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International Perspectives on Space Weapons

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CSIS | CENTER FOR STRATEGIC & INTERNATIONAL STUDIES

A Report of the
CSIS AEROSPACE SECURITY PROJECT

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Executive Summary

Little consensus exists in the international community on what constitutes a space weapon or the weaponization of space. This paper uses a broad framework for what may be considered a space weapon, organized by the domains in which they originate and have effects (Earth-to-space, space-to-space, and space-to-Earth) as well as the physical means by which these effects are achieved (kinetic and non-kinetic). While there are many other ways to categorize and subdivide the broad range of possible space weapons, the six resulting categories in this framework prove useful for highlighting differences in definitions, how countries view space weapons, and the current state of space weaponization. Of the six categories, three categories of space weapons have been demonstrated by nations either through testing, deployment, or operational use (Earth-to-space kinetic, Earth-to-space non-kinetic, and space-to-space kinetic). This means that by many definitions space has already been weaponized.

No international agreements exist today that completely limit space weapons within any of the six categories of the framework. However, some agreements limit certain types of space weapons that are subsets within the categories listed above. The Partial Test Ban Treaty and Outer Space Treaty are the major widely accepted international agreements that limit space weapons activity and testing. The Partial Test Ban Treaty of 1963 prohibits the testing and use of nuclear warheads on Earth-to-space and space-to-space kinetic weapons. It does not, however, affect the development, testing, deployment, or use of non-nuclear space weapons. Similarly, the Outer Space Treaty of 1967 prohibits nuclear-armed space-to-space and space-to-Earth kinetic weapons. It also prohibits all forms of space-to-space weapons from being tested and used in military maneuvers on other celestial bodies. However, the Outer Space Treaty does not prohibit conventionally armed space-to-space weapons in Earth orbit, in deep space, or in orbit around other celestial bodies nor does it prohibit conventionally armed space-to-Earth weapons. Moreover, it does not prohibit any Earth-to-space weapons.

Further insight into what other nations consider to be space weapons can be gleaned from the ongoing debate over the Russian and Chinese proposed treaty entitled "Prevention of the Placement of Weapons in Outer Space, the Threat or Use of Force against Outer Space Objects," otherwise known as the PPWT. China and Russia jointly submitted their draft PPWT proposal at the United Nations in 2008. The proposed treaty defined space weapons somewhat narrowly to only apply to space-to-space and space-to-Earth weapons, both kinetic and non-kinetic. It would not prohibit Earth-to-space kinetic weapons or Earth-to-space non-kinetic forms of attack, which China and Russia both possess.

In December 2008, the Council of the European Union approved its draft Code of Conduct for outer space activities. Among its many provisions, it called for states to "refrain from intentional destruction of any on-orbit space object," which would limit Earth-to-space and space-to-space kinetic weapons. By focusing on a narrow set of potential space weapons that have the potential to produce space debris, the Code of Conduct was fairly limited in scope. In 2014, the European Union published a fifth revision of the Code of Conduct that altered the limitation on Earth-to-space and space-to-space kinetic weapons to include an exception for when the destruction of a space object may be justified. The allowable justifications are for safety (particularly if human life is involved), the prevention of new space debris, and self-defense.

Russia and China also issued an updated draft of the PPWT in 2014 that altered the defined terms in the treaty in several ways. It modified the proposed definition of a space weapon to apply to any outer space object and included additional clarification on the protection of a state's right of self-defense to include the right of collective self-defense, which hues more closely to the wording in the EU Code of Conduct.

Ultimately, both the EU Code of Conduct and the PPWT failed to gain consensus. However, in December 2015, the UN General Assembly passed a resolution that urged the commencement of negotiations on the Chinese-Russian PPWT and encouraged states to uphold a "political commitment not to be the first to place weapons in outer space." The resolution specifically cited Argentina, Armenia, Belarus, Brazil, Cuba, Indonesia, Kazakhstan, Kyrgyzstan, Russia, Sri Lanka, Tajikistan, and Venezuela as having already stated that they would not be the first to place weapons in outer space. Moreover, Russia and Venezuela issued a joint statement to the UN Conference on Disarmament saying that they "will not be the first to deploy any type of weapon in outer space and will do their utmost to prevent outer space from being turned into a theatre for military confrontation and to ensure security in outer space activities." Such statements imply that these nations believe weapons have not already been placed in space. Given the different types of space weapons that have already been tested or demonstrated, these statements may simply be duplicitous or may indicate that these nations have a narrower view of what a space weapon is.

Current activities and statements by foreign governments and non-governmental organizations also shed light on how views on space weapons are evolving. Two non-governmental groups are currently developing reports on the military uses of space and what constitutes an act of war or aggression in space. McGill University's Center for Research in Air and Space Law initiated a project to develop a Manual on International Law Applicable to Military Uses of Outer Space, known as MILAMOS, with the objective to create a manual that "clarifies the fundamental rules applicable to military uses of outer space by both States and non-State actors in times of peace and in periods of rising tensions." Work is also underway on a similar project known as Woomera, which is a collaboration among four universities: the University of Adelaide in Australia, the University of Exeter in the United Kingdom, the University of Nebraska College of Law in the United States, and the University of New South Wales in Australia. Like MILAMOS, Woomera aims to create a manual that summarizes how existing international law applies to military uses of space.

France has become one of the most vocal nations on the need to develop better defenses in space. In 2019, it issued a new Space Defense Strategy that calls for the creation of a Space Command under its Air Force and renaming the Air Force to be the Air and Space Force. In some of the most direct and specific language by a government official from any nation on the need for active defenses in space, the French defense minister publicly stated that France intends to develop bodyguard satellites and high-powered lasers on satellites to protect French space assets from attack.

Japan has also taken a more proactive approach to space defense, largely driven by threats it perceives from China's space activities. In its 2019 defense white paper, the Japanese Ministry of Defense discusses various means of improving space control, such as bolstering its space situational awareness capabilities and passive defenses. Japan is also creating a Space Domain Mission Unit within the Air Self-Defense Force. An unnamed senior ministry of defense official was quoted in the press saying that Japan was deciding on whether or not to develop a co-orbital anti-satellite (ASAT) system using robotic arms, electronic attack, or cyberattack. According to the article, the Abe government has concluded that such a co-orbital ASAT system would be within the principals enshrined in Japan's 2008 Aerospace Basic Law.

In 2019, India became the fourth nation to demonstrate an Earth-to-space kinetic ASAT weapon. In a public address following the test, Indian prime minister Narendra Modi reiterated that India remains opposed to the weaponization of space. This statement would appear to indicate that India does not believe the capability it demonstrated—an Earth-to-space kinetic ASAT—is a space weapon or represents the weaponization of space.

The Republic of Korea (ROK) issued a new defense white paper in 2018 that, among other topics, addresses space security issues. The white paper notes that the ROK established a new space organization within the Ministry of National Defense and that it is actively working to increase its cooperation with allies in space, namely the United States. In 2015, the Korean Air Force stood up a Space Intelligence Center to develop its space control capabilities. The Korean and U.S. militaries have also conducted joint tabletop exercises that included the use of adversary jamming of satellite navigation and communications.

This analysis finds that the way other nations view space weapons hinges on several key distinctions. The first distinction is between nuclear and conventional space weapons. An international taboo against the placement and use of nuclear weapons in space endures through treaties that have garnered widespread support, but no such consensus exists for conventionally armed space weapons. A second distinction is whether the weapon is stationed on Earth or in space. The Chinese and Russian PPWT proposal would only prohibit weapons that are stationed in space, while the European Union's proposed Code of Conduct would limit weapons stationed on Earth and in space. A third distinction is whether the weapon produces orbital debris. Much of the focus of the Code of Conduct and the stated motivation of many non-aligned states is on the prevention of orbital debris and the preservation of the space environment for peaceful uses. A final, and more recent, distinction in how nations view space weapons is whether the weapons are used for self-defense rather than for offensive purposes. The latest version of both the PPWT and Code of Conduct include exceptions for self-defense, and the Code of Conduct is more specific in delineating when the use of space weapons in self-defense is legitimate.

Competing definitions for key terms have proven to be a particularly difficult issue to overcome. Nations use phrases such as space weapons, the militarization of space, and the weaponization of space to mean different things at different times, often to suit their own geopolitical agendas. A common framework for discussing space weapons could be useful to establish and clarify thresholds among likeminded nations for what constitutes conflict and escalation in space.

Efforts to place limits on the development of space weapons, create a code of conduct, or even establish norms of behavior in space have so far failed to gain consensus among the key nations needed for such an agreement to be effective, namely the United States, Russia, China, India, and the European Union. While discussions continue at the United Nations about preventing an arms race in space, the actions of some nations—namely Russia and China—are leading others to prepare for conflict.

Introduction

The past three decades have given rise to gradual but sweeping changes in the way the space domain is viewed and used by militaries around the world. From the launch of Sputnik in 1957 through the 1980s, the United States and Soviet Union primarily used military space systems to support strategic missions, such as missile warning, strategic intelligence, and nuclear command and control. The use of space systems to support conventional military operations was less of a priority by comparison. Beginning in the 1990s, however, the First Gulf War and the conflicts in Bosnia and Kosovo revealed the many ways space systems can serve as an enabler and force multiplier for conventional military operations. By the late-1990s, space systems had quickly become a critical enabler for military forces across the full spectrum of conflict. A 1997 United States Space Command publication stated that, "so important are space systems to military operations that it is unrealistic to imagine that they will never become targets. Just as land dominance, sea control, and air superiority have become critical elements of current military strategy, space superiority is emerging as an essential element of battlefield success and future warfare."[1]

Other nations took note of how important space had become to the U.S. military for conventional operations. They began to build similar capabilities for their own forces and to develop counterspace weapons to negate the U.S. advantage in space. In 2004, the Air Force produced its first doctrine publication on counterspace operations to provide "operational guidance in the use of air and space power to ensure space superiority."[2] Importantly, this document defined space superiority as the ability to ensure "the freedom to operate in the space medium while denying the same to an adversary."[3] In the years since the publication of this doctrine, senior military and civilian leaders in the United States have become more comfortable publicly referring to space as a "warfighting domain" and often cite the need for "American dominance in space."[4]

This shift—particularly in the way the nations talks about the space domain—has led some to become concerned that space will become weaponized or that

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1 United States Space Command, *Vision for 2020* (Peterson AFB, CO: February 1997), 6, https://thecommunity.com/vision-for-2020/.

2 John P. Jumper's foreword in Office of the Secretary of the Air Force, *Counterspace Operations* (Washington, DC: August 2, 2004), https://fas.org/irp/doddir/usaf/afdd2_2-1.pdf.

3 Ibid.

4 "Remarks by President Trump at a Meeting with the National Space Council and Signing of Space Policy Directive-3," Executive Office of the President, June 18, 2018, https://www.whitehouse.gov/briefings-statements/remarks-president-trump-meeting-national-space-council-signing-space-policy-directive-3/.

an arms race will begin in space. While debates over whether space will or should be weaponized continue to simmer, much of the language underlying this debate remains murky. What is a space weapon, and what does it mean to weaponize space? The answers depend in no small part on one's perspective, and the rhetoric used by different nations on this subject indicates they have significantly different understandings of what constitutes a space weapon and the types of systems and activities they believe are legitimate uses of space.

This paper explores the views of other nations in this debate and how they define space weapons and the weaponization of space. It also reviews major international efforts to prevent the weaponization of space and how these efforts have implicitly and explicitly defined space weapons. The United States, China, and Russia are among the main space powers involved in this debate, and much about their views is well known. This analysis therefore focuses relatively more on the views of other nations and their reactions to the rhetoric, policies, and actions of the United States, China, and Russia.

Defining Space Warfare and Space Weapons

If weapons are instruments of war, then defining what constitutes war in space can help elucidate what is or is not a space weapon. Clausewitz defined war as an "act of violence intended to compel our opponent to fulfill our will." He went on to further refine his definition of war, writing that "violence, that is to say, physical force . . . is therefore the *means*; the compulsory submission of the enemy to our will is the ultimate *object*. In order to obtain this object fully, the enemy must be disarmed, and disarmament becomes therefore the immediate object of hostilities in theory."[5] Thus, the act of making war includes actions intended to disarm one's opponent and to limit its ability to fight. While Clausewitz did not contemplate war extending into outer space, there is little reason to believe that the object of a war that begins or extends into space would be fundamentally different than terrestrial warfare.

Space has been used to support military planning and operations on Earth since the beginning of the space age, even before human spaceflight. Early military space missions used space systems for intelligence, surveillance, and reconnaissance (ISR); communications; position, navigation, and timing (PNT); and other functions to allow terrestrial forces to operate more effectively. These passive uses of space to support military forces are often referred to as the militarization of space, and there is little disagreement that space systems have and will continue to be used for military purposes.[6]

There is little reason to believe that the object of a war that begins or extends into space would be fundamentally different than terrestrial warfare.

The weaponization of space, however, is generally viewed as going beyond mere passive support to military forces on Earth. As Joan Johnson-Freese defines it in her book, *Space as a Strategic Asset*, "force application is the overt weaponization of space, as compared with the de facto weaponization that has occurred under the guise of space control."[7] Air Force doctrine previously defined space force application as "those forces that deliver kinetic effects to, from, or through space."[8] However, the most recent update to joint space operations doctrine in 2018 does not use this terminology and explicitly calls for

5 Carl Von Clausewitz, *On War*, 3rd ed., vol. 1 (New York: Dutton and Co., 1918), 2, http://oll-resources.s3.amazonaws.com/titles/2050/Clausewitz_1380.01_Bk.pdf.

6 United Nations Institute for Disarmament Research (UNIDR), *Prevention of an Arms Race in Outer Space: Guide to the Discussions in the Conference on Disarmament* (Geneva: United Nations, 1991), 14, https://www.unidir.org/files/publications/pdfs/prevention-of-an-arms-race-in-outer-space-a-guide-to-the-discussions-in-the-cd-en-451.pdf.

7 Joan Johnson-Freese, *Space as a Strategic Asset* (New York: Columbia University Press, 2007), 106.

8 Office of the Secretary of the Air Force, *Counterspace Operations*, 32.

its “removal from the DoD dictionary.”[9] The 2018 joint doctrine defines space control as both offensive and defensive operations “to ensure freedom of action in space for the US and its allies and, when directed, to deny an adversary freedom of action in space.”[10]

A 1991 United Nations report on space security adroitly noted that, “the adoption of common definitions must take account of complex technical, legal, and doctrinal meanings of words, phrases, terms, and weapon systems, as well as military and military-related space activities.”[11] The UN report notes that “the term weaponization of outer space has been used to include space-based weapons consisting of space/Earth-strike devices. For some delegations, however, weaponization of outer space also covers ground-based weapons consisting of space-strike devices.”[12]

A wide variety of nations have attempted to define what a space weapon is and is not. For example, in 1982 the Italian delegation to the United Nations Conference on Disarmament raised a number of key questions for defining anti-satellite (ASAT) weapons, such as whether non-kinetic means of interfering with a satellite (such as radio frequency jamming or lasing) should be considered ASAT activities. The Conference on Disarmament established an ad hoc committee to explore these issues in 1985. The following year the Venezuelan delegation proposed a definition for “space strike weapons” that included both offensive and defensive systems launched from the ground, air, sea, or space. However, it limited its initial definition to only include weapons that targeted an object in space. In 1988, Venezuela tabled a more comprehensive proposal that defined space weapons to also include systems capable of attacking targets on the land, air, and sea from space. It specifically included all types of weapons “whatever the scientific principle on which its functioning is based,” which includes both kinetic and non-kinetic forms of attack. Germany weighed into the definition debate in 1989, but the German proposal focused on kinetic forms of ASAT weapons from Earth and space-based platforms.[13]

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9 Joint Chiefs of Staff, *Joint Publication: Space Operations* (Washington, DC: April 2018), https://www.jcs.mil/Portals/36/Documents/Doctrine/pubs/jp3_14.pdf.

10 Ibid., 1-3.

11 UNIDR, *Prevention of an Arms Race in Outer Space*, 9.

12 Ibid., 14.

13 Ibid., 15-19.

Framework for Evaluating Space Weapons

While there is no universally agreed upon definition for what constitutes a space weapon, it is useful to begin by establishing a broad framework (with some boundaries) for what could potentially be considered a space weapon and then evaluating how different definitions fit into this framework. Using a broad view of space weapons, something could be considered a space weapon if it either originates in space or has effects in space. Weapons that originate on Earth and have effects on Earth are generally not considered space weapons even if they transit through space, such as intercontinental ballistic missiles.[14] Space systems that are merely used for passive support to other forces, such as communications, PNT, or intelligence collection, are also generally not considered to be space weapons. A space weapon is used to apply force directly against an adversary (force application) or to directly interfere with an adversary's ability to conduct military operations in, through, or enabled by space (space control).[15]

The proposed framework, shown in Table 1, categorizes potential space weapons by the domains in which they originate and have effects (Earth-to-space, space-to-space, and space-to-Earth) as well as the physical means by which these effects are achieved (kinetic and non-kinetic).[16] Of the six categories, three categories of space weapons have been demonstrated by nations either through testing, deployment, or operational use (Earth-to-space kinetic, Earth-to-space non-kinetic, and space-to-space kinetic).

While there are many other ways to categorize and subdivide the broad range of possible space weapons, the six resulting categories in this framework prove useful for highlighting differences in definitions, how countries view space weapons, and the current state of space weaponization. For example, within each category, the effects created can be permanent or temporary, depending on the means of attack. Another important subcategorization within kinetic attacks is between conventional and nuclear. This framework illustrates that unless one takes a rather narrow definition of space weapons that excludes space-to-space kinetic forms of attack, space has already been weaponized.

Earth-to-space weapons include direct-ascent ASAT missiles (kinetic), uplink satellite jamming (non-kinetic), directed energy ASAT weapons (non-kinetic), and cyberattacks against satellites (non-kinetic). The United States, China, Russia, and India have all demonstrated direct-ascent ASAT

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14 Ibid., 14.

15 While it is true that any satellite could theoretically be used as a crude weapon to collide with another satellite, it is also true that any hard object could be used as a weapon to strike another person. This line of logic leads to the trivial conclusion that everything is a weapon regardless of intent or use. This analysis looks instead at how objects are used or are intended to be used.

16 For the purposes of this analysis, Earth is defined as anything below 100 km altitude and space is anything 100 km and above, including the moon and other celestial bodies.

Table 1: Framework for Types of Space Weapons

	Kinetic	Non-Kinetic
Earth-to-Space	**Example** Direct-ascent ASAT **How do they work?** A missile fires a warhead or projectile into space to directly strike or detonate near a target satellite. The warhead can be conventional or nuclear. **What are the effects?** A kinetic Earth-to-space weapon produces space debris that can affect the safe operation of other satellites in affected orbits. Nuclear detonations in space increase the radiation exposure of other satellites and can significantly shorten their lifespan. **Have they been demonstrated?** Earth-to-space kinetic weapons have been tested by the United States, Russia, China, and India. The United States and Soviet Union tested nuclear weapons in space in the 1960s.	**Examples** Uplink Jammer, Laser Dazzler/Blinder, Cyberattack **How do they work?** Non-kinetic counterspace weapons can be stationed on ground, maritime, or airborne platforms and used to affect the operation of satellites or the sensors they carry, without making physical contact. **What are the effects?** Non-kinetic weapons disrupt or degrade the ability of satellites to function properly. They can have temporary or permanent effects, but they do not generally produce orbital debris or other collateral damage. **Have they been demonstrated?** Multiple nations have demonstrated these capabilities, including Russia, China, Iran, and others.
Space-to-Space	**Examples** Co-orbital ASAT, Space-based Missile Defense Interceptors **How do they work?** A satellite is placed into orbit and maneuvers to intercept its target by striking it directly or detonating a conventional or nuclear warhead in its vicinity. **What are their effects?** A kinetic space-to-space weapon would produce space debris that can affect the safe operation of other satellites in similar orbits. A nuclear detonation in space would increase the radiation exposure of other satellites and significantly shorten their lifespan. **Have they been demonstrated?** The Soviet Union tested co-orbital kinetic ASAT weapons repeatedly during the Cold War.	**Examples** Co-orbital Crosslink Jammer, Co-orbital High-powered Microwave **How do they work?** A satellite is placed into orbit and uses non-kinetic means (such as a high-powered microwave or jammer) to disrupt the operation of another satellite. **What are their effects?** They can degrade, disrupt, or destroy a target satellite without making physical contact, producing orbital debris or otherwise affecting other satellites. The effects can be temporary or permanent depending on the form of attack used and the protections on the target satellite. **Have they been demonstrated?** No open-source examples could be found of such a system being demonstrated, although such tests could look like remote proximity operations to outside observers.
Space-to-Earth	**Examples** Space-based Global Strike (e.g., "Rods from God") **How do they work?** Weapons are placed in orbit and, when commanded, deorbit and reenter the atmosphere to strike a target on the Earth. Damage can be inflicted using the kinetic energy of the weapon itself, or a warhead can be deployed from the reentry vehicle (either conventional or nuclear). **What are their effects?** The effects depend greatly on the type of warhead used (conventional or nuclear) but would be like terrestrial-based ballistic missiles in terms of their ability to hit targets anywhere on Earth with little warning. **Have they been demonstrated?** While the idea of using space-based weapons for prompt global strike has been contemplated by the U.S. military, there are no open-source examples of such a system being tested.	**Examples** Space-based Downlink Jammer, Space-based High-powered Laser **How do they work?** A satellite equipped with a non-kinetic weapon could target forces on Earth, such as a laser used to intercept missiles or aircraft in-flight or a jammer used to interfere with radars or satellite ground stations. **What are their effects?** When used, the effects would be localized to the target area, but such a system could theoretically strike anywhere without warning. **Have they been demonstrated?** While the U.S. military has contemplated space-based lasers for boost-phase missile defense, there are no open-source examples of such a system being tested.

capabilities.[17] Missile defense systems can also double as direct-ascent ASAT weapons against satellites in low Earth orbit (LEO), as the United States demonstrated in 2008 with its use of an SM-3 missile interceptor to strike its own malfunctioning satellite.[18] Uplink jamming of satellite communications signals, which interferes with the signal received on the satellite, is a more commonly available means of attacking space systems. Iran, Libya, and Egypt, for example, have each been accused of using uplink jammers to interfere with satellites.[19] Directed energy weapons, such as lasers designed to dazzle or blind the sensors on satellites, can also be used to attack satellites in space from Earth. China has demonstrated the ability to dazzle a satellite with a laser from Earth, and Russia is reportedly developing new land and airborne lasing systems to replace its older *Sokol Eshelon* airborne lasing aircraft.[20]

Unless one takes a rather narrow definition of space weapons that excludes space-to-space kinetic forms of attack, space has already been weaponized.

Space-to-space methods of attack include a broad range of kinetic and non-kinetic co-orbital ASAT weapons and space-based missile defense systems. A kinetic co-orbital ASAT can be used to crash into another satellite or to detonate a conventional or nuclear explosive near another satellite. During the Cold War, Russia conducted some 20 tests of its *Istrebitel Sputnikov* co-orbital ASAT system, and since then it has continued to develop and test kinetic co-orbital ASAT weapons.[21] A non-kinetic co-orbital ASAT weapon could use jamming to interfere with satellite-to-satellite communications links or a high-power microwave weapon to damage electrical components on other satellites. Non-kinetic space-to-space weapons could be difficult to detect because their use may not be readily observable from Earth, and on-orbit tests against one's own satellites could look like remote proximity operations to outside observers. Space-based missile defense systems, while not intended to target other satellites, would also have an inherent space-to-space capability. For decades the United States has studied and debated developing a constellation of space-based kinetic interceptors and space-based high-powered lasers capable of intercepting missiles in flight, although nothing has been deployed or demonstrated to date.[22]

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17 Todd Harrison, Kaitlyn Johnson, and Thomas Roberts, *Space Threat Assessment 2019* (Washington, DC: CSIS, April 2019), 3, 11-12, 19-20, https://www.csis.org/analysis/space-threat-assessment-2019.

18 Staff Reporters, "Navy Hits Satellite with Heat-Seeking Missile," Space.com, February 21, 2008, https://www.space.com/5006-navy-hits-satellite-heat-seeking-missile.html.

19 Harrison, Johnson, and Roberts, *Space Threat Assessment 2019*, 28-29, 35, 39.

20 Andrea Shalal-Esa, "China Jamming Test Sparks U.S. Satellite Concerns," Reuters, October 5, 2006, as quoted in Yousaf Butt, "Effects of Chinese Laser Ranging on Imaging Satellites," *Science & Global Security* 17, no. 1 (2009): 20-35; Pavel Podvig, "Russia Has Been Testing Laser ASAT," Russian Strategic Nuclear Forces, October 8, 2011, http://russianforces.org/blog/2011/10/russia_has_been_testing_laser.shtml.

21 Asif A. Siddiqi, "The Soviet Co-Orbital Anti-Satellite System: A Synopsis," *Journal of the British Interplanetary Society* 50, no. 6 (1997): 225–40, http://faculty.fordham.edu/siddiqi/writings/p7_siddiqi_jbis_is_history_1997.pdf.

22 See: Bob Preston et al., *Space Weapons Earth Wars* (Santa Monica, CA: RAND, 2002), https://www.rand.org/pubs/monograph_reports/MR1209.html.

Space-to-Earth weapons can be used to hold targets at risk across broad areas of the Earth. Kinetic space-to-Earth weapons can be armed with conventional or nuclear warheads, or they can use sheer kinetic energy to destroy targets. For example, the so-called "Rods from God" concept called for a constellation of satellites armed with tungsten rods that would deorbit and strike targets on Earth with explosive force, although no such system was ever developed or tested.[23] Non-kinetic space-to-Earth weapons include space-based jammers that could disrupt the downlink signals from satellites over large regions and space-based high-powered lasers that could target objects in the air or on the surface, although the technology required for this remains challenging.

Four of the six categories listed above involve weapons designed to attack satellites—commonly referred to as counterspace weapons. Not all counterspace weapons, however, are included in this framework. Weapons that are based on Earth and have effects on Earth are not considered space weapons under this framework, even if they may affect the ability to use space systems. An example of this would be a cruise missile or cyberattack against a satellite ground station. The attack originates on Earth and has effects on Earth, which means it would not be considered a space weapon under this framework, even though it would be a counterspace weapon.

Existing International Agreements

Existing international agreements that limit different types of space activities provide insight into other nations' perspectives on space weapons and which activities and capabilities they want to restrict. No agreements exist today that completely limit space weapons within any of the six categories of the framework. However, some agreements limit certain types of space weapons that are subsets within the categories listed above.

One of the first international agreements to limit activities in space was the Partial Test Ban Treaty of 1963. The treaty came about in part because both the United States and Soviet Union were testing nuclear weapons in space and, in the process, discovering the grave effects these weapons had on the overall space environment. In 1961 and 1962, the Soviet Union conducted a series of high-altitude nuclear tests with relatively low-yield warheads (1.2 to 40 kilotons), which prompted the United States to begin a high-altitude test program of its own. On July 9, 1962, the United States detonated a massive 1,400-kiloton warhead at an altitude of 400 km over the Pacific in a test known as Starfish Prime.[24] The Soviets followed suit by detonating a 300-kiloton warhead at an altitude of 290 km over Kazakhstan on October 22, 1962, followed days later by two similar tests at lower altitudes.[25] Notably, the Soviet tests occurred during the Cuban Missile Crisis, a period of particularly heightened tensions between the Soviet Union and the United States. Since the Partial Test Ban Treaty was signed in August 1963, however, no nuclear tests have been conducted in space by any nation.

Using the above framework, the Partial Test Ban Treaty prohibits the testing and use of nuclear warheads on Earth-to-space and space-to-space kinetic weapons. Specifically, the treaty says that the parties to it agree "to prohibit, to prevent, and not to carry out any nuclear weapon test explosion, or any other nuclear explosion, at any place under its jurisdiction or control: (a) in the atmosphere; beyond its limits, including outer space . . . ."[26] It does not, however, affect the development, testing, deployment, or use of non-nuclear space weapons. This treaty is widely accepted, with 104 signatory nations. Notably, France, China, and North Korea are among the few remaining countries that have not signed the treaty and are not bound by its limitations.[27]

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24 Phil Plait, "The 50th anniversary of Starfish Prime: the nuke that shook the world," Discover, July 9, 2012, https://www.discovermagazine.com/the-sciences/the-50th-anniversary-of-starfish-prime-the-nuke-that-shook-the-world.

25 Jerry Emanuelson, "The Soviet Nuclear EMP Tests over Kazakhstan," Futurescience, July 7, 2019, http://www.futurescience.com/emp/test184.html.

26 *Treaty Banning Nuclear Weapon tests in the Atmosphere, in Outer Space and Under Water*, Moscow, August 5, 1963, UNTS, no. 6964, https://treaties.un.org/doc/Publication/UNTS/Volume%20480/volume-480-I-6964-English.pdf.

27 Ibid. See: Status of the Treaty, http://disarmament.un.org/treaties/t/test_ban.

No agreements exist today that completely limit space weapons within any of the six categories of the framework.

The Outer Space Treaty of 1967 is arguably the most important international agreement for space. A total of 89 nations are signatories, and 109 nations are party to the treaty.[28] While it includes a number of critical provisions for how space and the activities within it are governed, it does little to prohibit the development, testing, deployment, and use of space weapons. Article III of the treaty says that nations should carry out activities in space "in accordance with international law, including the Charter of the United Nations." Article IV of the treaty prohibits nuclear weapons from being placed into orbit. Article IV also prohibits the testing of any type of weapon (nuclear or conventional) on the moon and other celestial bodies. Specifically, it says that parties to the treaty agree "not to place in orbit around the earth any objects carrying nuclear weapons or any other kinds of weapons of mass destruction, install such weapons on celestial bodies, or station such weapons in outer space in any other manner." It further states that "the establishment of military bases, installations and fortifications, the testing of any type of weapons and the conduct of military manoeuvres on celestial bodies shall be forbidden."[29]

Thus, the Outer Space Treaty effectively prohibits nuclear-armed space-to-space and space-to-Earth kinetic weapons. It also prohibits all forms of space-to-space weapons from being tested and used in military maneuvers on other celestial bodies. What is most notable about the treaty, however, is what it does not restrict. It does not prohibit conventionally armed space-to-space weapons in Earth orbit, in deep space, or in orbit around other celestial bodies nor does it prohibit conventionally armed space-to-Earth weapons. Moreover, it does not prohibit any Earth-to-space weapons, although the Partial Test Ban Treaty separately restricts nuclear-armed Earth-to-space kinetic weapons and was already in effect by the time the Outer Space Treaty was negotiated.

Another major international space agreement that helps define, but not limit, actions in space is the Liability Convention of 1972. Article I of the treaty defines several terms that are important for understanding space weapons and the weaponization of space. Specifically, it defines damage in a way that is not specifically limited to kinetic effects, and it defines the launching state broadly as both the state that launches or procures a launch and the state from whose territory or facility the launch is conducted. Importantly, the treaty distinguishes different types of liability for space-to-Earth and space-to-space damage. Article II makes the launching state absolutely liable for space-to-Earth damage, regardless of fault. Article III makes the launching state liable for space-to-space damage "if the damage is due to its fault or the fault of persons for whom it

28 "Status of International Agreements relating to activities in outer space as at 1 January 2019," Committee on the Peaceful Uses of Outer Space, April 1-12, 2019, https://www.unoosa.org/documents/pdf/spacelaw/treatystatus/AC105_C2_2019_CRP03E.pdf.

29 "Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (1967)," United Nations Office of Outer Space Affairs, https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/outerspacetreaty.html.

is responsible."[30] The Liability Convention has been ratified, signed, or otherwise accepted by 96 nations and international organizations.[31]

The Moon Agreement of 1979 reaffirmed the prohibitions on weapons and military activities on the moon as stated in the Outer Space Treaty. However, it was only ratified by 18 nations, including Australia, Belgium, France, India, the Netherlands, Pakistan, Saudi Arabia, and Turkey. Notably, it was not signed by the United States, Russia, China, the United Kingdom, Germany, and most other nations, and thus it remains limited in its relevance.

The Partial Test Ban Treaty and Outer Space Treaty are the major widely accepted international agreements that limit space weapons activity and testing today. Although the treaties do not specifically define space weapons or the weaponization of space, the prohibitions on nuclear weapons being used in space and the stationing of nuclear weapons in orbit are clear indications that these activities are widely considered space weapons. These agreements do not, however, provide a comprehensive view of whether other capabilities and activities not covered by the treaties are considered space weapons and weaponization, leaving much room for differences in interpretations and definitions.

30 "Convention on International Liability for Damage Caused by Space Objects (1972)," United Nations Office of Outer Space Affairs, https://www.unoosa.org/pdf/gares/ARES_26_2777E.pdf.

31 "Status of International Agreements relating to activities in outer space as at 1 January 2019," Committee on the Peaceful Use of Outer Space.

Proposed International Agreements

Further insight into what other nations consider to be space weapons can be gleaned from the ongoing debate over the Russian and Chinese proposed treaty entitled "Prevention of the Placement of Weapons in Outer Space, the Threat or Use of Force against Outer Space Objects," otherwise known as PPWT. Of particular interest is the way other nations have responded to the PPWT proposal and the alternative proposals that have been offered.

After the United Nations Conference on Disarmament's initial efforts in the 1980s, progress in creating an agreement or framework to prevent an arms race in space stalled for many years. In the early-2000s, China and Russia began working closely together to push the issue to the forefront of the conference's agenda again. In 2005, the two nations hosted an open meeting on the issue, and later that year the UN General Assembly approved two non-binding documents on the Prevention of an Arms Race in Outer Space (PAROS) and the need for Transparency and Confidence-Building Measures in space (TCBM).[32] While this was not the first time the United Nations had passed similar provisions, it marked the beginning of a more concerted effort on the part of Russia and China to build international support for restrictions on space weaponization activities. The PAROS document was co-sponsored by 36 nations, including Russia, China, India, Indonesia, Iran, Pakistan, and Saudi Arabia.[33]

In parallel, China was working to develop and test a direct-ascent ASAT weapon capable of destroying satellites in LEO. On January 11, 2007, after several failed attempts, China conducted its first successful ASAT test. It destroyed one of its own satellites and generated thousands of pieces of space debris in the process. The test was widely condemned by other nations, including the United States, Russia, Japan, India, and many European nations.[34] In June of that year, the UN Committee on the Peaceful Uses of Outer Space (COPUOUS) adopted a set of voluntary space debris mitigation guidelines (which had been in development for several years), and in December the guidelines were endorsed by the General Assembly. Among other things, these guidelines state that "the intentional destruction of any on-orbit spacecraft and launch vehicle orbital stages or other harmful activities that generate long-lived debris should be avoided. When intentional break-ups are necessary, they should be conducted at sufficiently low altitudes to limit the orbital lifetime of resulting fragments."[35] Notably, these guidelines stand in stark contrast to the Chinese ASAT test

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32 Center for Nonproliferation Studies, *Proposed Prevention of an Arms Race in Outer Space (PAROS) Treaty* (Washington, DC: Nuclear Threat Initiative, 2019), 10.

33 UNIDR, *Prevention of an Arms Race in Outer Space*.

34 Carin Zissis, "China's Anti-Satellite Test," Council on Foreign Relations, February 22, 2007, https://www.cfr.org/backgrounder/chinas-anti-satellite-test.

35 United Nations Office of Outer Space Affairs, *Space Debris Mitigation Guidelines of the Committee on the Peaceful uses of Outer Space* (Vienna: 2010), 3, https://www.unoosa.org/pdf/publications/st_space_49E.pdf.

that was conducted, which occurred at a relatively high altitude and resulted in many pieces of long-lived debris.

Also in 2007, the European Union introduced a draft Code of Conduct for space at the United Nations with one of the main principles of the code being "to prevent space from becoming an area of conflict" while also recognizing that space systems are "essential to the safeguarding of national security and strategic stability."[36] The proposed scope of the code mainly focused on the prevention of collisions and debris, which would mainly affect kinetic types of space weapons.

In February 2008, two important events occurred. First, China and Russia formally submitted their draft PPWT proposal at the United Nations. The following week, the United States shot down one of its own satellites using a Standard Missile-3 (SM-3) missile defense interceptor from a U.S. Navy ship in the Pacific. Unlike the Chinese test a year prior, this intercept took place at a relatively low altitude, and much of the debris burned up in the atmosphere within a few days.[37]

One of the stated goals of China and Russia in the PPWT treaty was "to keep outer space as a sphere where no weapon of any kind is placed." But it defined space weapons somewhat narrowly to mean "any device placed in outer space, based on any physical principle, specially produced or converted to eliminate, damage or disrupt normal function of objects in outer space, on the Earth or in its air." It further specified that placing a weapon in space means putting the object into an orbital trajectory or stationing it permanently somewhere else in space, such as the moon.[38] Therefore, the PPWT proposal only applies to space-to-space and space-to-Earth weapons, both kinetic and non-kinetic. It would not prohibit Earth-to-space kinetic weapons, such as the Chinese ASAT missile tested the year prior. The U.S. SM-3 missile used as an ASAT system in 2008 would also not be prohibited nor would any Earth-to-space non-kinetic forms of attack, which China and Russia both possess.[39]

In July 2008, the European Parliament passed a resolution on space security that said, "under no circumstances should European space policy contribute to the overall militarisation and weaponisation of space." While it did not define the terms militarization and weaponization, the resolution stated that it "deplored" the lack of an independent European ballistic missile warning capability and called for the development of "satellite-based early warning against ballistic missile launches." Given the resolution's call for additional space systems to support military missions, its use of the term militarization of space would not appear to mean the use of space systems to support military operations. The resolution also noted the need for more defenses for European satellites, to include "anti-jamming, shielding, on-orbit servicing, high-orbit and multi-orbital constellation architectures," which again would not appear to be included under its definition of

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36 "Transparency and Confidence-building measures in outer space activities," United Nations, September 17, 2007, 7, http://www.reachingcriticalwill.org/images/documents/Resources/Factsheets/paros/A-62-114-Add1.pdf.

37 Jim Wolf, "U.S. satellite shootdown debris said gone from space," Reuters, February 27, 2009, https://www.reuters.com/article/us-space-usa-china/u-s-satellite-shootdown-debris-said-gone-from-space-idUSTRE51Q2Q220090227.

38 "Treaty on the Prevention of the Placement of Weapons in Outer Space, the Threat or Use of Force against Outer Space Objects" (draft), 1-2, http://www.reachingcriticalwill.org/images/documents/Disarmament-fora/cd/2008/documents/Draft%20PPWT.pdf.

39 Harrison, Johnson, and Roberts, *Space Threat Assessment 2019*, 11-12, 19-20.

militarization or weaponization. The resolution recommended a legally binding ban on "the use of weapons against space assets and the stationing of weapons in space," which could be interpreted to include all six categories of space weapons in the proposed framework in Table 1.[40]

The PPWT proposal only applies to space-to-space and space-to-Earth weapons, both kinetic and non-kinetic.

In December 2008, the Council of the European Union approved the draft Code of Conduct for outer space activities. The code was intended to be voluntary and open for all nations to adopt beyond just EU states. Among its many provisions, it called for states to "refrain from intentional destruction of any on-orbit space object," which would limit Earth-to-space and space-to-space kinetic weapons.[41] By focusing on a narrow set of potential space weapons that have the potential to produce space debris, the Code of Conduct was fairly limited in scope.

Canada also weighed into the debate in 2009 in a working paper delivered to the UN Conference on Disarmament. The Canadian paper made the point that both the EU Code of Conduct and the Chinese-Russian PPWT allow for a potential proliferation path for ASAT weapons. It argued that a ban on the testing and use of weapons against a satellite should also be done in parallel with a ban on the placement of weapons in space, "lest we inadvertently provide a sanctuary for space-based weapons."[42] It further noted that the risks of settling for a weakened or ill-defined proposal are that it could implicitly endorse the proliferation of some types of ASAT weapons or inadvertently limit self-defense measures against space-based weapons.[43]

Deliberations in the UN Conference on Disarmament picked up in 2010, with several delegations making statements in support of the PPWT treaty. Specifically, Australia, Belarus, and Kazakhstan each came out in support of the draft PPWT submitted by China and Russia in 2008, and the delegations from Bangladesh, the European Union, Ireland, Libya, South Korea, Romania, and Switzerland made positive references to the treaty.[44] Brazil voiced support for the draft PPWT as a starting point for negotiations and expressed concern about the EU Code of Conduct, noting that "the reference to self-defense could be interpreted in a way that justifies the use of force in outer space. That is a scenario we cannot afford to contemplate, not even in theory."[45]

The First Committee of the UN General Assembly passed a resolution in 2010 creating a Group of Governmental Experts to explore the development of transparency and confidence building

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40 "European Parliament Resolution on 10 July 2008 on Space and Security," European Union, July 10, 2008, https://www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//TEXT%2BTA%2BP6-TA-2008-0365%2B0%2BDOC%2BXML%2BV0//EN&language=EN.

41 "Draft Code of Conduct for Outer Space Activities," Council of the European Union, December 17, 2008, 9, https://register.consilium.europa.eu/doc/srv?l=EN&f=ST%2017175%202008%20INIT.

42 "On the Merits of Certain Draft Transparency and Confidence-Building Measures and Treaty Proposals for Space Security," Government of Canada, working paper, June 5, 2009, 3, http://www.reachingcriticalwill.org/images/documents/Disarmament-fora/cd/2009/documents/CD1865.pdf.

43 Ibid., 4.

44 Center for Nonproliferation Studies, *Proposed Prevention of an Arms Race in Outer Space (PAROS) Treaty*, 8.

45 Statement by Brazil to the United Nations Conference on Disarmament, October 23, 2012, 3, https://unoda-web.s3-accelerate.amazonaws.com/wp-content/uploads/assets/special/meetings/firstcommittee/67/pdfs/Thematic/23%20Oct%20TD%20Clust%203%20Brazil.pdf.

measures for outer space. It involved representatives from 15 nations, including the United States, Russia, China, France, Brazil, and the United Kingdom. The group reported back to the General Assembly in July 2013 with a set of recommended voluntary measures that included the exchange of information on national space policy and military space spending, notifications of outer space activities, and visits to launch sites.[46] While the General Assembly encouraged states to adopt the proposed measures on a voluntary basis, little progress was made on building a broader consensus.

Discussions on the EU Code of Conduct continued, with meetings held to solicit input from experts through 2014. The European Union published a fifth revision of the code in March 2014 that incorporated some of the views and feedback from its consultations with other nations. The revised code altered the limitation on Earth-to-space and space-to-space kinetic weapons to say that subscribing states will "refrain from any action which brings about, directly or indirectly, damage, or destruction of space objects unless such action is justified." The allowable justifications are for safety (particularly if human life is involved), the prevention of new space debris, and self-defense.[47] An earlier version of the code only made passing reference to the right of individual or collective self-defense, as already allowed under the UN Charter, and did not specify that self-defense could be a justifiable reason for destroying a space object.

In June 2014, Russia and China issued an updated draft of the PPWT. The revised version altered the defined terms in the treaty in several ways. It no longer attempted to define outer space as above 100 km altitude and instead broadened the definition of an outer space object to be "any device placed in outer space and designed for operating therein." It also modified the proposed definition of a space weapon to apply to any outer space object (as newly defined) while retaining the key phrase "to eliminate, damage or disrupt normal functioning of objects in outer space, on the Earth's surface or in the air." The revised version also included additional clarification on the protection of a state's right of self-defense to include the right of collective self-defense, which was not explicitly stated in the original version and hues more closely to the wording in the EU Code of Conduct.[48] Importantly, the revised PPWT continued to be limited to space-to-space and space-to-Earth forms of kinetic and non-kinetic weapons and would not limit Earth-to-space weapons.

In 2015, the European Union brought the revised Code of Conduct to the United Nations for multilateral negotiations. Russia, China, Brazil, India, and South Africa were among the most vocal opponents of the EU proposal. They argued, among other things, that the European Union's drafting process was not inclusive enough, despite years of open meetings and subsequent revisions to the proposal. Ultimately, the Code of Conduct failed to gain consensus and stalled at the United Nations.

A non-governmental organization, the Women's International League for Peace and Freedom, weighed into the debate in 2015 with a letter to the UN Conference on Disarmament. The group voiced support for efforts to prevent the weaponization of outer space and lamented that little progress had been made. As examples, it cited that "some countries continue to research, design, test, and deploy 'missile defense' systems and antisatellite technologies," implicitly defining space

46 United Nations, *Report of the Ground of Governmental Experts on Transparency and Confidence-Building Measures in Outer Space Activities* (New York: July 13, 2013), 6, https://undocs.org/A/68/189.

47 "Draft International Code of Conduct for Outer Space Activities," Council of the European Union.

48 "Treaty on the Prevention of the Placement of Weapons in Outer Space, the Threat or Use of Force against Outer Space Objects" (draft).

weapons to include these systems. The letter also pointed to the tensions that exist between states that have robust space capabilities and those that do not in negotiating international agreements such as the EU Code of Conduct.[49]

In December 2015, the UN General Assembly passed resolution 70/27 on weapons in outer space. The resolution "urged" the commencement of negotiations on the Chinese-Russian PPWT and encouraged states to uphold a "political commitment not to be the first to place weapons in outer space." The resolution specifically cited Argentina, Armenia, Belarus, Brazil, Cuba, Indonesia, Kazakhstan, Kyrgyzstan, Russia, Sri Lanka, Tajikistan, and Venezuela as having already stated that they would not be the first to place weapons in outer space.[50] Moreover, Russia and Venezuela issued a joint statement to the UN Conference on Disarmament saying that they "will not be the first to deploy any type of weapon in outer space and will do their utmost to prevent outer space from being turned into a theatre for military confrontation and to ensure security in outer space activities."[51] Such statements imply that these nations believe weapons have not already been placed in space. Given the description in Table 1 of different types of space weapons and those that have already been tested or demonstrated, these statements may simply be duplicitous or may indicate that these nations have a narrower view of what a space weapon is.

49 "Statement to the Informal CD Civil Society Forum on Outer Space," Women's International League for Peace and Freedom, March 19, 2015, 1, http://www.reachingcriticalwill.org/images/documents/Disarmament-fora/cd/2015/statements/part1/19March_WILPF-OuterSpace.pdf.

50 "No first placement of weapons in outer space," United Nations Resolution 70/27, December 7, 2015, https://documents-dds-ny.un.org/doc/UNDOC/GEN/N15/409/53/pdf/N1540953.pdf?OpenElement.

51 "Letter from the Permanent Representatives of the Bolivarian Republic of Venezuela and the Russian Federation to the Secretary-General of the Conference on Disarmament," United Nations, April 4, 2016, https://undocs.org/pdf?symbol=en/CD/2060.

Recent Activities and Statements

NON-GOVERNMENTAL ORGANIZATIONS

Given the increased economic and military dependence on space and the increased development and proliferation of counterspace weapons, several non-governmental organizations have begun working to define and potentially limit the use of space weapons. Two of these efforts are of interest because they focus specifically on the military uses of space and what constitutes an act of war or aggression in space. In May 2016, McGill University's Center for Research in Air and Space Law initiated a project to develop a Manual on International Law Applicable to Military Uses of Outer Space, known as MILAMOS. The objective of MILAMOS is to create a manual that "clarifies the fundamental rules applicable to military uses of outer space by both States and non-State actors in times of peace and in periods of rising tensions." Funding for the project comes primarily from McGill University and the Canadian government, and the project includes partnering institutions from other countries, such as the Beijing Institute of Technology in China, the Saint Petersburg State University in Russia, and the Institute for Defense Studies and Analysis in India.[52] Although its initial deadline was 2019, work on the manual is still in progress.

Work is also underway on a similar project known as Woomera, named for the Woomera Test Range in South Australia. Like MILAMOS, Woomera aims to create a manual that summarizes how existing international law applies to military uses of space. Woomera is a collaboration among four universities: the University of Adelaide in Australia, the University of Exeter in the United Kingdom, the University of Nebraska College of Law in the United States, and the University of New South Wales in Australia.[53] The project is funded principally by the four universities involved, and it plans to produce a manual by 2021.

FRANCE

In September 2018, France publicly charged Russia with interfering with the operation of one of its satellites. The *Athena-Fidus* satellite is a jointly operated French-Italian military satellite that provides broadband military communications. France alleged that the Russian satellite, known as *Luch* or *Olymp-K*, maneuvered close enough to *Athena-Fidus* in 2017 to intercept military communications. The same Russian satellite was earlier accused of conducting similar close

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52 McGill University, *Manual on International Law Applicable to Military Uses of Outer Space: Rules for Peacetime* (Montreal: December 2018), https://mcgill.ca/milamos/files/milamos/milamos-description_and_structure_dec2018.pdf.

53 University of Adelaide, *The Woomera Manual on the International Law of Military Space Operations* (Adelaide: October 2018), https://law.adelaide.edu.au/woomera/system/files/docs/Woomera%20Manual.pdf.

proximity operations with three different Intelsat commercial communications satellites.[54] The alleged actions of the Russian *Luch* satellite could fall under the category of space-to-space non-kinetic weapons, depending on whether one considers intercepting communications to be a way of interfering with military operations. Maneuvering the satellite into close proximity with another satellite without prior coordination could also be interpreted as a threatening action, which would violate the Chinese-Russian PPWT prohibition on threats against outer space objects.

Following this public denunciation of Russian space activities, France issued a new Space Defense Strategy in 2019. Among other things, the French strategy calls for the creation of a Space Command under the Air Force and renaming the Air Force to be the Air and Space Force. The strategy notes that "renewed analysis of the space environment and its threats, risks and opportunities, as well as the recognition of the strategic nature of the space assets for France force our country to revisit its model in order to remain a leading space power." The strategy notes the need to develop a "space defense capacity" that will "enable the armed forces to impose a peaceful use of space, deter unfriendly or hostile acts against our space assets, and be able, as the case may be, to defend our space-based interests."[55]

France alleged that the Russian satellite, known as Luch or Olymp-K, maneuvered close enough to Athena-Fidus in 2017 to intercept military communications

French minister of defense Florence Parly spoke at some length about the change in space posture being implemented under the new strategy in a July 2019 speech. In some of the most direct and specific language by a government official from any nation on space defense, the defense minister said, "I want to be precise: active defence is not an offensive strategy, what it is about is self-defence." She went on to add that, "If our satellites are threatened, we will consider dazzling those of our opponents. We reserve the time and means of the response: this may involve the use of high-power lasers deployed from our satellites or from our patrol nano-satellites."[56]

JAPAN

Japan has also taken a more proactive approach to space defense, largely driven by threats it perceives from China's space activities. In its 2019 defense white paper, the Japanese Ministry of Defense notes that China is bolstering its ability to "restrict enemies' use of space" as part of its overall anti-access/area denial capabilities.[57] The document goes on to discuss the various

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54 Kyle Mizokami, "France Accuses Russia of Space Satellite Espionage," *Popular Mechanics,* September 10, 2018, https://www.popularmechanics.com/military/a23067892/france-charges-russia-with-space-satellite-espionage/.

55 French Ministry of Defense, *Defense Space Strategy Summary* (Paris: DICoD Publishing Office, July 2019), https://www.defense.gouv.fr/content/download/574375/9839912/Space%20Defence%20Strategy%20 2019_France.pdf.

56 Florence Parly, "Presentation of the Defense Space Strategy," July 25, 2019, English translation from gosnold, "France's new space defense strategy," SatelliteObservation.net, July 27, 2019, https://satelliteobservation.net/2019/07/27/frances-new-space-defense-strategy/.

57 Japanese Ministry of Defense, *Defense of Japan* (Tokyo: 2019), 58, https://www.mod.go.jp/e/publ/w_paper/2019.html.

counterspace activities and capabilities of other countries, including direct-ascent ASAT missiles, co-orbital "killer satellites," jammers, and laser ASAT weapons. It calls these developments a "risk to the stable use of outer space" and "one of the critical security challenges for countries." Moreover, it notes that existing treaties and international agreements, such as the Outer Space Treaty, do not directly prohibit the destruction of space objects and the creation of space debris.[58] Although the white paper does not attempt to define space weapons, its discussion of space threats includes kinetic and non-kinetic Earth-to-space and space-to-space capabilities as part of what Japan considers to be a threat to peace and stability in space.

To protect its space systems, the white paper discusses various means of improving space control, such as bolstering its space situational awareness capabilities, passive defenses, and other measures to disrupt an adversary's command and control capabilities on the ground. It calls on the Japanese Self-Defense Forces to enhance cooperation with the United States and other countries in space and to set up a new organization, known as the Space Domain Mission Unit, within the Air Self-Defense Force that specializes in space defense.[59] More recently, Japanese prime minister Shinzo Abe announced that this new organization would be operational by April 2020. Citing Japan's need to bolster its defenses from adversary missiles and electromagnetic interference, Prime Minister Abe said this new organization will work closely with its American counterparts, the U.S. Space Force and U.S. Space Command. With a small core established in 2020, the Space Domain Mission Unit plans to be fully operational by 2022 and will be responsible for operating the ground stations necessary to conduct space defense operations.[60]

Japan is reportedly deciding whether or not to develop a co-orbital ASAT system that can "disable the operations of other countries' military satellites," using robotic arms, electronic attack, or cyberattack.

A senior ministry of defense official was also quoted in the press on the need for Japan to develop active defenses in space. The unnamed official was quoted as saying that the Self-Defense Forces "don't have any defense capability for the satellites." Japan is reportedly deciding whether or not to develop a co-orbital ASAT system that can "disable the operations of other countries' military satellites," using robotic arms, electronic attack, or cyberattack. It expects to make a decision on whether to begin such a program by the end of fiscal year 2020, with initial deployment of the system in the mid-2020s. According to the article, the Abe government has concluded that the type of defensive co-orbital ASAT system it is considering would be within the principals enshrined in the 2008 Aerospace Basic Law.[61] Article 14 of the Aerospace Basic Law states, "The State shall take

58 Ibid., 162.

59 Ibid., 219.

60 Mari Yamaguchi, "Japan reveals plan for space defense unit," *Defense News,* January 21, 2020, https://www.defensenews.com/space/2020/01/21/japan-reveals-plan-for-space-defense-unit/.

61 Yomiuri Shimbum, "Satellite interceptor sought by mid-2020s," Japan News, August 19, 2019, https://the-japan-news.com/news/article/0005948349.

necessary measures to promote Space Development and Use to ensure international peace and security as well as to contribute to the national security of Japan."[62]

INDIA

Over the past two decades, India has emerged as a significant space power. The Indian Space Research Organization (ISRO) has focused on developing space capabilities to advance India's economy, including the development of a fleet of reliable, indigenously produced launch vehicles and satellites. The ISRO is now one of the six largest space agencies in the world, and it uses space-based capabilities to deliver important services to its population, ranging from telemedicine to distance education.[63]

As a rising space power, India took note of the Chinese ASAT test in 2007. As one scholar noted, "It suddenly reminded them that their diverse space assets were now at risk, hostage to the dangers emanating from their most formidable regional threat." This led India to focus more on how to protect its space capabilities from the Chinese threat. Defense planners debated the merits of conducting a similar kinetic ASAT test to signal to China and other nations that India had the ability to retaliate in kind if its space assets were attacked.[64]

India does not believe the capability it demonstrated—an Earth-to-space kinetic ASAT—is a space weapon or represents the weaponization of space.

In 2019, India became the fourth nation to demonstrate an Earth-to-space kinetic ASAT weapon. On March 27, 2019, it launched a Prithvi Delivery Vehicle Mark-II (PDV MK-II) missile defense interceptor at one of its own satellites. The target satellite, *Microsat-R*, was launched specifically for this purpose on January 24, 2019, into a sun-synchronous orbit at just 282 km altitude. The first attempt to intercept the satellite failed on February 12, leading to the successful second attempt on March 27. The Indian ASAT test did not receive the same level of international outcry as the Chinese ASAT test, in part because it produced much less orbital debris. Because the intercept took place at a relatively low altitude and while the interceptor was on a downward trajectory, it appears that the Indian government was attempting to limit the potential for long-lasting orbital debris.[65] By the end of 2019, just 18 pieces of debris large enough to track remained in orbit.[66]

In a public address following the test, Indian prime minister Narendra Modi reiterated that "India has always been opposed to the weaponization of space and an arms race in outer space, and this

62 Government of Japan, Basic Space Law (Law No. 43 of 2008), enacted May 21, 2008, http://stage.tksc.jaxa.jp/spacelaw/country/japan/27A-1.E.pdf.

63 Ashley J. Tellis, "India's ASAT Test: An Incomplete Success," Carnegie Endowment for International Peace, April 15, 2019, https://carnegieendowment.org/2019/04/15/india-s-asat-test-incomplete-success-pub-78884.

64 Ibid.

65 Ibid.

66 Jonathan McDowell, Twitter post, December 27, 2019, 8:54 PM, https://twitter.com/planet4589/status/1210786046943739904.

test does not in any way change this position."[67] This statement would appear to indicate that India does not believe the capability it demonstrated—an Earth-to-space kinetic ASAT—is a space weapon or represents the weaponization of space. But Modi hinted at the true intent of India's actions, saying that by conducting the test "India registered its name as a space power."[68]

SOUTH KOREA

The Republic of Korea (ROK) issued a new defense white paper in 2018 that, among other topics, addresses the issue of space security. The paper states that, "the ROK Armed Forces will also build the capabilities and systems for effective response to cyber and space threats."[69] It established a new space organization within the Ministry of National Defense and is actively working to increase its cooperation with allies in space, namely the United States. In 2014, the United States and ROK signed a memorandum of understanding on the sharing of space situational awareness data, and in 2015, the Korean Air Force stood up a Space Intelligence Center to develop the "fundamental capabilities for space control." The Korean and U.S. militaries conducted joint tabletop exercises in 2017 that included "risky space situations over the Korean Peninsula, such as the jamming of navigation and communications satellite[s]."[70] While the Korean military does not appear to be developing defensive counterspace capabilities yet, its recent actions and policy statements indicate it is concerned about developments in the space domain and the use of weapons against its space assets in a conflict.

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67 Daniel Oberhaus, "India's Anti-Satellite Test Wasn't Really About Satellites," *Wired*, March 27, 2019, https://www.wired.com/story/india-anti-satellite-test-space-debris/.

68 David Dickinson, "What India's Anti-Satellite Test Means for Space Debris," Sky & Telescope, April 5, 2019, https://www.skyandtelescope.com/astronomy-news/what-indias-anti-satellite-test-means-for-space-debris/.

69 Republic of Korea Ministry of National Defense, *2018 Defense White Paper* (Seoul: 2018), 47, http://www.mnd.go.kr/user/mnd/upload/pblictn/PBLICTNEBOOK_201907110548253080.pdf.

70 Ibid., 74-76.

Conclusions

Since the Outer Space Treaty was signed in 1967, little progress has been made in negotiating international agreements that would limit the testing, deployment, and use of weapons in outer space. The main sticking points are a lack of consensus on what constitutes a space weapon and mechanisms for verification and enforcement of an agreement. Competing definitions for key terms have proven to be a particularly difficult issue to overcome. Nations use phrases such as space weapons, the militarization of space, and the weaponization of space to mean different things at different times, often to suit their own geopolitical agendas. A common framework for discussing space weapons could be useful to establish and clarify thresholds among like-minded nations for what constitutes conflict and escalation in space.

This analysis finds that the way other nations view space weapons hinges on several key distinctions. The first distinction is between nuclear and conventional space weapons. An international taboo against the placement and use of nuclear weapons in space emerged early in the space age and endures through treaties that have garnered widespread support. However, no such consensus has emerged on the use or placement of conventional weapons in space. A second distinction is whether the weapon is stationed on Earth or in space. The Chinese and Russian PPWT proposal would only prohibit weapons that are stationed in space, while the European Union's proposed Code of Conduct would limit weapons stationed on Earth and in space. A third distinction is whether the weapon produces orbital debris. Much of the focus of the Code of Conduct and the stated motivation of many non-aligned states is on the prevention of orbital debris and the preservation of the space environment for peaceful uses. The actions in space that provoke the loudest protests by other nations tend to be those that create large amounts of orbital debris.

A final and more recent distinction in how nations view space weapons is whether the weapons are used for self-defense rather than for offensive purposes. The latest version of both the PPWT and Code of Conduct include exceptions for self-defense, and the Code of Conduct is more specific in delineating when the use of space weapons in self-defense is legitimate. France is perhaps at the forefront of this space self-defense movement, having announced publicly that it intends to field non-kinetic space-to-space weapons to defend its satellites. Japan also notes the need for improved self-defense capabilities in space, but it has not yet publicly endorsed active defenses. With its 2019 ASAT test, India made clear that it believes kinetic Earth-to-space ASAT weapons are a legitimate means of self-defense by deterrence. Yet many other nations, particularly in Latin America, continue to oppose any weapons in space, even if they are intended solely for self-defense.

In the United Nations, much of the focus on space weapons has been in the Conference on Disarmament and its efforts to prevent an arms race in space. But concern about preventing an arms race is based largely on the assumption that weapons in space would lead to instability and ultimately conflict. However, conflict could occur in space without an arms race, and an arms race in space could potentially lead to a stable deterrence posture that prevents conflict—just as the nuclear arms race between the United States and Soviet Union ultimately helped avoid nuclear war on Earth by making the consequences of war intolerable to both sides.

Efforts to place limits on the development of space weapons, create a code of conduct, or even establish norms of behavior in space have so far failed to gain consensus among the key nations needed for such an agreement to be effective, namely the United States, Russia, China, India, and the European Union. While discussions continue at the United Nations about preventing an arms race in space, the actions of some nations—namely Russia and China—are leading others to prepare for conflict.

About the Author

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Mr. Harrison joined CSIS from the Center for Strategic and Budgetary Assessments, where he was a senior fellow for defense budget studies. He previously worked at Booz Allen Hamilton where he consulted for the U.S. Air Force on satellite communications systems and supported a variety of other clients evaluating the performance of acquisition programs. Prior to Booz Allen, he worked for a small startup (AeroAstro Inc.) developing advanced space technologies and as a management consultant at Diamond Cluster International. Mr. Harrison served as a captain in the U.S. Air Force Reserves. He is a graduate of the Massachusetts Institute of Technology with both a BS and an MS in aeronautics and astronautics.

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United Nations Secretary-General António Guterres addresses the Conference on Disarmament's High-Level Segment 2019.

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Key Governance Issues in Space

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The Aerospace Security Project (ASP) at CSIS explores the technological, budgetary, and policy issues related to the air and space domains and innovative operational concepts for air and space forces. Part of the International Security Program at CSIS, ASP is led by Senior Fellow Todd Harrison. ASP's research focuses on space security, air dominance, long-range strike, and civil and commercial space. Learn more at aerospace.csis.org.

Project Scope

This paper analyzes the views of nations on key governance issues in the space domain, focusing on countries other than the United States, Russia, and China. It examines how existing and proposed international mechanisms define and regulate space sustainability and debris mitigation, rendezvous and proximity operations, and insurance requirements for private and national space missions.

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Contents

List of Abbreviations

Abbreviation	Phrase
ADR	*Active Debris Removal*
ASAT	*Antisatellite*
CONFERS	*Consortium for Execution of Rendezvous and Servicing Operations*
COPUOS	*Committee on the Peaceful Uses of Outer Space*
CSA	*Canadian Space Agency*
DARPA	*Defense Advanced Research Projects Agency*
EOL	*End-of-Life*
ESA	*European Space Agency*
GEO	*Geostationary Orbit*
GPS	*Global Positioning System*
GTO	*Geostationary Transfer Orbit*
IADC	*Inter-Agency Space Debris Coordination Committee*
IDA	*Institute for Defense Analyses*
ISO	*International Organization for Standardization*
ISS	*International Space Station*
ITU	*International Telecommunications Union*
JAXA	*Japan Aerospace Exploration Agency*
LEO	*Low Earth Orbit*
LTS	*Long-Term Sustainability*
MILAMOS	*Manual on International Law Applicable to Military Uses of Outer Space*
NOTAM	*Notice to Airmen*
OOS	*On Orbit Servicing*
OST	*Outer Space Treaty*
PNT	*Positioning, Navigation, and Timing*
QZSS	*Quasi-Zenith Satellite System*
RFID	*Radio-Frequency Identification*
RPO	*Rendezvous and Proximity Operation*
SIA	*Satellite Industry Association*
SSA	*Space Situational Awareness*
SSR	*Space Sustainability Rating*
STM	*Space Traffic Management*
WEF	*World Economic Forum*
UN	*United Nations*
3SOS	*Safety, Security, and Sustainability of Outer Space*

Executive Summary

Each year, new actors enter the space domain and bring new technologies, practices, and challenges. This paper explores how current international governance structures are keeping pace with the increased activity and diversity of space missions. It dives into three key governance areas for the space domain: sustainability and debris mitigation, rendezvous and proximity operations, and insurance requirements, and it evaluates national, multinational, and industry efforts to develop better norms or operating standards for space governance.

The best developed of these areas is space sustainability and debris mitigation efforts. An indiscriminate issue for the space domain, space debris is a growing problem with almost every launch. Many space experts acknowledge that without norms of behavior or debris removal missions, the space environment may be permanently damaged.

There are several international mechanisms, national policies, multinational activities, and industry efforts to curb the creation and proliferation of space debris. Several organizations, such as the United Nations Committee on the Peaceful Uses of Outer Space, the Inter-Agency Space Debris Coordination Committee, and the Satellite Industry Association have published collaborative guidelines that suggest best practices for operating in the space domain in a sustainable manner. Several nations, especially Japan, have also taken significant steps to reduce debris on orbit.

Despite this progress, few international standards or norms exist. The few that are in place—such as the commonly practiced 25-year deorbit norm—are out of date with today's technology and the proliferation of commercial satellites. Many in the space community are rightly concerned that without dedicated international action, possibly legal action, there will be a day where a debris-creating event is so significant that it sets off a chain reaction of more collisions on-orbit. This is often referred to as the Kessler syndrome.[1] If such a day arises, the global space economy and services that are built into our everyday life (such as GPS, the global financial system, and daily weather forecasts) will no longer function as they do today.

The second issue area covered in this assessment is rendezvous and proximity operations—intentional maneuvers on orbit that put one satellite in a similar orbit or close to another satellite. Similar to space debris mitigation and the sustainability of the space environment, there are little to no agreed-upon definitions of what constitutes a safe interaction between satellites on orbit. Rendezvous and proximity operations are likely to become more commonplace as on orbit servicing (OOS) and active debris removal (ADR) technologies are tested and proven. Before this occurs, experts are working to develop standards or norms both for technical activities and for communicating movements while on orbit. However, unlike space debris mitigation and sustainability efforts, national and international discussions about rendezvous and proximity operations are either non-existent or at initial stages.

Lastly, this report addresses national policies and perspectives of space insurance. There are several ways to insure a satellite for both launch and on orbit operations, but insurance options are currently expensive and can cost up to one-third the total cost of a satellite, depending on the risk. There are also minimal national policies requiring any sort of insurance—especially once the satellite is out of the Earth's atmosphere and therefore in little to no danger of harming civilians or property on Earth.

However, for space insurers, the crowded space domain is making insuring satellites riskier and less profitable. This is already causing insurers to drop out of the space insurance market or reframe their insurance to not cover certain popular orbits. Until significant movement on cleaning and preserving the space domain occurs on an international level, space insurers may put such high premiums on coverage that companies cannot afford to buy insurance.

Through the following discussion and evaluation of national, multinational, international, and industry perspectives on the aforementioned topics, several issues for further action emerge, including:

- Creating international definitions for key space terminology;
- Developing normative rules of the road for satellite behavior, especially for rendezvous and proximity operations; and
- Assessing the stability and sustainability of satellite insurance and how the increasingly crowded space domain might affect satellite lifetime risk.

These options for future pursuit, and others, are elaborated upon in the following report.

Introduction

The global space economy was valued at $360 billion in 2018 and is only expected to increase as space becomes more accessible through declining costs.[2] As more countries rely on space for not only national security but also commercial opportunity, global governance and consensus on acceptable behaviors in space are becoming increasingly necessary.

A recent near miss of two satellites on orbit highlights the importance of the key governance issues discussed in this analysis. On September 2, 2019, two active satellites in low Earth orbit (LEO) nearly collided. Aeolus, an Earth observation satellite from the European Space Agency (ESA), and *Starlink 44*, one of SpaceX's first satellites for its highly proliferated satellite constellation intended to provide broadband internet, were in danger. As part of its satellite traffic management service, the U.S. Air Force provided both satellite operators with an assessment of the likelihood and timeframe for the collision. Due to the lack of defined international regulations on how to address a potential collision, the choice of how to proceed is left to the satellite operators, as was done during the *Aeolus-Starlink 44* incident.

As the date of collision neared, the chance of collision increased from 1 in 50,000 to 1 in 1,000. This caused the ESA great alarm, and they attempted to reach out to SpaceX. Currently, this process is done through direct email, however, due to a bug in SpaceX's software, the company did not receive the ESA's message. The collision was avoided after the ESA chose to maneuver Aeolus away from *Starlink 44's* orbital path.[3] Of course, a collision would have been detrimental to both satellites and significant amounts of debris in LEO would have been created—perhaps to the scale of the *Iridium-Cosmos* collision of 2009 that created almost 2,000 trackable pieces of debris.[4]

In just this single example, it is clear that the lack of agreed international norms and processes for space traffic management (STM) could have caused a devastating event in the space environment. Collisions in space are incredibly damaging to space sustainability and can be equally devastating to companies. While the ESA self-insures its satellites, there is no evidence that SpaceX's Starlink satellite was insured. A similar occurrence recently took place in late January 2020. Two satellites were on a collision course, with a 1 in 100 chance of collision, even greater than the *Aeolus-Starlink 44* incident.[5] However, unlike the *Aeolus-Starlink 44* near miss, these two satellites were not operational, meaning they could not maneuver out of one another's way. All the international community could do was wait and watch as the two satellites nearly collided. Luckily the satellites did not crash; however, this incident throws into sharp relief the increasing danger of on orbit collisions in a crowded space domain.

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2. "State of the Satellite Industry Report," Bryce Space and Technology, May 2019, 2, https://brycetech.com/reports.

3. "ESA Spacecraft Dodges Large Constellation," European Space Agency (ESA), March 9, 2019, https://www.esa.int/Safety_Security/ESA_spacecraft_dodges_large_constellation.

4. Brian Weeden, "2009 Iridium-Cosmos Collision Fact Sheet," Secure World Foundation, November 10, 2010, http://swfound.org/media/205392/swf_iridium_cosmos_collision_fact_sheet_updated_2012.pdf.

5. Jeff Foust, "Potential satellite collision shows need for active debris removal," Space News, January 29, 2020, https://spacenews.com/potential-satellite-collision-shows-need-for-active-debris-removal/.

Space situational awareness (SSA) and STM are the building blocks for the sustainability of the space domain, including mitigating debris, performing safe rendezvous and proximity operations, and having accurate insurance requirements and assessments. Rather than attempting to provide a comprehensive assessment of all perspectives, this analysis provides highly relevant or unusual cases that may highlight consensus or change in the aforementioned areas of space governance. It examines national and international policies and efforts that may present opportunities for international consensus or contention in the upcoming years in the areas of space sustainability and debris mitigation, rendezvous and proximity operations, and space insurance requirements.

DEFINITIONS

There is little to no consensus on definitions for SSA, STM, space debris mitigation, or space sustainability. In fact, a 2018 Institute of Defense Analyses study on global trends for SSA and STM highlights 14 distinct definitions for SSA and 5 definitions for STM.[6] While there are no concrete internationally accepted definitions for these terms, this study will attempt to clarify these terms through a few selected definitions.

Most definitions surrounding SSA focus on tracking and identifying objects in space, and they agree that without good SSA, the future of operating in space will become increasingly difficult. The lack of an internationally agreed-upon definition of SSA through the United Nations (UN) was lamented by a recent UN-sponsored working group, which further emphasized the need to define SSA.[7] For the ESA, SSA is the collective understanding of three main areas: space weather, near-Earth objects, and space surveillance and tracking.[8]

Perhaps a more descriptive SSA definition comes from the Secure World Foundation:

> [T]he ability to accurately characterize the space environment and activities in space. Civil SSA combines positional information on the trajectory of objects in orbit (mainly using optical telescopes and radars) with information on space weather. Military and national security SSA applications also include characterizing objects in space, their capabilities and limitations, and potential threats . . . It requires a network of globally distributed sensors as well as data sharing between owner-operators and sensed networks.[9]

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6. Bhavya Lal, Asha Balakrishnan, Becaja M. Caldwell, Reina S. Buenconsejo, and Sara A. Carioscia, *Global Trends in Space Situational Awareness (SSA) and Space Traffic Management (STM)* (Alexandria, VA: Institute for Defense Analyses, April 2018), B-1—B-4, https://www.ida.org/-/media/feature/publications/g/gl/global-trends-in-space-situational-aware-ness-ssa-and-space-traffic-management-stm/d-9074.ashx.

7. United Nations, "Operating in space: towards developing protocols on the norms of behaviour," Committee on the Peace-ful Uses of Outer Space, June 13, 2019, https://www.unoosa.org/res/oosadoc/data/documents/2019/aac_1052019crp/aac_1052019crp_12_0_html/AC105_2019_CRP12E.pdf.

8. The ESA defines these three key areas as: (1) space weather (SWE): monitoring and predicting the state of the Sun and the interplanetary and planetary environments, including Earth's magnetosphere, ionosphere, and thermosphere, which can affect spaceborne and ground-based infrastructure thereby endangering human health and safety; (2) near-Earth objects (NEO): detecting natural objects such as asteroids that can potentially impact Earth and cause damage; (3) and space surveillance and tracking (SST): watching for active and inactive satellites, discarded launch stages, and fragmentation debris orbiting Earth. "SSA Programme Overview," ESA, accessed March 03, 2020, https://www.esa.int/Safety_Security/SSA_Programme_overview.

9. Brian Weeden, "Space Situational Awareness Fact Sheet," Secure World Foundation, May 2017, https://swfound.org/media/205874/swf_ssa_fact_sheet.pdf.

This definition highlights the intricacies of what is required of good SSA and why many nations are prioritizing SSA investments.

STM is another building block toward space sustainability, and good STM is foundational in debris mitigation strategies. A 2006 International Academy of Astronautics study defines STM as "the set of technical and regulatory provisions for promoting safe access into outer space, operations in outer space and return from outer space to Earth free from physical or radio-frequency interference."[10] The intent of this definition was to make clear that the purpose of STM is to create safe and appropriate methods for conducting space operations without harmful interference. This supports the free and open use of outer space by any nation or entity, which is the cornerstone of the 1967 Outer Space Treaty (OST).

Space debris mitigation practices and activities are made possible through a solid knowledge of the space environment, such as robust SSA, and effective STM practices to operate safely in the space environment. Space debris mitigation has historically been defined by either the accidental or intentional breakup of objects on orbit, which often produces long-lasting debris, or by debris that is intentionally released from launch vehicles or satellites on orbit—such as payload fairings or lens caps on optical sensors.

The UN Committee on the Peaceful Uses of Outer Space (COPUOS) divides space debris mitigation measures into "two broad categories: those that curtail the generation of potentially harmful space debris in the near term and those that limit their generation over the longer term." The first involves mitigating or curtailing debris production of ongoing missions and avoiding further breakups. The second category focuses on end-of-life (EOL) procedures that mitigate new debris creation or the potential for safely removing existing debris on orbit.[11] Some of these procedures include: ADR; deorbiting a satellite into the Earth's atmosphere, causing it to break up and incinerate; pushing a satellite into a non-usable or uncommon orbit; and creating reusable launch vehicles that do not contribute debris into orbit.

SSA, STM, and space debris mitigation activities all contribute to the common goal of space sustainability. COPUOS defines space sustainability "as the ability to maintain the conduct of space activities indefinitely into the future in a manner that realizes the objectives of equitable access to the benefits of the exploration and use of outer space for peaceful purposes, in order to meet the needs of the present generations while preserving the outer space environment for future generations."[12] Better knowledge of the space environment, more cohesive communication about satellite movements, and either taking harmful debris out of orbit or not creating new debris will all add to preserving the space domain for future use.

With the above definitions in mind, the following analysis evaluates national policies and attitudes toward space sustainability and debris mitigation, rendezvous and proximity operations, and space

10. Corinne Contant-Jorgenson, Petr Lála, and Kai-Uwe Schrogl, eds., "Cosmic Study on Space Traffic Management," International Academy of Astronautics, 2006; as defined in Claudiu Mihai Taiatu, "Space Traffic Management: Top Priority For Safety Operations," International Institute of Space Law, 2017, https://iislweb.org/docs/Diederiks2017.pdf.

11. Office of Outer Space Affairs, *Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space* (Vienna: United Nations, 2010), 1, https://www.unoosa.org/pdf/publications/st_space_49E.pdf.

12. Committee on the Peaceful Uses of Outer Space, *Guidelines for the Long-term Sustainability of Outer Space Activities* (Vienna: United Nations, June 2018), 2, https://cms.unov.org/dcpms2/api/finaldocuments?Language=en&Symbol=A/AC.105/L.315.

insurance. The analysis also accounts for work in progress in multinational fora and new industry-led initiatives and standards. With these cases, likely areas for consensus within the next decade emerge, along with possible trigger points where contention among nations or between nations and private entities may arise.

Space Sustainability and Debris Mitigation

At the International Astronautical Congress in 2019, several panels of policymakers, experts, and technicians from around the world discussed the risks of space debris. During these sessions and in private discussions held that week, the international space community collectively called for better SSA and increased coordination for STM and highlighted the need to mitigate debris-creating events in the space domain.

To have a comprehensive debris mitigation strategy or efforts to secure the sustainability of the space domain, one must first have robust SSA. Understanding where objects are in space and projecting their orbital path is a cornerstone of developing a global STM system that encourages economic activity, global space debris mitigation regulations, and sustainability requirements.[13] These three key elements—SSA, STM, and debris mitigation—will determine the sustainability of the space domain for decades to come.

INTERNATIONAL MECHANISMS

Several international mechanisms exist that play a large role in creating norms, best practices, and guidelines for mitigating space debris. Examples include both UN-based organizations such as COPUOS and other mechanisms such as the Inter-Agency Space Debris Coordination Committee (IADC), an intergovernmental forum for worldwide coordination of activities related to space debris.[14] In general, these international bodies are working to establish clear, internationally-recognized policies and technical frameworks for nations to adopt or use as a basis for their own national space sustainability policies.

UNITED NATIONS COMMITTEE ON THE PEACEFUL USES OF OUTER SPACE

Guidelines for space sustainability were first introduced in 2007 by COPUOS. Twenty-one of these guidelines were approved by all 92 member states in June 2019. While the guidelines are voluntary and not legally binding, they do signify a united effort to better coordinate SSA and STM measures in order to track all objects in space and to limit the amount of new space debris created. These objectives are in line with Article I of the 1967 Outer Space Treaty, which states "the exploration and use of outer space . . . shall be carried out for the benefit and in the interests of all countries . . . and shall be the province of all mankind."[15] While not all of the guidelines are relevant for

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13 Brian Weeden and Victoria Samson, "Insight - Improving Space Situational Awareness," Secure World Foundation, November 11, 2019, https://swfound.org/news/all-news/2019/11/insight-improving-space-situational-awareness?mc_cid=01e8c0ff72&mc_eid=8de9226597.

14 Members include the national space agencies of Italy, France, China, Canada, Germany, India, Japan, South Korea, the United States, Russia, Ukraine, and the United Kingdom. The ESA is also a member.

15 Office for Outer Space Affairs, *Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies* (New York: United Nations, 1966), https://www.unoosa.org/pdf/gares/

this analysis, several show consensus between both spacefaring and non-spacefaring nations on initiatives governments and non-governmental entities may take to ensure the sustainability of the space domain for future endeavors.

The first guideline presented encourages states to "adopt, revise and amend, as necessary, national regulatory framework for outer space activities," particularly in order to ensure the long-term sustainability of outer space.[16] The guidelines that follow recommend additions or revisions that could be made in national frameworks to encourage responsible behavior by the state and its entities (such as commercial industry) to maintain the integrity of the space domain. Specifically, the UN guidelines suggest: limiting debris released during operations; minimizing the potential for breakups on orbit; and avoiding destruction or harmful activities that may further create debris.[17]

The guidelines also highlight the need to increase communication between countries and non-governmental entities to better manage potential conjunctions between space assets. To this point, the guidelines also suggest "the establishment of a United Nations information platform" that would serve as a basis for an international SSA system to more effectively manage STM. A later guideline suggests that states require all satellites launched from their territory to use either passive or active on-orbit tracking aids (such as radio-frequency identification, or RFID) in order to have more accurate SSA data. This is especially critical for emerging space programs, who often rely on smaller, less sophisticated satellite designs.[18] These objects are inherently harder to track because of their size and may not have active propulsion components to maneuver in space, which makes the suggestion of including active and passive tracking aids even more critical.

Furthermore, the guidelines encourage pre-conjunction assessments. This is when, prior to launch, a satellite operator will determine the likelihood that the satellite will be at risk for collision with another active or inactive space object. This would help a country or company plan and anticipate the risks a satellite will incur over its lifetime.[19] Several nations have adopted this mechanism in their national policies on space sustainability, as it is also in line with the 1972 UN Convention on International Liability for Damage Caused by Space Objects standards.[20] Pre-conjunction assessments are critical for determining risk and evaluating insurance costs for satellites.

The final guideline suggests states and international intergovernmental organizations should investigate debris removal technologies and consider how to effectively reduce or manage space debris in the future. The document is clear that these efforts, however, should not "impose undue costs on the space programmes of emerging spacefaring nations."[21]

Reception of the COPUOS guidelines has been quite positive in the space community, although some believe more stringent guidelines could have been adopted. However, this international

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16 Committee on the Peaceful Uses of Outer Space, *Guidelines for the Long-term Sustainability of Outer Space Activities*, 5.

17 Office of Outer Space Affairs, *Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space.*

18 Committee on the Peaceful Uses of Outer Space, *Guidelines for the Long-term Sustainability of Outer Space Activities*, 10-11, 15-16,

19 Ibid., 12-13.

20 For more on the Liability Convention, see page 25 in chapter on Insurance Requirements for Space Missions.

21 Committee on the Peaceful Uses of Outer Space, *Guidelines for the Long-term Sustainability of Outer Space Activities*, 20.

consensus to protect the space domain and limit debris creation is an encouraging first step for international space policy.

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION

Often cited in national policies are the International Organization for Standardization (ISO) standards for mitigating space debris. Founded independently of other international organizations in 1947, the ISO crafts and promotes international standardization for a variety of policy areas, including space. Comprising 164 national standards bodies, the ISO has coordinated international standards in food safety, health care, agriculture, and commercial technology. For space safety, ISO standards are notable for providing several technical means or frameworks for evaluating the potential of an object to create space debris or breakup on orbit.[22] These include the common 25-year EOL disposal standard for LEO.[23] This is one of the most successful norms in the space domain to date.

In 2019, the ISO updated its primary document on space debris mitigation guidelines.[24] In this update, requirements across the board were made stricter, including "the requirement for a spacecraft or orbital stage to exceed a specified threshold for its probability of successful disposal."[25] Several nations follow ISO guidelines and either write ISO standards directly into their national policies or use them as a basis for crafting unique policy.

INTERNATIONAL TELECOMMUNICATIONS UNION

Since many communications satellites populate geostationary orbit (GEO), the UN International Telecommunications Union (ITU) released its own guidelines for sustainable practices in this protected region of near-Earth space. The ITU specifically provides guidance on safe disposal practices for GEO satellites, which includes defining the protected area around GEO so that satellites are disposed of in an orbit no less than 200 km above the geostationary altitude, in order to minimize potential interference. Colloquially, these are often referred to as "graveyard orbits." The ITU guidelines also address tactics for minimizing radio frequency interference during EOL maneuvers.[26] The ITU is composed of 193 member states, "as well as some 900 companies, universities, and international and regional organizations."[27]

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22 Office of Outer Space Affairs, *Compendium: Space Debris Mitigation Standards Adopted by States and International Organizations* (Vienna: United Nations, February 25, 2019), 70-75,https://www.unoosa.org/documents/pdf/spacelaw/sd/Space_Debris_Compendium_COPUOS_25_Feb_2019p.pdf.

23 Hedley Stokes et al., "Status of the ISO Space Debris Mitigation Standards," ESA, June 2017, 2-3, https://conference.sdo.esoc.esa.int/proceedings/sdc7/paper/979/SDC7-paper979.pdf.

24 "ISO 24113:2019 - Space systems — Space debris mitigation requirements," International Organization for Standardization, July 2019, https://www.iso.org/standard/72383.html.

25 Hedley Stokes et al., "Evolution of ISO's Space Debris Mitigation Standards," Universities Space Research Association, 2019, https://www.hou.usra.edu/meetings/orbitaldebris2019/orbital2019paper/pdf/6053.pdf.

26 Office of Outer Space Affairs, *Compendium*, 76.

27 "About the International Telecommunications Union," International Telecommunications Union, accessed March 20, 2020, https://www.itu.int/en/about/Pages/default.aspxl.

INTER-AGENCY SPACE DEBRIS COORDINATION COMMITTEE

The IADC is a voluntary collection of 13 of the world's space agencies, which collectively work to provide technical recommendations "for the worldwide technical/scientific coordination of activities related to space debris in Earth orbit issues."[28]

The IADC's Space Debris Mitigation Guidelines were developed in 2002, updated in 2007, and became the backbone on which the COPUOS long-term sustainability guidelines were built. The IADC guidelines focus on limitation of debris creation in normal operations over a satellite's lifetime, the minimization of the probability of breakup on orbit, plans for EOL disposal, and the prevention of on orbit collisions with other spacecraft.[29] However, like the COPUOS guidelines, the IADC guidelines are non-binding, but several countries have policies that enforce these guidelines nationally.

NATIONAL POLICIES

While there are few officially stated national policies on space sustainability and debris mitigation, there are several indications of what nations are prioritizing within SSA, STM, debris removal, and sustainability efforts. In a 2018 study entitled Global Trends in Space Situational Awareness (SSA) and Space Traffic Management (STM), the Institute for Defense Analyses (IDA) presents several key findings from its case studies that shed light on national priorities and perspectives on sustainability and debris removal activities. Some countries demonstrated "concerns that if they do not participate in global discussions (e.g., long-term sustainability [LTS] guidelines), their national interests will not be appropriately reflected in the rules, and they will miss out on critical opportunities." The IDA suggests that this indicates countries' willingness to work toward sustainable operations in space to keep the domain safe and clear of debris for future endeavors. The IDA further concluded that Europe, in particular, needed to work cohesively—between EU member countries' national space agencies and the EU's European Space Agency—in order to affect decisions on future STM regulations.[30]

Many countries are looking to be leaders and responsible actors in space and therefore support growing international efforts to develop responsible behaviors and norms for space operators. The IDA found that countries such as Brazil, China, France, Japan, and South Africa all prioritize the effort to establish norms of behavior in space. Many countries are looking to protect their assets in space through better SSA and STM. This may include advocating for responsible behaviors. The following selection of national policies from 10 different countries demonstrates this breadth and highlights some unique cases.

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28 The 13 IADC space agencies include: ASI (Agenzia Spaziale Italiana), CNES (Centre National d'Etudes Spatiales), CNSA (China National Space Administration), CSA (Canadian Space Agency), DLR (German Aerospace Center), ESA (European Space Agency), ISRO (Indian Space Research Organisation), JAXA (Japan Aerospace Exploration Agency), KARI (Korea Aerospace Research Institute), NASA (National Aeronautics and Space Administration), ROSCOSMOS (State Space Corporation "ROSCOSMOS"), SSAU (State Space Agency of Ukraine), and UKSA (United Kingdom Space Agency). Alberto Tuozzi, "The Inter-Agency Space Debris Coordination Committee (IADC) an overview of IADC's annual activities," International Committee on Global Navigation Satellite Systems, November 4-9, 2018, 2, https://www.unoosa.org/documents/pdf/spacelaw/sd/IADC-2002-01-IADC-Space_Debris-Guidelines-Revision1.pdf.

29 Tuozzi, "The Inter-Agency Space Debris Coordination Committee (IADC) an overview of IADC's annual activities," 6, 9.

30 Lal et al., *Global Trends in Space Situational Awareness*, 20-21.

There is a wide spectrum of national space debris mitigations standards and guidelines. Some nations are just starting their evaluation processes to inform their national perspective and potential policies or regulations, while others have well-developed and exacting guidelines for both national and commercial space missions. Several additional nations were surveyed but did either not have enacted national policies or only had minimal language addressing space debris mitigation. These include Brazil, New Zealand, Saudi Arabia, South Africa, and the United Arab Emirates.

AUSTRALIA

Australia has agreed to prioritize the debris mitigation guidelines laid out by COPUOS but has no specific national policy toward space debris creation or the mitigation of existing debris. However, Australia has official guidelines for applicants seeking to apply for an overseas launch license that include developing a debris mitigation strategy in line with COPUOS guidelines.[31] Australia also recently brought a C-band space surveillance radar system online that will track space debris as part of its operations.[32] This is one step toward building out Australia's SSA and debris monitoring capabilities—a national priority, according to the country's new civil space strategy.[33] Better SSA data, especially from the Southern Hemisphere, will help with STM and sustainability practices globally.

AUSTRIA

Despite not having a strong space presence, Austria has detailed official policies to curtail the creation of space debris. The Austrian Outer Space Regulation states that as a condition for authorization of launch the operator must submit a detailed plan showing that provisions have been made for the mitigation of space debris, including mitigating on-orbit debris creation, preventing on-orbit collisions or breakups, and removing space objects at EOL, and that non-maneuverable objects operators must show that the orbit chosen will ensure the reentry of the object within 25-years post-mission.[34]

CANADA

Canada also has a regulatory framework to mitigate the creation of space debris. For remote sensing satellites, operators must provide an assessment of the expected debris created on orbit and a plan for disposal after EOL.[35] The Canadian Space Agency (CSA) has adopted the IADC Space

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31 Office of Outer Space Affairs, *Compendium,* 7.

32 "Western Australia ready to start tracking space debris," Engineers Australia, accessed March 20, 2020, https://www.engineersaustralia.org.au/News/western-australia-ready-start-tracking-space-debris.

33 Australian Space Agency, *Advancing Space: Australian Civil Space Strategy 2019 – 2028* (Canberra: Government of Australia, April 2019), https://publications.industry.gov.au/publications/advancing-space-australian-civil-space-strategy-2019-2028.pdf.

34 "Regulation of the Federal Minister for Transport, Innovation and Technology in Implementation of the Federal Law on the Authorisation of Space Activities and the Establishment of a National Space Registry (Outer Space Regulation)," Government of Austria, 2015, 2, http://www.spacelaw.at/wp-content/uploads/2016/05/Austrian-Outer-Space-Regulation-2015.pdf.

35 *Remote Sensing Space Systems Act*, Government of Canada, November 25, 2005, https://laws-lois.justice.gc.ca/eng/acts/r-5.4/page-1.html#h-427028.

Debris Mitigation Guidelines and intends to apply it to all CSA activities. Additionally, within licensing procedures for spacecraft that use the radio spectrum, the Canadian government requires that licensees submit a space debris mitigation plan. If the satellite will be in GEO, the plan must be in accordance with the ITU guidelines.[36]

FINLAND

In 2018, Finland enacted the Act on Space Activities, which governs any space activities on the territories or vessels registered in Finland. One of the conditions for authorization of space activities is that the operator "shall restrict the generation of space debris during normal operations" and has a plan for EOL or termination of the mission.[37] The same act also details that space activities should be carried out in a sustainable manner for the space environment. This includes that a space object must be maneuvered to a non-crowded orbit or deorbited into the Earth's atmosphere within 25 years of its EOL.[38]

FRANCE

French policies on space debris mitigation can mainly be found within the Decree on Technical Regulation issued in 2011, which focuses on launch and orbital licenses. For launch systems, the vehicle must be "designed, produced and implemented in such a way as to minimize the production of debris during nominal operations, including after the end-of-life of the launcher and its component parts."[39] However, for each payload launched, a single launcher element (such as a faring component or rocket stage) may be placed into orbit. Initially, this may seem like a limitation, but the Ariane-5 is capable of launching several payloads to orbit simultaneously. In the past five years, it has never launched less than two payloads at the same time.[40] Additionally, since the Ariane vehicles are operated by a joint venture between the ESA and France's national civil space agency they do not fall under these national restrictions.[41] The ESA is the owner of all launch infrastructure out of French Guiana, the European spaceport, including the launch site and vehicle.[42]

For orbital systems, the Decree on Technical Regulation states that these systems must also be designed, produced, and implemented in a way that avoids generating debris during nominal operations. The probability of breakup on orbit at the time of launch must be less than 1 in 1,000. Additionally, the regulations demand that once a space object has completed its mission, it must be able to safely deorbit with controlled atmospheric reentry. If it cannot deorbit, it must be sent

36 Office of Outer Space Affairs, *Compendium*, 17.

37 *Act on Space Activities*, Ministry of Economic Affairs and Employment, Government of Finland, 2018, 6, https://tem.fi/documents/1410877/3227301/Act+on+Space+Activities/a3f9c6c9-18fd-4504-8ea9-bff1986fff28/Act+on+Space+Activities.pdf.

38 Office of Outer Space Affairs, *Compendium*, 24.

39 Ibid., 25.

40 "Ariane-5," Gunter's Space Page, accessed March 25, 2020, https://space.skyrocket.de/doc_lau/ariane-5.htm.

41 About 63 percent of Arianespace's capital is held by France. The rest is unequally held by Germany, Switzerland, Sweden, Italy, Spain, Norway, the Netherlands, and Belgium. "Company Profile," ArianeSpace, accessed March 24, 2020, https://www.arianespace.com/company-profile/.

42 "Who does what?," ArianeSpace, accessed March 24, 2020, https://www.arianespace.com/spaceport-facility/who-does-what/.

into a non-usable orbit, or graveyard orbit, by 25 years after the EOL of the spacecraft.[43] This is in accordance with the ITU's protections for GEO.

INDIA

Despite being one of the foremost launching states, with six orbital launches in 2019, India does not have any specific language in national policy documents promoting space sustainability.[44] Despite this, India is focusing on further building out national SSA capabilities through developing an SSA control center dedicated to "protecting high valued space assets from space debris close approaches and collisions."[45] India is a founding member of COPUOS and a signatory to the long-term sustainability guidelines.[46]

JAPAN

In 2016, Japan published the Space Activities Act, which gives guidance on regulation and licensing of varied space activities for the Japanese commercial sector. For both satellite launch and control, non-governmental organizations need government approval. This includes pre-launch examinations for compliance and safety reasons. To obtain a license, the company must have space debris mitigation measures in line with those from the Outer Space Treaty. However, unlike some national laws, Japan has limited its scope to only launches from Japanese territory. In contrast, many other nations regulate businesses registered in their country but launching elsewhere.[47] Satellite licensees must also include plans for EOL in their application. The steps for EOL must be one of the following choices, barring any accidental explosion or malfunction on orbit: "(1) de-orbiting and re-entry to Earth, with public safety at landing ensured; (2) deploying the satellite into 'graveyard orbit'; or (3) deploying the satellite into the orbit of another celestial body or allowing the satellite to fall into the celestial body." These measures are in line with modern norms for limiting the creation of space debris.[48]

In 2017, Japan's Committee on National Space Policy, which reports directly to the Japanese prime minister, established a new task force focused on space debris. The Task Force for Space Debris is composed of Japan's state ministers and the president of the Japan Aerospace Exploration Agency (JAXA). The task force convened twice in 2019.[49]

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43 Office of Outer Space Affairs, *Compendium*, 27.

44 "Space Environment: Total Launches by Country," Aerospace Security Project, last updated January 2, 2020, https://aerospace.csis.org/data/space-environment-total-launches-by-country/.

45 Indian Space Research Organization, "Foundation stone of Space Situational Awareness Control Centre by Chairman, ISRO," Government of India, August 03, 2019, https://www.isro.gov.in/update/03-aug-2019/foundation-stone-of-space-situational-awareness-control-centre-chairman-isro.

46 Office of Outer Space Affairs, "Committee on the Peaceful Uses of Outer Space: Membership Evolution," United Nations, accessed March 20, 2020, https://www.unoosa.org/oosa/en/ourwork/copuos/members/evolution.html.

47 Setsuko Aoki, "Domestic Legal Conditions for Space Activities in Asia," *AJIL Unbound* 113 (2019): 103–108, doi:10.1017/aju.2019.14.

48 Hiroko Yotsumoto and Daiki Ishikawa, "Japan," The Space Law Review, December 2019, accessed February 4, 2020, https://thelawreviews.co.uk/edition/the-space-law-review-edition-1/1211969/japan.

49 Charity Weeden et al., "Development of global policy for active debris removal services," First International Orbital Debris Conference, 2019, 4, https://www.hou.usra.edu/meetings/orbitaldebris2019/orbital2019paper/pdf/6077.pdf.

Furthermore, JAXA was among the world's first space agencies to define national space debris mitigation guidelines. Its primary space debris mitigation standards document includes the following requirements:

- Preventing on orbit breakups of space systems after mission completion;
- Transferring GEO spacecraft into a graveyard orbit at EOL;
- Reducing the orbital lifetime in which a stage in geostationary transfer orbit (GTO) may interfere with the protected GEO region;
- Minimizing objects released on orbit during normal operations; and
- Reducing orbital lifetime after mission completion of LEO spacecraft.

JAXA applies the above guidelines and more to its own space missions and contractors on JAXA projects, but the agency does not have authority over non-JAXA space missions.[50] JAXA recently selected an emerging ADR company, Astroscale, as a commercial partner for the space agency's first debris removal demonstration.[51]

JAXA is mostly focused on civil space missions, while the Japanese Ministry of Defense focuses on military space missions. There is a great deal of technology sharing across the two agencies, and the two also share a common concern for space debris.[52]

The government of Japan is currently pursuing new programs for space debris monitoring and has established a data-sharing agreement focused on SSA between the Japanese Self-Defense Forces, JAXA, and the United States.[53] As part of this initiative, Japan has agreed to host SSA payloads from the United States on its Quasi-Zenith Satellite System (QZSS)—a national positioning, navigation, and timing (PNT) satellite constellation.[54] The QZSS program is run by the Cabinet Office rather than JAXA or the Ministry of Defense.[55]

NIGERIA

An emerging space nation with a relatively nascent space agency and only nine national satellites to date, Nigeria enacted basic national regulations to mitigate the creation of space debris. In order to obtain a license for any space activities in Nigeria, the licensee in question

50 Office of Outer Space Affairs, Compendium, 37-38; and "Space Debris Mitigation Mechanism: The Case of JAXA," UNCOPUOS Legal Subcommittee, March 23-April 3, 2009, https://www.unoosa.org/pdf/pres/lsc2009/pres-05.pdf

51 For more on Astroscale, see page 16. "Astroscale Selected as Commercial Partner for JAXA's Commercial Removal of Debris Demonstration Project," Astroscale, Press Release, February 12, 2020, https://astroscale.com/astroscale-selected-as-commercial-partner-for-jaxas-commercial-removal-of-debris-demonstration-project/.

52 "Japan to assign 100 personnel to new satellite monitoring unit," *Japan Times,* May 14, 2019, https://www.japantimes.co.jp/news/2019/05/14/national/science-health/japan-assign-100-personnel-new-satellite-monitoring-unit/#.Xg-pvbEdKiUk.

53 "Japan, US to collaborate on space surveillance," *The Mainichi*, March 30, 2019, https://mainichi.jp/english/articles/20190330/p2a/00m/0na/002000c.

54 "Joint Statement: The Sixth Meeting of the U.S.-Japan Comprehensive Dialogue on Space," Government of Japan, July 24, 2019, 2, https://www.mofa.go.jp/mofaj/files/000501699.pdf.

55 "Basic Policy on the Implementation of the Operational Quasi-Zenith Satellite System (QZSS) Project," Government of Japan Cabinet Decision, September 30, 2011, https://www8.cao.go.jp/space/english/basicpolicy.html.

must show that it can conduct its space operations in such a way as to mitigate the creation of space debris and govern the disposal of the spacecraft at its EOL. However, there are few specifics on exactly what constitutes safe operations in space or how and when to dispose of dying spacecraft.[56]

UKRAINE

Ukraine also has specific laws addressing space debris mitigation. In the Law of Ukraine on Space Activity, the government institutes several technical regulations in order to mitigate the creation of space debris. This includes: eliminating or minimizing space debris creation during normal operations of a spacecraft; minimizing the possibility of breakups on orbit, including at EOL of a spacecraft; removal of a spacecraft and launch vehicle from orbit at completion of mission; and preventing in-space collisions in near-Earth space.[57] While Ukraine is not a member of COPUOS, nor has it adopted the recent COPUOS guidelines for space sustainability, there were Ukrainian representatives present at the final working session to adopt the guidelines for the long-term sustainability of outer space activities.[58]

THE UNITED KINGDOM

For the United Kingdom, the national policy mechanism for space activities, which includes measures for space sustainability, is the Outer Space Act of 1986. In order to obtain a license from the secretary of state, the licensee must conduct operations in a way that will prevent or mitigate the creation of space debris. The license applicant must show quantitative and qualitative analysis on the potential hazards for not only the launch and on-Earth operations but also hazards posed to other on-orbit spacecraft. Applicants are also required to demonstrate that they are in line with the current best practices relating to space debris mitigation, including several international mechanisms, such as the IADC Space Debris Mitigation Guidelines, the COPUOS guidelines, and other international standards for space debris mitigation.[59]

MULTINATIONAL ACTIVITIES

THE EUROPEAN SPACE AGENCY

In 2014, the ESA updated its Space Debris Mitigation Policy, which was originally released in 2008. The 2014 update focused on minimizing the impact of operations in the space environment, reducing the risk of collision on orbit, and ensuring safe reentry of spacecraft. This document sets forth specific technical standards for risk of reentry.[60]

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56 Office of Outer Space Affairs, *Compendium*, 42.

57 Ibid., 54.

58 Office of Outer Space Affairs, *Report of the Committee on the Peaceful Uses of Outer Space: Sixty-second session* (New York: United Nations, June 2019), https://www.unoosa.org/res/oosadoc/data/documents/2019/a/a7420_0_html/V1906077.pdf.

59 "Licence to operate a space object: how to apply," Government of the United Kingdom, April 16, 2014, last updated September 3, 2019, https://www.gov.uk/guidance/apply-for-a-license-under-the-outer-space-act-1986.

60 "Space Debris Mitigation Policy for Agency Projects," ESA's Director General's Office, March 24, 2014, https://www.iadc-home.org/documents_public/view/id/121#u.

A year later, the ESA released the ESA Space Debris Mitigation Compliance Verification Guidelines. These guidelines provide detailed information on verification methods and implementation of mitigation measures for ESA projects.[61]

The ESA lays out future space sustainability goals on their website. These goals include: having a fleet of spacecraft by 2030 that are resilient to the threat of space debris; having the ability to monitor and safely manage traffic in space, including being able to clean or dispose of existing debris in popular orbits; and developing an "Automated Collision Avoidance System" to ensure no damage is caused that creates new debris. The ESA also plans on developing an ADR system that can act as both an OOS satellite, possibly extending the life of spacecraft on orbit, and as a cleaning unit that will be able to deorbit or move satellites into non-popular orbits for the safety of other space missions.[62]

One ADR system sponsored by the ESA is through a Swiss company called ClearSpace. Their first demonstration satellite, *ClearSpace-1*, is scheduled to launch in 2025. *ClearSpace-1* will perform proximity operations to approach its target, extend tentacle-like arms to grab the target, and use its own propellant to deorbit both itself and the target—burning up both systems in the Earth's atmosphere on descent.[63]

ESA Director General Jan Woerner recently announced that he strongly believes all satellite operators—including nation states and companies—should act to mitigate the creation of new debris now and not wait for international regulations. Woerner is particularly concerned about the amount of planned mega constellations, such as those planned by SpaceX and OneWeb.[64] Specific direction from the director general may push the ESA, and its member states, to take stronger actions to prevent the creation of space debris or to mitigate the amount of debris already on orbit.

EUROPEAN UNION

Through the European Union's multinational foreign policy and security service, the European External Action Service, the European Union is also focusing efforts on mitigating space debris. This effort is known as the Safety, Security and Sustainability of Outer Space (3SOS) initiative and intends to promote ethical conduct, particularly focused on limiting and mitigating the amount of debris in space.[65] Special Envoy for Space and Head of the European External Action Service Space Task Force Carine Claeys stated in early September 2019 that she believed the commonly-

61 Ibid.

62 "Plans for the Future," ESA, accessed March 20, 2020, http://www.esa.int/Safety_Security/Plans_for_the_future.

63 Andrew Jones, "European Space Agency Targets Orbital Debris, Solar Storms," IEEE Spectrum, January 22, 2020, https://spectrum.ieee.org/tech-talk/aerospace/satellites/european-space-agency-esa-mission-news-orbital-debris-solar-storms.

64 Debra Werner, "ESA Director General calls for aggressive action on space debris," Space News, November 19, 2019, https://spacenews.com/woerner-debris-regulation/.

65 "SOS SOS SOS: EU calls for ethical conduct in space to avoid collision and orbital debris," European External Action Service, September 19, 2019, https://eeas.europa.eu/headquarters/headquarters-homepage/67538/sos-sos-sos-eu-calls-ethical-conduct-space-avoid-collision-and-orbital-debris_en.

practiced norm of deorbiting 25 years post EOL, especially in LEO, was outdated.[66] This echoes sentiments from much of the space policy community and could be one of the first items on the docket for this new task force.

INDUSTRY EFFORTS

Without coherent international attention until recently, several space companies have been leading voices in sustainability and debris removal best practices. Planet, a U.S. satellite company, has spoken publicly about its commitment to a sustainable space environment and the requirement for the company to produce no long-lasting space debris. Planet ensures its constellations of Earth observation satellites are in low orbits so that they will deorbit easily and burn up in the Earth's atmosphere. Additionally, the company pledges that no debris from their products will be created during launch or on-orbit operations.[67]

American company OneWeb announced in December 2019 its intent to place grappling fixtures on its constellation of LEO communications satellites. These fixtures, developed by Altius Space Machines, will allow for the OneWeb constellation to engage in both satellite-servicing and EOL disposal. OneWeb executive Tim Maclay stated, "It is critical we do all we can to employ responsible design and operational practices to ensure a sustainable environment for future generations."[68]

Iridium Communications also wants to be a leader in space sustainability efforts. The company is particularly responsible in its deorbiting and EOL measures.[69] Iridium often deorbits satellites within 30 days of the end of the mission. Recently, Iridium CEO Matt Desch also acknowledged that Iridium would be willing to pay for ADR services for its existing and future fleet of satellites.[70]

Space sustainability and the threat of space debris impacting future space operations has also led to several new space companies focused on ADR or EOL maintenance. For Astroscale, a Japanese company, the desire to mitigate debris in space is foundational for its business case. Astroscale is developing a fleet of satellites to perform ADR and EOL deorbiting services. The company plans to launch an initial test in 2020 that includes two satellites—a retriever satellite and a target. The retriever satellite is capable of performing rendezvous and proximity operations and carries a magnetic plate in order to dock with the target satellite carrying a matching magnetic plate.[71]

66 "3SOS initiative: a new public diplomacy initiative for safety, security and sustainability of outer space activities," European External Action Service, October 18, 2019, https://eeas.europa.eu/headquarters/headquarters-homepage_bg/69068/3SOS%20initiative:%20a%20new%20public%20diplomacy%20initiative%20for%20safety,%20security%20and%20sustainability%20of%20outer%20space%20activities.

67 "Code of Ethics," Planet, accessed March 2, 2020, https://www.planet.com/ethics/.

68 "OneWeb and OneWeb Satellites bolster commitment to Responsible Space with advanced grappling technology from Altius Space Machines," OneWeb, December 10, 2019, https://www.oneweb.world/media-center/oneweb-and-oneweb-satellites-bolster-commitment-to-responsible-space-with-advanced-grappling-technology-from-altius-space-machines.

69 Jeff Foust, "Iridium to complete next-generation satellite deployment by this fall," Space News, May 14, 2018, https://spacenews.com/iridium-to-complete-next-generation-satellite-deployment-by-this-fall/.

70 Caleb Henry, "Iridium would pay to deorbit its 30 defunct satellites — for the right price," Space News, December 30, 2019, https://spacenews.com/iridium-would-pay-to-deorbit-its-30-defunct-satellites-for-the-right-price/.

71 "ELSA-d," Astroscale, accessed March 5, 2020, https://astroscale.com/missions/elsa-d/.

This indicates that Astroscale's technology may only be able to "clean-up" satellites that have been outfitted with one of its magnetic plates prior to launch. However, the company acknowledges that a market exists to remove debris already on orbit, and it is working with national space agencies and international bodies to assist with a solution.[72]

In October 2019, the Satellite Industry Association (SIA) released its own space sustainability guidance entitled the Principles of Space Safety for Space Actors. The SIA is a U.S.-based trade association representing dozens of leading satellite companies. These principles are dedicated to cooperating and communicating with national space agencies, key regulatory agencies, and the United Nations. It also recommends implementing measures such as designing geostationary objects that are trackable, providing a 24/7 point of contact in the case of a potential collision of satellites, and minimizing the intentional creation of debris on launch and on orbit.[73]

Finally, a coordinated effort led by the World Economic Forum (WEF) has brought together several stakeholders in order to create a Space Sustainability Rating (SSR), including the ESA, Massachusetts Institute of Technology's Media Lab, University of Texas at Austin, and Bryce Space and Technology. This initiative is in the early stages, with these organizations working to define the technical elements and operation of the SSR.[74] The rating is likely to include the physical elements of a satellite as well as its concept of operations for avoiding potential collisions and EOL disposal. The SSR has had positive feedback from the international space community, including the space industry.[75]

PRESSING CONCERNS

A concern expressed by several in the space community is that real efforts to protect the space domain will not occur until another major debris-creating event occurs. It is possible that the next collision that creates hundreds or thousands of pieces of debris on orbit could resemble the Iridium-Cosmos collision in 2009. In that incident, an active commercial satellite, *Iridium-33*, collided with an inactive Russian satellite, *Cosmos-2251*, creating 1,875 pieces of debris large enough to track (greater than 10 cm).[76] To date, about 1,300 pieces of trackable debris remain on orbit from this collision.[77] But without international standards and norms to build on, even a devastating debris-creating event may not be enough to spur international action.

However, there is a strong industry and multinational consensus that protecting the space environment and focusing on efforts to mitigate the creation of new space debris should be an international priority. This can be seen in the strong support of the recent COPUOS guidelines for

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72 "Active Debris Removal (ADR)," Astroscale, accessed March 5, 2020, https://astroscale.com/missions/active-debris-removal-adr/.

73 "Principles of Space Safety for the Commercial Satellite Industry," Satellite Industry Association, October 22, 2019, https://sia.org/space_safety/.

74 "Space Sustainability Rating," World Economic Forum, accessed March 24, 2020, https://www.weforum.org/projects/space-sustainability-rating.

75 Jeff Foust, "Work advances on space sustainability rating," Space News, January 20, 2020, https://spacenews.com/work-advances-on-space-sustainability-rating/.

76 Weeden, "2009 Iridium-Cosmos Collision Fact Sheet."

77 Author analysis using T.S. Kelso's Celestrak Visualizer. "Celestrak Orbit Visualization," Celestrak, accessed March 26, 2020, https://celestrak.com/.

space sustainability. Ninety-one world powers have agreed to follow these guidelines and best practices. This includes the largest spacefaring nations—the United States, Russia, and China—which notoriously disagree on many UN space resolutions.

The last guideline in the UN Guidelines for the Long-term Sustainability of Outer Space Activities hits on the contentious issue of who, if anyone, is responsible for cleaning up existing space debris. The guideline does not suggest responsibility, but the burden of cleaning up a polluted environment would certainly be a sizable cost for any nation or company and lead to higher insurance costs. Therefore, a likely area of contention is exactly who is responsible for clearing the growing debris cloud.

Rendezvous and Proximity Operations

Rendezvous and proximity operations, commonly referred to as RPOs, often refer to a spacecraft intentionally maneuvering to dock or operate in close proximity to a target space object. According to an Aerospace Corporation report, an "RPO generally refers to orbital maneuvers in which two spacecraft arrive at the same orbit and approach at a close distance. This rendezvous may or may not be followed by a docking procedure."[78]

However, like SSA and STM, there is no international consensus on a definition or homogenous concept of activities that can be classified as an RPO.[79] A U.S.-led group called the Consortium for Execution of Rendezvous and Servicing Operations (CONFERS) has defined rendezvous as the "process wherein two space objects (artificial or natural body) are intentionally brought close together through a series of orbital maneuvers at a planned time and place." The group also defines proximity operations as a "series of orbital maneuvers executed to place and maintain a spacecraft in the vicinity of another space object on a relative planned path for a specific time duration to accomplish mission objectives."[80]

RPOs are foundational for several key space activities, such as on-orbit servicing and refueling, docking with space stations for human spaceflight, and ADR. In the next decade, RPO maneuvers will likely become commonplace due to several OOS and ADR projects planned both by governments and private industry. Furthermore, two of the largest spacefaring nations are both planning long-term projects that will rely on RPOs to fully function: the new Chinese space station and the American Lunar Gateway project. With the projected increase in frequency of these activities, there have been calls for international standardization of RPO interactions.

Another consideration is that the RPO technology needed for OOS activities or EOL disposal is similar to the technology needed for an effective co-orbital antisatellite (ASAT) weapon. Co-orbital ASATs may perform RPOs in order to physically collide or detonate near a satellite or maneuver near enough to interfere with the target's electronics or communications.[81] Normalizing RPO behaviors may help build trust or confidence in satellite operators' RPO intentions or to

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78 Rebecca Reesman and Andrew Rogers, *Getting in your Space: Learning from Past Rendezvous and Proximity Operations* (El Segundo, CA: Aerospace Corporation, May 2018), 2, https://aerospace.org/sites/default/files/2018-05/GettingInYour-Space.pdf.

79 Committee on the Peaceful Uses of Outer Space, "Meeting hosted by Switzerland on possible further work on the long-term sustainability of outer space activities: Background and Chair's Summary," United Nations, June 12-21, 2019, 4, https://www.unoosa.org/res/oosadoc/data/documents/2019/aac_1052019crp/aac_1052019crp_16_0_html/AC105_2019_CRP16E.pdf.

80 "Guiding Principles for Commercial Rendezvous and Proximity Operations (RPO) and On-Orbit Servicing (OOS)," CONFERS, November 7, 2018, 2, https://www.satelliteconfers.org/wp-content/uploads/2018/11/CONFERS-Guiding-Principles_7Nov18.pdf.

81 Todd Harrison, Kaitlyn Johnson, and Thomas G. Roberts, *Space Threat Assessment 2019* (Washington, DC: CSIS, April 2019), 2-7, https://aerospace.csis.org/wp-content/uploads/2019/04/SpaceThreatAssessment2019-compressed.pdf.

discriminate between a planned and peaceful RPO and one that may have nefarious intent. Despite the increasing need, no national or international policies explicitly regulate RPOs.[82]

REACTIONS TO RUSSIAN RENDEZVOUS AND PROXIMITY OPERATIONS

A Russian satellite in GEO has become notorious for skirting the line between acceptable and unacceptable behavior on orbit when it comes to RPOs. *Olymp-K*, commonly also known as *Luch*, frequently performs maneuvers in GEO, a region often characterized by its "stationary" attributes. Thus far in its operational lifetime, *Luch* has stopped at 19 orbital locations in the GEO belt.[83] To have more than two or three orbital locations on the GEO belt throughout a satellite's lifetime is uncommon for any GEO satellite.

In 2015, *Luch* positioned itself between two satellites operated by a U.S. communications company, Intelsat.[84] According to SSA data, the two Intelsat satellites were likely in the same orbital slot and only separated by approximately 150 km in the geostationary belt.[85] This close approach could allow for the observation or inspection of the Intelsat satellites or the interception of cross-link or uplink communications to the satellites. At the time, Kay Sears, president of Intelsat General, commented that this was not "normal behavior" and that the company was "concerned."[86] Later, in September 2015, *Luch* approached a third Intelsat satellite.[87]

In 2017, *Luch* again caused international outcry for maneuvering near a French-Italian military satellite, *Athena-Fidus*. This RPO caused French Minister of the Armed Forces Florence Parly to accuse Russia of performing espionage on *Athena-Fidus*. Similar to the Intelsat incident, it is possible *Luch* was observing or intercepting communications.[88] Space expert Jonathan McDowell tracked *Luch's* RPO in GEO and concluded that in reality *Luch* was parked nearer to a Pakistani satellite dubbed *Paksat-1R*. However, unlike France, there was no official outcry from the Pakistan government about the abnormal behavior.[89]

France responded to the *Luch* rendezvous with a national refocus on space. The nation created a new space command within the French air force focused on defending national space assets. This includes developing active defense measures, such as investing in "bodyguard" satellites

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82 Reesman and Rogers, "Getting in your Space," 4.

83 This data was updated as of January 2020. Todd Harrison, Kaitlyn Johnson, Thomas G. Roberts, Tyler Way, and Makena Young, Space Threat Assessment 2020 (Washington, DC: CSIS, March 2020), 24, http://aerospace.csis.org/sta2020.

84 Mike Gruss, "Russian Satellite Maneuvers, Silence Worry Intelsat," Space News, October 9, 2015, https://spacenews.com/russian-satellite-maneuvers-silence-worry-intelsat/.

85 This approximation was derived from 0.2 degrees longitude on the geostationary belt. The formula used was distance = 2 * orbital radius * Sin (0.5 * angular separation). In this particular case, the orbital radius is 42,164 km at GEO and the angular separation is 0.2 degrees.

86 Gruss, "Russian Satellite Maneuvers, Silence Worry Intelsat."

87 Harrison, Johnson, and Roberts, *Space Threat Assessment 2019*, 21.

88 Ibid., 21-22.

89 Jonathan McDowell, Twitter Post, September 7, 2018, 3:30PM, https://twitter.com/planet4589/status/1038147610073341953?lang=en.

to protect national space assets, such as *Athena-Fidus*.[90] These bodyguard smallsats would be responsible for monitoring and observing the space around French satellites and reporting or taking pictures of an object that enters into their proximity.[91] Florence Parly announced that she had also requested cameras be integrated on France's two new military communications satellites, destined for GEO in the early-2020s. France is also investing in a new space academy to coalesce space-focused military training courses, promote space careers, and develop a new cadre of military space professionals. They expect to one day have a space-focused military general.[92]

However, the geostationary belt is not the only place where Russia is conducting extensive RPOs. Russian satellite *Cosmos 2543* launched on November 25, 2019. *Cosmos 254*3 was described as entering an orbit "from which the state of domestic satellites can be monitored" by the Russian Ministry of Defense.[93] Within two weeks after launch, the Ministry of Defense announced that a subsatellite had been deployed from *Cosmos 2543*, dubbed *Cosmos 2542*. This is not the first time Russia has deployed a subsatellite.

Only three days later, *Cosmos 2542*, the subsatellite, performed an orbital maneuver in order to synchronize its orbit with a U.S. government satellite, *USA 245*. Amateur satellite trackers observed and shared orbital observations online that *Cosmos 2542* appeared to be trailing *USA 245*. *USA 245* soon performed its own irregular maneuver, possibly to drop *Cosmos 2542* off its tail.[94] However, in January 2020, *Cosmos 2542* maneuvered once again toward *USA 245*, coming as close as 50 km from the American satellite.[95] After this flyby, *USA 245* maneuvered once more to distance itself from the Russian subsatellite.[96] General John Raymond, commander of U.S. Space Command and chief of space operations of the U.S. Space Force, indicated in a later press interview that he believed the actions of *Cosmos 2542* were intentional.[97]

What these two encounters highlight is that there is little to no definition of what is a normal RPO behavior or how satellite operators may discriminate between a normal maneuver and a nefarious one.

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90 Brian G. Chow and Henry Sokolski, "The United States should follow France's lead in space," Space News, September 9, 2019, https://spacenews.com/the-united-states-should-follow-frances-lead-in-space/.

91 Gosnold, "Space Situational Awareness news from the Paris Airshow," SatelliteObservation.net, June 20, 2019, https://satelliteobservation.net/2019/06/20/space-situational-awareness-news-from-the-paris-airshow/.

92 Florence Parly, "Présentation de la stratégie spatiale de défense," (speech, Paris, France, July 25, 2019), https://satelliteobservation.files.wordpress.com/2019/07/discours-de-florence-parly-prc3a9sentation-de-la-stratc3a9gie-spatiale-de-dc3a9fense-c3a0-lyon-le-25-juillet-2019.pdf.

93 "Orbital Launches of 2019," Gunter's Space Page, 2020, https://space.skyrocket.de/doc_chr/lau2019.htm; Ministry of Defence of the Russian Federation, "Russian Aerospace Forces successfully launches Soyuz-2 lanch vehicle from Plesetsk Cosmodrome," Russian Federation, November 26, 2019, http://eng.mil.ru/en/news_page/country/more.htm?id=12263690@egNews.

94 Anatoly Zak, "Soyuz-2-1v Launches Classified Payload," Russian Space Web, January 29, 2020, accessed on February 2, 2020, http://www.russianspaceweb.com/cosmos-2542.html.

95 Jonathan McDowell, Twitter post, January 31, 2020, 8:37 p.m., https://twitter.com/planet4589/status/1223420130576818176.

96 Michael Thompson, Twitter post, January 31, 2020, 11:40 p.m., https://twitter.com/M_R_Thomp/status/1223466202967760896.

97 Sandra Erwin, "Raymond calls out Russia for 'threatening behavior' in outer space," Space News, February 10, 2020, https://spacenews.com/raymond-calls-out-russia-for-threatening-behavior-in-outer-space/.

INDUSTRY STANDARDS

As more commercial companies build their business plans around RPO capabilities, the need for defined and internationally accepted norms of behavior grows. RPOs are foundational for OOS and ADR missions, and companies such as Surrey Satellite and Astroscale are developing technologies without guidance from the international community on accepted behavior or even reporting of RPO maneuvers.

Although there are not many international industry-led initiatives focused on RPOs, a successful ongoing mechanism in the United States may illuminate particular industry concerns. CONFERS is an industry-led initiative supported by the U.S. Department of Defense's Defense Advanced Research Projects Agency (DARPA). CONFERS "aims to leverage best practices from government and industry to research, develop, and publish non-binding, consensus-derived technical and operations standards for OOS [on-orbit servicing] and RPO."[98] CONFERS is working with over 30 global industry corporations to develop these technical and operations standards.[99] In October 2019, CONFERS released Recommended Design and Operational Practices as a first step to implementing the CONFERS Guiding Principles for Commercial Rendezvous, Proximity Operations and On-Orbit Servicing (OOS).[100] CONFERS guiding principles focus on consensual operations, compliance, responsible operations, and transparency.[101] However, no national governments have officially commented on recommendations from CONFERS thus far, likely because the effort is still ongoing.

INTERNATIONAL ENGAGEMENT

There has been little engagement in the United Nations or other international mechanisms focused on defining standards or norms of behaviors for RPOs. The UN sustainability guidelines encourage states and international intergovernmental organizations to consider providing timely and appropriate information on changes in operating status of their satellites. This includes providing information about changes on orbital position, but not specifically RPOs.[102] In a COPUOS meeting hosted by Switzerland in June 2019, meeting notes indicate that part of the discussion on long-term sustainability of outer space activities focused on RPOs. While discussion indicates that there may be interest in developing multinational efforts focused on better monitoring and regulating RPOs to include sharing information about RPO activities on-orbit, including notification, the details from the meeting are minimal, and there is no indication which countries may support these efforts. However, "[t]he modalities of such notifications (by who? to whom? including which information? according to which timing?) would need to be discussed by COPUOS."[103]

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98. David A. Barnhart et al., "Using Historical Practices to Develop Safety Standards for Cooperative On-Orbit Rendezvous and Proximity Operations," 69th International Astronautical Congress (IAC), October 1-5, 2018, 1, https://www.isi.edu/sites/default/files/centers/serc/CONFERS_IAC_Paper_PUBLISH.PDF.

99. "Current Members," CONFERS, accessed January 8, 2020, https://www.satelliteconfers.org/members/.

100. "Guiding Principles for Commercial Rendezvous and Proximity Operations (RPO) and On-Orbit Servicing (OOS)," CONFERS; and "CONFERS Recommended Design and Operational Practices," CONFERS, October 1, 2019, https://www.satelliteconfers.org/wp-content/uploads/2019/10/CONFERS_Operating_Practices.pdf.

101. "Guiding Principles for Commercial Rendezvous and Proximity Operations (RPO) and On-Orbit Servicing (OOS)," CONFERS.

102. Committee on the Peaceful Uses of Outer Space, *Guidelines for the Long-term Sustainability of Outer Space Activities, 9*.

103. Committee on the Peaceful Uses of Outer Space, "Meeting hosted by Switzerland on possible further work on the

One ongoing effort of international engagement for normalizing operations in space—which could potentially include RPOs—is the Woomera Manual on the International Law of Military Space Operations. The Woomera Manual is an ongoing academic effort to "articulate and clarify extant law applicable to military activities associated with the space domain, especially that which is relevant in periods of tension (when States and non-State actors may consider using force) or outright hostilities." These efforts are being undertaken by researchers from the University of Adelaide, University of Exeter, University of Nebraska College of Law, and University of New South Wales in Canberra.[104]

Another international ongoing academic effort to better define the legal structure of operating in space is the Manual on International Law Applicable to Military Uses of Outer Space (MILAMOS) project. This effort is led by McGill University, supported by the Canadian government, and is partnering with international institutions from China, Germany, India, the United States, Russia, and Australia.[105] Similar to the Woomera Manual, the MILAMOS project is not solely focusing on RPOs but on a wide range of international law that may include norms of behavior for missions involving RPOs.[106]

In late 2019, the ESA announced a contract for independent organizations to bid on a project that will "define requirements and guidelines for close-proximity orbital operations to ensure safe rendezvous and capture operations." The overall goal of this new Safe Rendezvous and Proximity Operations' Technology Research Programme is to take into account all possible aspects of RPO activities and create consistent guidelines to ensure safety and sustainability of the space environment. Despite the bid closing date in August 2019, there has been no announcement regarding which organization will lead the program.[107]

The ISO is also currently working on a draft for review on programmatic principles and practices of RPOs and OOS missions. This is in part to contribute to the UN Sustainable Development Goals.[108] As of February 2020, the draft was under review by experts from Brazil, France, Germany, Japan, Russia, Ukraine, the United Kingdom, and the United States. The expectation at that time was for a vote to occur in April 2020 to move the draft to a full committee draft stage.[109] Despite this initial work, there is little further detail on what the draft may contain or how it might evolve in the ongoing process.

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long-term sustainability of outer space activities."

104. "The Woomera Manual on the International Law of Military Space Operations," University of Adelaide, October 2018, https://law.adelaide.edu.au/woomera/system/files/docs/Woomera%20Manual.pdf.

105. "Manual on International Law Applicable to Military Uses of Outer Space: Partner and Collaborating Institutions," McGill University, accessed January 10, 2020, https://www.mcgill.ca/milamos/partner-institutions.

106. Ibid.

107. Jessica, "Writing the rules on close-proximity orbital operations," ESA, July 8, 2019, http://blogs.esa.int/cleans-pace/2019/07/08/writing-the-rules-on-close-proximity-orbital-operations/.

108. "ISO/AWI 24330: Space systems — Rendezvous and Proximity Operations (RPO) and On Orbit Servicing (OOS) — Programmatic principles and practices," International Organization of Standardization, accessed March 24, 2020, https://www.iso.org/standard/78463.html.

109. Brian Weeden, "Update on the Consortium for Execution of Rendezvous and Servicing Operations (CONFERS)," United Nations Office of Outer Space Affairs, February 6, 2020, https://www.unoosa.org/documents/pdf/copuos/stsc/2020/tech-15E.pdf.

LIKELY OUTCOMES

Unlike space debris mitigation, national and international conversations on best practices surrounding RPOs appear to be in the initial stages. Most of the focus is on the offensive and defensive effects of RPO activities, and little movement to create standards or norms of behavior has progressed. One area where the international community—along with the United States—could make headway is to have a consensual definition on what an RPO is and what kinds of boundaries need to be set to protect one's assets in space. With increasingly transparent satellite activities due to worldwide investments in SSA, it may be possible to develop a standard operating procedure to make the international community aware when one country or company is conducting a cooperative RPO. Additionally, setting distance guidelines for intentional maneuvers by satellite operators for uncooperative or uncoordinated RPOs could help protect satellites and distinguish between an attack and a necessary or routine space operation.

As more countries and companies create operational OOS and ADR satellites, notification of an imminent RPO may become more necessary. Experts' concerns focus on the lack of normal behavior or standards with RPOs on orbit. Another proposed option for establishing norms of behavior or international standards is to require a notification of maneuvering a spacecraft. This could be similar to a notice to airmen (NOTAM)—a notice filed with an aviation authority to inform aircraft of potential hazards or operations in the area. Some space experts believe this is a smart place to start introducing regulations on RPOs, with international notifications if an operator intends to maneuver its spacecraft.[110]

Experts at the Aerospace Corporation have expressed similar concerns for the need to establish international norms of behavior or technical standards for RPOs. They assess that with ever-crowded orbits and mission lifetime extension opportunities through OOS, internationally sanctioned rules for safe and transparent interactions are needed. A 2018 report highlights that several technical standards have already been agreed upon by some spacefaring nations through documents for the International Space Station (ISS). For the ISS, there is a 4 km nominal approach ellipsoid for active satellites. This acts as a defined barrier for ISS operators to watch and monitor satellites that might come within that space. Additionally, the ISS has a defined 200 m "keep out zone."[111] Only preapproved spacecraft—such as a Soyuz capsule bringing new astronauts to the station—may enter this zone and are carefully tracked and monitored. Even during final approach, spacecraft are required to stay at least 2 m away from the space station. Spacecraft are then manually maneuvered to dock with the ISS with a robotic arm, the CanadArm.[112] While the situation with the ISS is different from other proposed RPOs, the Aerospace Corporation suggests that these rules could be a foundation for developing internationally agreed-upon standards. The ISS consortium of nations includes Canada, Japan, Russia, the United States, and 11 countries of the ESA: Belgium, Denmark, France, Germany, Italy, the Netherlands, Norway, Spain, Sweden, Switzerland, and the United Kingdom.

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110. James A. Vedda and Peter L. Hays, *Major Policy Issues in Evolving Global Space Operations* (Alexandria, VA: Mitchell Institute for Aerospace Studies, February 2018), 45, https://aerospace.org/sites/default/files/2018-05/Space_Policy_FINAL_interactive_0.pdf.

111. The idea of a keep out zone for satellites is often compared to similar standards in the maritime domain.

112. Reesman and Rogers, "Getting in your Space," 1.

POTENTIAL CHALLENGES

The largest challenge for standards on RPO behavior is perhaps national recognition of the issue. There are currently no explicit national policies or statements on RPO activities for civil, commercial, or military space missions. Thus far, there have only been cases of nations calling out one another for unusual or unwelcomed behavior.

Several nations, including Russia, China, and the United States, may be wary of restricting their sovereignty and current freedom of action in space. These nations may not be willing to sign onto an alert system or keep-out zone for several reasons. For example, it could inhibit technology development or emergency servicing of a satellite. These restrictions may also limit activities these nations see as ensuring their own national security—such as the inspection or verification of satellites on orbit, both their own and others'.

Private companies may also voice similar technology development concerns. Business cases built around RPO maneuvering are still fragile, and the space industry is waiting to see if the technology and use cases can be successfully proven and if the price of these services will be reasonable. OOS only succeeds if the servicing that can guarantee life extension of a satellite already on orbit is less costly than the remaining value of the satellite it is servicing. For large exquisite satellites, this may be an easier case to close. But if a company such as SpaceX is launching 60 Starlink satellites a month, its mass-production line likely means the cost of launching a new satellite to replace an old or non-responsive one is lower than paying for an OOS mission. While there are several suggestions for regulating RPO activities, the hurdles for international barriers are high.

Insurance Requirements for Space Missions

Insurance for space missions is increasingly required in some form or fashion by various nations. The issue of liability in space is challenging and stems from unclear, and in some respects outdated, guidance in the Outer Space Treaty of 1967. In the treaty, states are responsible for "national space activities whether carried out by governmental or non-governmental entities" and are "liable for damage caused by their space objects."[113] This clause, along with the 1972 UN Convention on International Liability for Damage Caused by Space Objects (commonly referred to as the Liability Convention), makes clear that states are responsible for both their own actions in space and those of private enterprises, if launched from their territory. The Liability Convention makes clear that a nation is liable for damage to third parties arising out of its space activities.[114] Most of the national policies described in this section were created to pass along potential costs from the launching state to the private actor in the case of a liability claim. This has led to states self-insuring their own space activities as well as the rise of private insurance for commercial space activities. For a commercial company, purchasing insurance is often the third-highest cost for the satellite operator, after the cost of the satellite itself and the cost of launch.[115]

FUNDAMENTALS OF SPACE INSURANCE

Like all insurance, the fundamental value of space insurance is to manage risk and protect against financial loss. The space business remains a risky business. There are many critical points of failure, and until new technologies such as OOS emerge, very few mechanisms exist for correcting an on orbit failure on a satellite. Even new technologies designed to reduce risks, such as OOS, can introduce new risks to satellites and the missions they support. Space insurance can cover a variety of these risks, including launch failure, deployment failure, and mission failure. The most common form of independent insurance is "launch plus one," or the coverage of the launch of the satellite into orbit and one year of its operations. Launch plus one covers the highest-risk phase of a satellite's lifetime. Using analysis from the Aerospace Corporation, the table below depicts a more detailed assessment of types of space insurance.[116]

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113. Office of Outer Space Affairs, "Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies," United Nations, https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/introouterspacetreaty.html.

114. Office of Outer Space Affairs, "Convention on International Liability for Damage Caused by Space Objects," United Nations, November 29, 1971, https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/introliability-convention.html.

115. Lindsay D. Chaney and Nicholas S. Hirano, *End of an Era? Satellite Insurance Faces Changing Landscape* (El Segundo, CA: Aerospace Corporation, November 2019), 2, https://aerospace.org/sites/default/files/2019-11/Chaney_SatelliteInsurance_11132019.pdf.

116. Ibid.

<table>
<tr><th colspan="4">TYPES OF INSURANCE COVERAGE FOR SATELLITES</th></tr>
<tr><th>PRE-LAUNCH</th><th>THIRD-PARTY LIABILITY</th><th>LAUNCH</th><th>ON ORBIT</th></tr>
<tr><td rowspan="2">Coverage includes damage to satellite or space launch vehicle during manufacturing, transportation, assembly, and processing phases. All prior to launch.</td><td rowspan="2">Coverage protects satellite operators from claims from third parties for injury or property damages during pre-launch, or on orbit activities.</td><td colspan="2">Launch Plus One Year</td></tr>
<tr><td>Coverage includes loss, damage, or failure of satellite. This coverage begins at the initial ignition of the rocket through the separation of the payload from the launch vehicle.</td><td>Coverage includes complete or partial failure of the satellite during its operational lifetime. Coverage begins after initial separation of the satellite from the launch vehicle. Coverage is typically renewed annually.</td></tr>
</table>

SPACE INSURANCE INDUSTRY

Space insurance originally began as a subset of the aviation insurance industry. However, insurers quickly realized the need for a separate specialized sector of insurance focused on space. The differences between the risk levels and technologies involved in aviation and space were too different for the lines of effort to remain together.[117]

In 2018, the International Union of Aerospace Insurers reported over 60 percent of commercial launches to orbit were insured. This is in comparison to 2010, when about 36 percent of commercial launches to orbit were insured.[118] As of January 2019, 212 of the 492 active satellites in GEO were insured—about 43 percent of active GEO satellites at the time. Of these, only 23 percent of GEO operators buy little to no insurance beyond launch plus one. In LEO, only 95 satellites of 1,715 total active satellites were insured—about 5.5 percent.[119]

Despite advances in increasing the success rates of launch, the insurance community has been suffering the past few years, paying out more claims than the annual premiums cover. For example, there were about $600 million in insurance claims in 2018 from failed launches or on orbit failures. According to Seradata, a UK-based firm that tracks international space insurance claims, premiums for 2018 only totaled about $460 million—a nearly $140 million loss for the international space insurance market.[120] A July 2019 launch failure is the largest single claim to date, almost $415 million for the United Arab Emirates' *Falcon Eye 1* imaging satellite.[121] The International Union of Aerospace Insurers expects this trend to continue.[122]

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117. Katarzyna Malinowska, *Space Insurance: International Legal Aspects* (Alphen aan de Rijn, The Netherlands: Kluwer Law International B. V., 2017).

118. Schenone, "2019 Space Insurance Update," 11.

119. Ibid., 8.

120. Caleb Henry, "Big claims, record-low rates: Reshaping the space insurance game," Space News, September 6, 2019, https://spacenews.com/big-claims-record-low-rates-reshaping-the-space-insurance-game/.

121. Jeff Foust, "Space insurance rates increasing as insurers review their place in the market," Space News, September 14, 2019, https://spacenews.com/space-insurance-rates-increasing-as-insurers-review-their-place-in-the-market/.

122. Robert Schenone, "2019 Space Insurance Update," International Union of Aerospace Insurers, June 2019, 15, 19, and

Swiss Re, one of the leading providers of reinsurance and insurance, announced in 2019 that it would be pulling out of the space insurance market. This was due to the "bad results of recent years and unsustainable premium rates." According to insurance experts, the space insurance market is facing, and will continue to face, rough conditions as new insurance providers get into space insurance, GEO satellite missions transfer to LEO constellations, and the overall prices of satellites and launch services decline.[123] Again, an estimated 43 percent of GEO satellites have some sort of insurance, while LEO satellites only average about 5.5 percent. If fewer GEO satellites are being launched, whether due to extended lifespans or technology advancing so that LEO satellites can perform missions typically reserved for GEO, then less insurance may be purchased.

NATIONAL PERSPECTIVES

Most spacefaring nations self-insure national space missions. This means that the government assumes all financial liability and risk if a space mission should fail. Self-insurance by states is predicated on the assumption that "the magnitude of the Government's resources, with many exposure units and geographic dispersion, makes it more advantageous for the Government to assume its own risks rather than to insure them through private insurers at rates sufficient to pay all losses and operating expenses together with a profit for the insurer."[124]

Few national space policies require the purchase of insurance for commercial space missions. This may seem surprising since the OST makes states liable for any spacecraft launched from or operated by an entity within their jurisdiction.

Finland is one of the few nations to require satellite insurance, and it recently enacted its national Act on Space Activities in 2018. Section 8 of this act, entitled "Obligation to Insure," lays out the national requirement for private entities to purchase space insurance for "damage caused by the space activities to third parties."[125] This was likely adopted into the national legislature due to the Liability Convention, which is the foundation for space liability worldwide. This requirement may be bypassed if: "the insurance of the launching company or a corresponding insurance substantially covers the operator's and the State's liability for damage" or if the official risk assessment required for license determined that "the activities will not cause any particular risk to persons, property or public safety."[126]

According to the UN Compendium on Space Debris Mitigation Standards, Greece reserves the right to require the provision of insurance for space objects in its licensing processes.[127] Similarly, the United Kingdom requires a space operator, during the license process, to insure the spacecraft "against liability incurred in respect of damage or loss suffered by third parties, in the United

22, https://iuai.org/IUAI/Study_Groups/Space_Risks/Public/Study_Groups/Space_Risk.aspx.

123. Caleb Henry, "Space insurer Swiss Re leaves market," Space News, August 1, 2019, https://spacenews.com/space-insurer-swiss-re-leaves-market/.

124. General Accounting Office, *Report to Congress: Extending The Government's Policy Of Self-Insurance In Certain Instances Could Result In Great Savings* (Washington, DC: U.S. Department of Defense, August 1975), 1, https://www.gao.gov/assets/120/114854.pdf.

125. *Act on Space Activities,* Ministry of Economic Affairs and Employment,

126. *Act on Space Activities,* Ministry of Economic Affairs and Employment, 3, 5.

127. Office of Outer Space Affairs, *Compendium*, 33.

Kingdom or elsewhere, as a result of the activities authorised by the licence." The space operator must also indemnify the UK government against claims brought "against the government in respect of damage or loss arising out of activities."[128]

Despite not calling directly for space insurance, Sweden's 1982 Act on Space Activities may give Swedish space operators reason to purchase insurance. The act specifies that if Sweden is liable for damage that has been caused by a space operator, said operator will be held accountable for reimbursing the state for any costs accrued.[129]

In the Law Concerning Japan Aerospace Exploration Agency, JAXA is required to secure proper insurance through the government of Japan in the case that the satellite in question damages a third-party actor. However, when working with a cosigner for a spacecraft, the nation retains the right to require reimbursement of funds from the cosigner if damages are caused by the willful misconduct of said party. In fact, the head of the space agency is liable for a fine if a satellite is launched without proper insurance protocols being followed.[130]

For space launch, Japan's 2016 Space Activities Act includes a provision focusing on third-party liability for damage "caused by falls, collisions and the explosion of rockets after commencement of the launch operation." The law is strict and in the favor of the third party, who does not need to prove negligence in order to pursue compensation for damage. The launching party is the only actor liable in any such case. In order to regulate this, Japan may require a launching party to take out liability insurance for each launch. However, satellites are also regulated for third-party liability. Satellite operators are liable for third-party damage for crashes or explosions on orbit.[131] This language currently appears to be unique to Japan.

Other countries have similar language reducing the liability of the state if a non-state actor is responsible for triggering the Liability Convention. Most include language allowing for reimbursement of funds if the damage was due to willful misconduct.[132] However, the Philippines, with the newest space agency, does not include liability details in its foundational space law, despite being a signatory to the Liability Convention.[133] Instead, the state assumes all liability for space operations.[134]

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128. Ibid., 56.

129. Office of Outer Space Affairs, "Selected Examples of National Laws Governing Space Activities: Sweden," United Nations, accessed March 23, 2020, https://www.unoosa.org/oosa/en/ourwork/spacelaw/nationalspacelaw/sweden/act_on_space_activities_1982E.html.

130. "Law concerning Japan Aerospace Exploration Agency," Government of Japan, 6-7, https://global.jaxa.jp/about/law/law_e.pdf.

131. Yotsumoto and Ishikawa, "Japan."

132. France is one prominent example for such a state.

133. Committee on the Peaceful Uses of Outer Space, "Status of International Agreements relating to activities inouter space as at 1 January 2019," United Nations, April 1-12, 2019, 8, https://www.unoosa.org/documents/pdf/spacelaw/treatystatus/AC105_C2_2019_CRP03E.pdf.

134. *An Act Establishing the Phillipean Space Development and Utilization Policy and Creating the Phillipean Space Agency, and for Other Purposes*, Republic of the Philippines, Republic Act No. 11363, Manila, July 23, 2018, 13, https://www.officialgazette.gov.ph/downloads/2019/08aug/20190808-RA-11363-RRD.pdf.

NEAR-TERM ISSUES

The International Union of Aerospace Insurers reported that among its current topics of particular interest, or perhaps concerns, are LEO satellite constellations.[135] The current projected growth of LEO constellations adds thousands of new satellites into an already crowded and debris-filled domain.[136] This understandably adds more risk of collision and the possibility of interference. However, many of these large fleets reduce the risk of the service or mission failing. With hundreds of satellites on orbit, the loss of one or a few may not cripple the entire constellation, fundamentally changing the dynamics of the business environment. This is already causing insurers to pull out of the market for LEO. Assure Space, a space insurance underwriter, says that the company will continue to insure launches but will not insure LEO satellites for the near future. The managing director for Assure Space stated at a conference in March 2020 that he believes they are one to two years early but that eventually all space insurers will stop insuring LEO satellites. In his opinion, there is too much risk and too little being done about mitigating space debris or managing space traffic globally.[137]

In CSIS's Space Threat Assessment 2020, cyber trends are highlighted as a more-easily accessible form of counterspace attack than a highly-advanced direct-ascent ASAT missile.[138] Cyber counterspace operations can have several intrusion points such as the uplink or downlink data transfer to and from the satellite or the ground station itself. Cyber operations are relatively low cost, and though the nature of attack varies by target, the fundamental skills are the same whether it is an attack on a satellite or an electrical grid.

As more companies and non-state actors venture into space with larger constellations or non-maneuverable spacecraft, the risk of liability and damage may increase. This could cause more nations to write regulations requiring insurance or placing liability on the parties involved to protect the state in case the Liability Convention is invoked.

Additionally, states may require insurance for launch or on orbit, just as nations often require car or aviation insurance. This, however, is unlikely to happen soon. With much of space technology in early development stages, countries may be wary of imposing too high of costs, including insurance, on companies in exchange for these companies pursuing innovative ideas and processes.

One thing to watch in the near future is how OOS and ADR missions may affect satellite insurance. The ability to fix, maneuver, or add fuel to a satellite on orbit decreases the cost of a failure and can increase the stability of the business case, if done in a responsible manner. This may allow for insurance premiums for satellites to lower, making insurance more accessible.[139]

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135. Schenone, "2019 Space Insurance Update."

136. Analytical Graphics Inc., "10 Years of Planned Satellites - Spacecast 28," YouTube video, 7:15, December 18, 2019, https://www.youtube.com/watch?v=8sYtPe9ycWQ.

137. Debra Werner, "Assure Space won't cover collision risk in low Earth orbit," Space News, March 11, 2020, https://spacenews.com/assure-space-leaves-leo/.

138. Harrison et al., *Space Threat Assessment 2020.*

139. Rebecca Reesman, *Assurance Through Insurance and On-Orbit Servicing* (El Segundo, CA: Aerospace Corporation, February 2018), https://aerospace.org/sites/default/files/2018-05/OnOrbitServicing.pdf.

However, OOS also introduces new risks and liabilities that insurance companies will have to analyze and quantify. Since many of the ADR and OOS proposed technologies vary, this may have to be evaluated separately by ADR or OOS companies.

Conclusion

The global landscape of national space policies concerning space sustainability, rendezvous and proximity operations, and insurance requirements is uneven and irregular. This is also reflected in international policies and standard-setting mechanisms. Interestingly, some space nations with less satellites on orbit are defining clearer and more precise policies than more active space nations. While some nations seem to be laying out policies in advance of need in some areas, these same nations may be relatively unengaged in other key areas that need immediate attention. For example, there is a broad lack of dialogue or consensus on defining RPO activities and requirements for satellite and launch insurance.

Without clear national regulations and policies, the challenge to find international consensus and define technical standards for key issues in space governance remains bleak. However, there are a few areas of consensus among nations, such as the need from the global space community for nations to support solutions for space sustainability. Easy first steps may be establishing norms of behavior or updating EOL guidelines to be stricter and more broadly accepted. Moreover, several states have already suggested an international mechanism for STM.

There are several examples of international consensus for traffic or transportation management in the aviation, automobile, and maritime communities. While these frameworks have been suggested by space policy experts in the past as a basis for building an international STM organization, a strong movement from the international community has yet to occur. Even if the international community agreed on a system for STM, it would take years to negotiate and make such a system a reality. The non-binding COPUOS guidelines alone took over a decade to develop.

AREAS REQUIRING FUTURE COOPERATION AND CONVERSATION

Despite the momentum of focus on space sustainability and the broad international concern for space debris, there are no realistic mechanisms for incentives or enforcement of these best practices. Enforcement is a key tenant of arms control agreements and presents an incredible challenge for space systems.

For rendezvous and proximity operations, timely verification is paramount in the face of nefarious behavior. While it may be possible to one day establish clear guidelines or norms of behavior using a keep-out zone or the NOTAM model, especially in the protected region of GEO, accurate SSA is necessary for not only tracking and attributing behavior but also potentially determining intent. This unclassified assessment assumes that in the case of an unfriendly RPO, many target satellites will have no way to defend or maneuver in a timely fashion. In fact, the satellite operators may not be aware of the attack until after it occurs. One challenge in developing an international monitoring SSA system for verification requires that the system will "detect 'militarily meaningful' violations before the offending party can gain advantage from the violation."[140] Through combining the keep-out zone and NOTAM model, it may allow satellite

140. Daniel Porras, "Eyes on the Sky," United Nations Institute for Disarmament Research, October 2019, 33, https://www.unidir.org/publication/eyes-sky.

operators to more easily detect and determine threats and give the operator a chance to respond or protect their space system.

While this may sound like a promising solution, it is predicated on all actors having access to strong SSA capabilities. Currently, many satellite operators rely on the U.S. Air Force to warn them of possible collisions. There would likely have to be international SSA data access from a collective source or an international body responsible for managing STM with access to an international network of SSA data.

Space insurance also represents a global mismatch. While some states require higher levels of liability insurance, requiring start-ups or burgeoning commercial space companies to spend almost 33 percent (on average) of the satellite cost on space insurance is a high asking price. Additionally, there is a flux of insurance providers entering and leaving the market, causing further uncertainty. Liability on the state is the highest concern, but that may be less critical if states want to encourage the development of a national commercial space sector. Some states, such as the Philippines, appear to be assuming liability as an incentive for the growth of commercial and national space activities. Furthermore, countries continue to self-insure because governments can accept higher risk. This trend does not appear to be changing.

One suggestion from the space policy community is that insurance may possibly be used as an incentive or enforcement mechanism for other sustainability goals.[141] Thus far, few forums exist—intergovernmental, academic, or otherwise—for discourse on the use of insurance as an enforcement mechanism for responsible state behavior in space. While insurance as an enforcement mechanism could serve as an avenue to ensuring space domain sustainability, several potential challenges may stymie this strategy. For one, requiring space insurance could serve as a barrier to entry for new space nations, and their nascent space industrial bases as the cost of space insurance could be prohibitive for some. As previously mentioned, satellite insurance accounts for approximately one-third of the overall cost to develop and launch a space asset. Such costs are likely untenable for many new space companies and emerging space nations. This idea, and an evaluation of national, industry, and insurance perspectives, may be an interesting topic worthy of further study.

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141. This suggestion was made at a Chatham House Rule private workshop held by the Secure World Foundation at the 2019 AMOS Conference. The author was in attendance.

About the Author

Kaitlyn Johnson is an associate fellow and associate director of the Aerospace Security Project at the Center for Strategic and International Studies. Ms. Johnson manages the team's strategic planning and research agenda. Her research specializes in topics such as space security, military space systems, commercial space policy, and U.S. air dominance. Previously, Ms. Johnson has written on national security space reorganization, threats against space assets, the commercialization of space, escalation and deterrence dynamics, and defense acquisition trends. Ms. Johnson holds an MA from American University in U.S. foreign policy and national security studies, with a concentration in defense and space security, and a BS from the Georgia Institute of Technology in international affairs.

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