If these developments do not deter Beijing and Moscow from pursuing their counterspace capabilities, the United States has no choice but also to develop its own means... In parallel, tripartite conversations ought to start on this matter. Informally first, then in a dedicated arena. I would not recommend the Conference on Disarmament (CD) which may lead to nowhere."

“[The] primary [US focus] must be [on creating] a philosophy of resilience—clear eyed assessments of what space capabilities are critical, what can be done decently well without exquisite systems and instead with smaller, less sophisticated systems or using commercial capabilities. It may not be that one can replicate exactly the capabilities that a large, expensive satellite constellation can provide, but if such systems provide too big a risk of loss, then the process that led to them being considered the solution might need to be retooled. Commercial satellites can increasingly take many important roles.”

“Clearly, missile defense is going to be an issue here, but I think that it would be very worthwhile for the United States to take a longer view at how useful strategic missile defenses are going to be ... and how their development negatively affects space security. Most theater missile defenses will create no issue for space security; most strategic missile defenses will, and smart limits on these will permit the security of all space assets to be better assured.”

“The most significant step the United States can take to deal with Chinese and Russian counterspace activities is to change its mindset from ‘space as sanctuary’ to ‘space as battlefield.’... However, for better or worse, current generation satellites tend to last a long time, and to meet rapidly evolving threats in a timely way, DOD leaders will have to summon the will to transition from current architectures to new ones before the end of the useful lifetimes of current satellites.”

“If our nation is to maintain its unique and asymmetric space enabled advantages—even as potential adversaries grow their capabilities and seek to put our assets at risk—increased investments in these vital mission areas must begin and continue for years to come.”

“More needs to be done to lower US classification barriers to ‘blaming and shaming.’ China, in particular, may be sensitive to publicity that makes it appear to be an aggressor in space, despite its rhetoric. This could be used to the advantage of the most transparent nations. Over time, it is likely that commercial or other non-governmental entities will bring greater transparency to the counterspace realm, whether governments like it or not.”

“One comment about the constellations of small satellites to be launched on short notice—this is a great idea but it can’t work on the tempo of the intelligence community. It will have to be controlled by the military and seen as [a] tactical capability (versus a strategic capability controlled by the [Intelligence Community]). Also command and control structures for Army and Navy users must be put into place to allow front line users to access this network without having everything being routed via headquarters.”

“We need to contextualize what the Russians and Chinese are doing in terms of how it compares to capabilities that we already use or also have. I’m not as convinced that they’re moving ahead so much as catching up. I understand that we need to have reliable and continued access to our space capabilities but striving to have 100 percent freedom of action in space is unrealistic in a democratized space domain.”

Relating Space Deterrence to Everything Else

Is deterrence indivisible or is space deterrence a useful analytical concept? Can space deterrence be strengthened? What is the role of anticipatory self-defense, or preemption, in space? How should Standing Rules of Engagement be considered or modified for space?

Background

Understanding how deterrence operates in other domains may provide insights into similarities and differences with respect to how deterrence may operate in space. The fortunate reality that there have been no overt kinetic attacks in space and certainly no war in space makes the study of space deterrence doubly difficult—since study focuses not just on why specific types of space attacks have not taken place, but also why no space attacks have ever happened. Challenges for strategists and policy-makers include considering the role of deterrence in keeping war from spreading to space as it has with every other domain humanity has encountered, how deterrence in space might be strengthened, and how the attributes of space

systems and operations may need to alter our approaches toward anticipatory self-defense and standing rules of engagement. None of these are simple or clearly defined issues with consensus on solutions.

Findings

Many experts consulted for this paper provided detailed responses on this issue, but it is difficult to identify clear and central themes from this group. The clearest delineation is between those who believe it is useful to examine space deterrence separately and those who do not see utility in drawing this distinction.

Not useful to separate space deterrence.

Several respondents believe there is not great utility in separating space deterrence from deterrence in other domains. Air Force Gen John

Hyten, commander of US Strategic Command, has publicly taken this position as well.²⁷ These analysts and officials believe that the complexities and specific situations involved in any deterrence calculus reduce the utility of looking at space deterrence in isolation. Aggressors look for any weaknesses in the United States' integrated military capabilities across all domains, and do not necessarily focus on just the space domain. If an aggressor becomes convinced there are weaknesses in US space posture, space attacks may look attractive, but these attacks would very likely

be in support of or in conjunction with attacks supporting terrestrial objectives.

It currently is very difficult to conceive of scenarios where objectives that are only in the space domain would be the drivers for deterrence failure. This deterrence calculus may change as the value of space capabilities grow, however, perhaps through space-based terrestrial strike capabilities or significant wealth extraction from space manufacturing or mining. Attacks against space capabilities may also look attractive if adversaries believe this will reduce overall US military effectiveness or make American intervention less likely. In addition, several analysts emphasized that since the United States has the most to

lose in a conflict confined to space, it would be counterproductive to consider space deterrence in isolation. Indeed, the United States has long held that deterrence is strengthened when it has more vertical and horizontal response options, maintained that attacks would not necessarily be met in kind, and emphasized that responses are not limited to a particular domain or set of options.

Useful to separate space deterrence. Other respondents believe that space deterrence is a useful concept in isolation, possesses unique technical and physical attributes such as space debris, and feel that it might be further subdivided to emphasize more tailored deterrence messages across domains in different scenarios. For example, space deterrence might be focused on a range of lesser deterrence goals including deterring attacks on nuclear command and control, civil and commercial satellites, or third-party space systems. Space capabilities could also contribute to deterring terrestrial aggression by holding aggressor satellites at risk, denying space-enabled capabilities that support terrestrial operations, or threatening to embargo, blockade, or deny use of all space capabilities. The challenge for both those who consider space deterrence separately and those who consider deterrence holistically remains how to strengthen deterrence.

Approaches for strengthening deterrence.

Some analysts believe that too much emphasis on developing military space capabilities and deterring their use is counterproductive. They advocate advancing US space leadership through civil agencies or commercial entities. Others favor use of the containment concept rather than deterrence, arguing that self-interest and naming and shaming can contain bad behavior in space. Most respondents emphasized the potential to strengthen deterrence through leveraging allied capabilities and large commercial constellations to support national security, developing responsive small satellite launch capabilities, and creating more agile and adaptive architectures. A few analysts emphasized that credible deterrence requires the United States not only to have but perhaps even to demonstrate selective, survivable, and effective offensive space control capabilities, and that it would be particularly useful if these

If an aggressor becomes convinced there are weaknesses in US space posture, space attacks may look attractive, but these attacks would very likely be in support of or in conjunction with attacks supporting terrestrial objectives.

were non-kinetic capabilities to avoid being self-deterred from use due to debris creation.

Respondents consulted for this paper disagreed about the value of clearly articulated and definitive redlines versus deliberate ambiguity in US declaratory policies, and standing rules of engagement (SROE). Those favoring definitive redlines emphasized their value in potentially deterring adversaries from crossing these lines, while those favoring deliberate ambiguity emphasized that adversaries would be likely to take actions just short of a redline—and this could be highly provocative. In both cases, high fidelity space situational awareness, improved communications and ability to signal to China and Russia more clearly, and enhanced

“Space deterrence borrows quite a bit from traditional deterrence theory. However, space deterrence is still useful as a separate concept, both for technical differences, such as the long-lasting nature of space debris, and the difficulty in responding to a hostile action despite the immediate severity of impact in the event of an attack...”

attribution capabilities are key to strengthening credibility and deterrence. Other respondents indicated that working with all major space actors, and perhaps even initially with the Chinese and Russians, on more clearly identifying what constitutes hostile intent in space and reaching more consensus on what self-defense options are acceptable could be among the most useful steps in refining SROE and strengthening space deterrence.

Wargaming can help to provide some of the best insights on how SROE may need to be refined, however, most respondents believe that the United States will allow enemies to take the first shots in space and this reinforces the need for resilient architectures able to withstand initial attacks. In this regard, identification, attribution, and deterrence of directed energy attacks presents one of the most difficult challenges.

Finally, several respondents emphasized that strengthening deterrence requires a significant effort to lower and declassify current space security classification levels in order to develop better informed constituencies, alert the public, and encourage civil society to observe when potentially hostile actions are undertaken.

Selected Quotes on Space Deterrence from Subject Matter Experts

“Deterrence can exist in the space domain, and it already exists in certain norms and rules against interference with National Technical Means (NTM), debris generation, and commercial jamming.”

“Space deterrence borrows quite a bit from traditional deterrence theory. However, space deterrence is still useful as a separate concept, both for technical differences, such as the long-lasting nature of space debris, and the difficulty in responding to a hostile action despite the immediate severity of impact in the event of an attack (‘satellites have no mothers’).”

“Actions in space can promote or enhance overall deterrence. The question is an academic one. Can space deterrence be strengthened? Yes.”

“In a conflict scenario, the United States will need to be prepared to defend systems from attacks in any domain, and recognize that attacks in space and cyberspace may precede attacks in other domains.”

“Deterrence works when you have a common understanding of the term and the game. The Chinese have a completely different idea of how escalation works and it, frankly, is scary. We need to sort out our basic definitions of these concepts and do so in a public manner so that the information is made available to potential adversaries.”

“We need to recognize that operations in space (especially robotic operations in space) are not perceived the same way as the same actions might be on the ground, on the sea, or in the air (space operations often garner much more attention and concern). Also, given the current state of world affairs, we should not assume that other countries would have the same understanding that we do of a particular action or response. Things have changed since the days of Mutually Assured Destruction.”

“Containment is a more apt approach to security in outer space than deterrence, and containment fits well with the current focus on resilience in outer space.”

“The United States should proactively prepare for the contested space environment by fully leveraging

the US commercial space launch and small satellite industries to deter aggression, enhance deterrence, and the responsible use of space.”

“Space deterrence can be strengthened by establishing new efforts in the national security and intelligence communities to implement responsive space launch and satellite programs. Responsively-launched small satellite constellations offer unprecedented capabilities and a new level of resilient deterrence against emerging threats.”

“Generally speaking, belligerents are unlikely to constrain their consideration of threats, costs, opportunities, incentives and options to any single domain.

- Belligerents generally have the option to extend threats and costs (horizontally) to any place they can threaten, and are emboldened to do so if it appears to be differentially costly to their adversary.*
- Since the United States has more to lose in space than any other adversary today, an adversary has a strong incentive to threaten the United States in space to deter US action from intervention in some terrestrial conflict (deterrence by punishment).*
- Since US space capabilities provide extremely significant force multipliers critical for the United States to prevail in an overseas intervention, an adversary has an obvious incentive to negate these capabilities and reduce the US ability to accomplish its objectives (deterrence by denial).*
- It would be irrational and irresponsible for an adversary of the United States not to pursue such an advantage unless there were commensurately greater costs for the individual authorizing or constraining activity in space.*
- Generally, the United States should realize that restraint is unlikely to be an efficacious strategy to secure its assets, and restraint is only likely to instead communicate ‘fear’ to an adversary, confirming that space is a ‘soft underbelly’ where the United States can be effectively threatened or attrited.”*

“Every ROE and tactic should be considered with attribution in mind; our adversaries are masters at fake news and propaganda spin, and we need to be in a place where we can show ironclad evidence of a safety problem that affects the sustainability of

space. The safety/sustainability card is the only one we can all agree on and it should be used to the maximum.”

“The United States should create an environment where adversaries do not have any incentive to attack because they do not believe they can create advantages. On SROE: it is very hard to contemplate but the United States probably must let the enemy take the first shots. DEW [directed energy weapons] are the most difficult problem—distribution, cross-domain resilience, and within domain resilience can contribute to countering DEW.”

“Under what conditions would the United States consider a preemptive military strike on a peer or near peer? I think the answer to that is very, very few. If we are already engaged in a military conflict, then we shouldn’t be concerned specifically with preempting an enemy’s space capabilities. An integrated set of capabilities and a concept of operations that can prevail may—or may not—entail attacking an enemy’s space assets before he attacks ours.”

Space Protection for Commercial and Foreign Entities

As threats increase, protection becomes more central to system planning. What should the US government do about protecting commercial and foreign systems on which it depends? Should the US government’s policy be to support indemnification of commercial satellites when they are damaged while supporting US national security? What types of protection (e.g., physical, electromagnetic, cyber) are best suited for commercial and foreign systems, and how should the costs for increased protection be paid?

Background

As the number, capabilities, and sophistication of commercial space services grows, their ability to augment and even replace government

owned and operated capabilities also expands. With the exploding number of commercial capabilities expected on orbit in the near term, now is the time for the United States to carefully consider how it can best leverage these capabilities and determine which space missions must remain with the government, which government space capabilities should be augmented by commercial capabilities, and which traditional government space mission areas might be performed completely by commercial services. A key aspect of these considerations is how the United States can best protect and ensure the availability of commercial and international space capabilities that support national security.

Findings

Near-term options. Almost all respondents strongly support maintaining current policies that encourage development of private space capability, expand government use of commercial space services, prevent direct competition between the government and private sectors, and allow access to US markets only for states that are open to US goods and services. They believe the United States should also work toward more focused and proactive measures to bolster commercial and international space capabilities that support national security. Key approaches include indemnification, public-private-international partnerships, and building

appropriate mechanisms to allow space applications to operate along the lines of Air Mobility Command's Civil Reserve Air Fleet (CRAF).²⁸

Early, clear, and public legal processes to indemnify all commercial and international space services and systems that support national security is essential to building resilient architectures with robust contributions from these sectors. Closely related issues include the extent of obligations for the US government to provide warning of attacks and what information to

share, with whom, when, and how. The executive and legislative branches should work together to clarify and strengthen the US government's indemnification obligations for domestic providers. As commercial and international space capabilities

grow and the lines between space sectors become more blurred, more work and creativity will also be needed to find ways to incentivize and indemnify public-private-international partnerships that support national security. A final near-term option is to adapt the CRAF model to incentivize and sustain commercial sector development of space capabilities and services most needed by the US government that industry might not otherwise include, such as satellite hardening or robust data encryption. Of course, since airlift and space capabilities are not directly analogous in several important aspects, careful analysis and creative thinking will be needed to adapt the most useful parts of the CRAF model as well as other standards for incentivizing and sustaining commercial and international space capability development. In the future, protection versus reconstitution for cost and capability should be an important consideration in the design of any system, and should be similar to today's government decisions to develop space capabilities or to buy space services.

Longer-term approaches. Several respondents believe that over the long run a "space guard" (like the US Coast Guard) is likely to become necessary for many reasons. They believe that US national strategic advantage is held in check because the preponderance of American space forces are within a service (the US Air Force) that sees space as primarily contributing to airpower's kinetic strike capability in a terrestrial fight. These respondents feel that the Air Force is not clearly engaged in the conversation about the vast future potential of space industrialization and neither is NASA, which is focused on novel science and human spaceflight for global prestige, and not on national economic advantage, space industrialization, and space development. Respondents advocate that the United States should today take the steps necessary to move space from a support function for terrestrial combat to a space guard, where day-to-day safety of navigation, constabulary authorities, and services enable mission growth along the lines detailed above. While space could end up being heavily weaponized, it is unclear that this outcome would be a competitive advantage for the United States. A US Coast Guard-like model offers the clearest method for the types of mission growth that will

Early, clear, and public legal processes to indemnify all commercial and international space services and systems that support national security is essential to building resilient architectures with robust contributions...

Conclusion

In a little more than a half century, humanity's space operations have gone through, and continue to experience, multiple transitions:

- The Space Age began with a competition between two global superpowers, and the development of space was driven by government investment. But even before the end of the Cold War the number and diversity of actors began to grow and now consists of a wide array of national and subnational organizations. Some have called this the “democratization” of space. Business investment is now the driver of most space applications.
- Early perceptions of the vastness of orbital space did not prompt concerns about congestion or debris. More recently, these factors have been identified as hazards and limitations that must be taken into consideration for missions of all types.
- National security space efforts were initiated primarily to support strategic decision-making through intelligence gathering, early warning, and targeting of deterrent forces. In the 1980s, space systems started serving tactical-level warfighters more directly with communications, navigation, and remote sensing. Today, senior US officials repeatedly tell us that while space continues to provide support functions for terrestrial activities it has also become a warfighting domain in its own right.
- Plans for private space stations, space tourism, on-orbit manufacturing and servicing, and harvesting of lunar and asteroid materials were long considered to be so far in the future that there was no practical reason to talk about them. Today, we are working to establish mechanisms to track these activities, ensure their safe operation, and integrate them with existing laws and regulations—and we are concerned that non-traditional business plans may become operational before these mechanisms can be put in place.
- The United States government is in the process of handing off routine human access to orbit to the private sector—the first country to do so, but probably not the last.

Observers of the Space Age who believe we should already have a base on the Moon, an outpost

be required to maintain the United States as the leading space power: real time space situational awareness, space traffic management, active debris removal, space infrastructure development (similar to the terrestrial work done by the Army Corps of Engineers), and planetary defense. These missions simultaneously create an infrastructure advantage for markets and space industrialization, and they would help ensure the United States would enjoy an industrial and information advantage (and cost advantage) should America ever choose to (or be forced) to weaponize space.

Selected Quotes on Space Protection from Subject Matter Experts

“The US government either needs to protect those systems, or it needs to develop an architecture that does not require all of those systems. There is no free lunch, although there can certainly be mutually beneficial arrangements.”

“All commercial and/or foreign entities that support national security ought to be protected like ships at sea. Indemnification and early, proactive involvement with commercial actors is key. The US government should emphasize anti-jam and cyber protection (not kinetic defense) with the commercial sector. We should also reconstitute the Mission Assurance Working Group (MAWG) and explore CRAF-model opportunities with the US government paying up front and service costs.”

“Protection is probably unlikely to be as cheap as resilience, and it also comes with externalities and costs. Still, there may be a limited number of very high-value satellites where this makes sense, but probably not many.”

“Cyber protection should not even be a question; commercial systems already resist far more cyber attacks than government systems, and maybe the US government can learn something from Intelsat and others.”

“Some ideas such as ‘fighter escorts’ can have direct applicability provided they have adequate mobility to protect sectors and not just individual space objects.”

The United States government is in the process of handing off routine human access to orbit to the private sector—the first country to do so, but probably not the last.

on Mars, and large numbers of people living and working in space may feel that development in this area has been sluggish. However, the list above indicates that the pace of evolution is brisk and does not seem to be slowing down. In such an environment, decision-makers should be hungry for expert input in this highly technical and potentially very rewarding area.

The authors recognize that the experts consulted for this paper do not constitute a scientifically selected, statistically significant random sample from the community of space policy professionals. Nonetheless, the group includes a wealth of experience and a diversity of opinions sufficient to convey important insights and lessons on the range of questions they were asked to address.

There are differences of opinion among the participants regarding specific approaches to the implementation of solutions (for example, whether tracking aids should be mandatory on all smallsats). However, important areas of consensus emerged on the best ways to address the changing strategic space environment. Based on this consensus, the following summarizes the majority of our respondents' message to decision-makers, which we hope will aid efforts to shape the future of the US space enterprise:

Lead by example. Important components of US space leadership are: sharing knowledge and experience regarding best practices for the safety and sustainability of space operations, and better US compliance with practices the United States helped to establish, such as orbital debris mitigation. This will sometimes entail difficult tradeoffs, but the economic and mission costs of compliance should be weighed against the potential leadership impacts of non-compliance, not just the direct consequences. Additionally, the United States should craft its own path and should not be content to be reactive to the technical evolution, programmatic developments, or perceived intentions of other countries.

Establish clear roles and missions where feasible, and blend responsibilities where desirable. The US government needs to decide which space

mission areas are inherently governmental, which can be augmented by commercial and international involvement, and which can be completely handed over to the commercial and international sectors. This is a dynamic environment in which the capabilities and resources of the different sectors continuously evolve, but the US government can take advantage of this environment by developing specific approaches that incentivize and leverage commercial and international actors in ways that serve the national interest.

Embrace emerging technologies and services—don't obstruct them. New space applications that go beyond communications, remote sensing, and navigation should be encouraged and facilitated so US entities can be competitive or even dominant in the world market. Potentially threatening developments like rendezvous and proximity operations (RPO) and non-Earth imaging (NEI) are going to proliferate, so the US government should learn to live with them and maximize their benefits. Maintaining artificial roadblocks that non-US competitors will not have to face will not prevent these developments from occurring, but they will put the US space industrial base at a disadvantage.

Reduced classification of space operations could help international and cross-sector collaboration. Expansion in the number and diversity of space operators worldwide may force this issue as activities formerly treated as sensitive become openly displayed and discussed.

Reform of international agreements should be approached with caution and patience. Decades-old treaties may not have all the answers for today's and tomorrow's space operations, and they may not have strong enforcement mechanisms, but they are still useful and may be the best thing we are likely to have for the foreseeable future. Replacing or altering them may not be in the best interest of the United States if important provisions or understandings are lost.

The US should continue its policy of requiring US government payloads to use US launch vehicles. But as in any protected market, domestic providers should not be allowed to become complacent, and a monopoly relationship between the government and a single provider should not be allowed. ★

Decades-old treaties may not have all the answers for today's and tomorrow's space operations, and they may not have strong enforcement mechanisms, but they are still useful and may be the best thing we are likely to have for the foreseeable future.

Endnotes

- 1 Authors' note: US Strategic Command catalogue data is available, free of charge, to all satellite owners, operators, and other interested parties worldwide at <http://www.space-track.org> (accessed November 27, 2017).
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- 8 Authors' note: The US Department of Commerce has used a 50-percent rule for determining what constitutes a US launcher. However, this is used only for decisions on case-by-case advocacy of international business deals. It is very flexible, measured by components, dollar value, or other means to shape the decision in the way that brings the most benefit to the United States.
- 9 SpaceWorks Enterprises Inc., *2017 Nano/Microsatellite Market Forecast*, January 2017, Atlanta, GA, http://spaceworksforecast.com/docs/SpaceWorks_Nano_Microsatellite_Market_Forecast_2017.pdf (accessed November 14, 2017).
- 10 Interagency Space Debris Coordination Committee, *US Government Orbital Debris Mitigation Standard Practices*, December 2000, http://www.iadc-online.org/References/Docu/USG_OD_Standard_Practices.pdf (accessed November 15, 2017).
- 11 Authors' note: In 2011, Canada's MacDonald Dettwiler & Associates (MDA) proposed a satellite refueling demonstration as early as 2015 with Intelsat as its anchor customer (see Peter B. deSelding, "Intelsat Signs Up for Satellite Refueling Service," *Space News*, March 14, 2011). However, the project stalled, illustrating the challenge of initiating this service (Jeff Foust, "Satellite Servicing Efforts Grapple with the Business Case," *Space News*, April 15, 2013, <http://www.spacenews.com/article/satellite-telecom/34747satellite-servicing-efforts-grapple-with-the-business-case>, 17). This effort has been revived with the announcement that its first customer would be communications satellite operator SES (MDA Holdings Inc., "MDA Announces On Orbit Satellite Servicing Business Formation and Contract Awards for Spacecraft and First Life Extension Customer," news release, June 28, 2017, <http://mdacorporation.com/news/pr/2017062803.html>).
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