Space Traffic Management in the New Space Age

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Abstract

Since 2018, at least 11 US space officials and intelligence agencies at the highest level have expressed serious concerns about the threat from dual-use rendezvous and proximity operations. Yet the United States and the world are still not prepared for this rapidly approaching threat. However, its destabilizing nature is prone to turn a crisis into a war. This article analyzes the characteristics of the proximity threat and identifies opportunities—whether technical, economic, or political—to resolve the problem. The United States should declare that it will enact self-defense or warning zones and enforce them with bodyguard spacecraft and urge other countries to do the same. It should lead the way in pursuing a Western space traffic management (STM) system and an international STM version, both of which will have zones and bodyguards. Additionally, the West should offer China and Russia access to Western space markets and technical know-how if they abide by the zone/bodyguard rules under Western STM. The natural consequence would be for all countries to join the international STM system, as both regimes have virtually identical rules.

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In November 2015, the U.S.-China Economic and Security Review Commission released its annual report to Congress stating that "since 2008, China has . . . conducted increasingly complex tests involving spacecraft in close proximity to one another."[1] It added, "China is setting a strong foundation for future co-orbital anti-satellite systems that could include jammers, robotic arms, kinetic kill vehicles, and lasers."[2] Two and half years later, in a surge of government statements between June 2018 and February 2020, at least 11 space officials and intelligence agencies at the highest level expressed serious concerns about this proximity threat. In August 2018, Vice President Pence did not mince words: "Both China and Russia have been conducting highly sophisticated on-orbit activities that could enable them to maneuver their satellites into close proximity of ours, posing unprecedented new dangers to our space systems."[3] The other 10 government sources sounded similar alarms.[4] On 27 July 2020, the

United States and Russia held their first space security talks since 2013. Trump administration officials hoped that these talks would lead to a set of voluntary norms for operating in space.[5] The next day, US Space Command nominee Army lieutenant general James Dickson echoed during a confirmation hearing that "norms of behavior" should be established for the space domain.[6]

The proximity threat has unique characteristics that can make traditional remedies ineffective. China, Russia, the United States, the European Union, and others have planned to deploy spacecraft[7] capable of rendezvous and proximity operations (RPO) during the first half of the 2020s, if they have not already done so. Many of these robotic spacecraft will be used to refuel, repair, and upgrade satellites already in orbit and to remove or reposition space debris.[8] However, these spacecraft are dual use. If a robotic spacecraft can grapple space debris, it can also grapple another country's satellite. Russia and China have been proposing to keep peace in space by prohibiting the placement of any weapons there.[9] As these dual-use spacecraft can readily turn into antisatellite weapons (ASAT), weapons will soon be present in space. In the new age of proximity operations, banning dual-use robotic spacecraft is not desirable. The United States, as well as other countries, should learn how to use space traffic management (STM) as a key instrument to deter and defend against these potentially threatening spacecraft.

The 18 June 2018 Space Policy Directive-3, National Space Traffic Management Policy, states that "we must develop a new approach to space traffic management" that must "incorporate national security considerations" and "encourage growth of the US commercial space sector."[10] It also emphasizes that "the contested nature of space is increasing the demand for DOD focus on protecting and defending US space assets and interests."[11] The more recent *Defense Space Strategy Summary* of June 2020 reemphasizes that the DOD will "deter aggression in space" and "support US leadership in space traffic management."[12] While both documents state that STM must keep peace and foster prosperity, a widespread presumption is that the Space Force should focus on space security and STM on economic prosperity. Unfortunately, hostile and legitimate RPOs can be indistinguishable. An adversary can use dual-use spacecraft to hide co-orbital ASAT attacks under the guise of peacetime maneuvers in proximity of our critical satellites. Currently, international law does not prevent a nation from stalking another country's satellites.[13]

Western and international STM systems, still in their early stage of development, can be designed to resolve the threat of dual-use proximity operations while providing economic prosperity.[14] This article first describes why STM is needed to protect against the proximity threat. Then it proposes two core measures: self-defense zones and bodyguard spacecraft for STM to deter and defend against the proximity threat. Third, it designs a dual-track approach to pursue Western and international STM in parallel. Next, it identifies incentives to attract China and Russia to participate in STM. Finally, it recommends a strategy for STM that maintains peace and supports economic prosperity.

The Necessity for Space Traffic Management

In 2018, the Long Term Sustainability (LTS) Working Group of the Committee on the Peaceful Uses of Outer Space (COPUOS) tried to establish voluntary "measures for the safe conduct of proximity space operations."[15] Russia blocked adding these RPO measures to the 21 guidelines developed by the working group over the prior eight years.[16] Finally, in June 2019, Russia endorsed the 21 guidelines, but RPO rules were not included. While these guidelines will help avoid accidental collisions of functional satellites with space debris, they will not prevent satellites from being deliberately threatened or disabled by robotic spacecraft.

Even if Russia and China agreed to reconsider RPO measures, there is another problem. COPUOS has long focused only on guidelines for commercial safety, not military security. Taking advantage of this tradition, Russia and China could steer RPO guidelines toward helping commercial operators avoid accidental collisions but leaving the option of using proximity operations to threaten critical US military satellites. This threat could be a powerful instrument for executing their asymmetric strategies to counterbalance the more superior US military capabilities in space. For example, in its 2019 document *China Military Power*, the US Defense Intelligence Agency states, "PLA [People's Liberation Army] writings emphasize the necessity of 'destroying, damaging, and interfering with the enemy's reconnaissance . . . and communications satellites,' suggesting that such systems, as well as navigation and early warning satellites, could be among the targets of attacks designed to 'blind and deafen the enemy.'"[17]

Such an attack would be most damaging if it is the fateful opening of a war in space or on Earth. China could pre-position and maintain multiple dual-use robotic spacecraft arbitrarily close to our critical satellites. Even more worrying is that this threat will grow. Sometime in the latter half of the 2020s, China will have the capability to pre-position dozens of cheap RPO small satellites (smallsats[18]) close to dozens of our satellites, such as the Global Positioning System (GPS). Although these spacecraft are slowmoving, they will be able to legally pre-position during peacetime and get unreasonably close. After "legitimately" setting up this threatening posture, China would have an advantage in a crisis, such as one involving Taiwan. If the US intervenes, China could disable critical satellites so quickly that we would not have enough time to defend them. The disabling could severely degrade US war-fighting capabilities. Furthermore, knowing an intervention could fail, the US might decide not to intervene in the first place and would risk its credibility among allies.[19] The US could prevent such a threat scenario and outcome by creating and enforcing a more comprehensive STM regime that provides timely warning and prevention.

Already, "rumors have been circulating for years that the Chinese Communist Party (CCP) has developed small satellites with robotic arms that could be used as anti-satellite weapons." The rumors indicate that "some of the smaller satellites are lighter than 22 pounds, yet have a triple-eye sensor to gauge the shapes of targets and can adjust their speed and rotation, allowing them to grab objects within a distance of six inches, using a single robotic arm."[20] Considering their significant research and development in RPOs and smallsats,[21] China as well as Russia can likely deploy a few attackers in the first half of the 2020s and then, in the second half of the decade, dozens of inexpensive smallsats capable of RPOs to mount a simultaneous proximity attack. These proximity ASATs would have a cost ratio (e.g., millions each for ASATs versus hundreds of millions each for a victim's satellites) highly favorable to the attacker. It would be even more favorable to the attacker if one includes the high cost to the victim of losing the services provided until its satellite capability is fully replaced. Constellations of even dozens of satellites could still be vulnerable. For example, the 32 GPS III satellites, which will replace the current GPS by 2025, cost about half a billion dollars each.[22] Dozens of cheap, robotic ASATs could defeat most of these 32 satellites, degrading or eliminating a critical service needed in peacetime and wartime.

It is important to note that existing space treaties focus heavily on commercial and not military space. For example, the Liability Convention allows up to three and a half years for compensation after a satellite is damaged.[23] While this may be satisfactory for settling commercial disputes, compensation is not a key goal in military space. The military objective is the survival of national technical capabilities in space for peacetime and wartime operations. Therefore, the Department of Defense has a great interest in STM to prevent hostile proximity operations.

Moreover, unless the DOD plays a more active role in steering STM to deal with satellite security, not just safety, the Consortium for Execution of Rendezvous and Servicing Operations (CONFERS)—an industry-led initiative—may reinforce the wrong notion that STM should focus on commercial activities only. CONFERS aims to "leverage best practices from government and industry to research, develop, and publish non-binding, consensus-derived technical and safety standards that servicing providers and clients for on-orbit servicing operations would adopt."[24] It recommended design and operational practices on 1 February 2019 that echo Space Policy Directive-3 in stating that "specific techniques [for spaceflight safety] may include passive safe orbits, safety zones, and keep-out spheres or volumes for RPO and OOS [on-orbit servicing] activities."[25] While mention of safety zones sounds promising, Brian Weeden, executive director of CONFERS, is noncommittal toward self-defense zones.[26] Another concern is that an adversary may not follow the CONFERS "non-binding, consensus-derived" standards during times of crisis or war. Like COPUOS, this industry-led initiative is likely to favor economic prosperity over military security. The DOD must pursue self-defense zones and bodyguard spacecraft within expanded STM to deter and defend against the RPO threat.

Deterring and Defending against the Proximity Threat

While RPO spacecraft cannot be banned, their dual-use threat can be eliminated by prohibiting close proximity operations without prior consent. A self-defense zone can be used for timely alert to indicate whether a spacecraft is too close, and a bodyguard spacecraft can provide the necessary protection.

Self-Defense Zones

The first and most important space treaty, the 1967 Outer Space Treaty, does not mention self-defense zones or similar measures. However, Article IX of the treaty says, "States Parties to the Treaty shall be guided by the principle of cooperation and mutual assistance and shall conduct all their activities in outer space, including the Moon and other celestial bodies, with due regard to the corresponding interests of all other States Parties to the Treaty."[27] It also states that the principle of due regard should be used to prevent "potentially harmful interference."[28]

More than five decades later, in May 2020, NASA released the Artemis Accords concerning the Moon, which propose the following:

> Avoiding harmful interference is an important principle of the Outer Space Treaty which is implemented by the Artemis Accords. Specifically,

> via the Artemis Accords, NASA and partner nations will provide public information regarding the location and general nature of operations which will inform the scale and scope of "Safety Zones." Notification and coordination between partner nations to respect such safety zones will prevent harmful interference, implementing Article IX of the Outer Space Treaty and reinforcing the principle of due regard.[29]

The Artemis Accords raise a question far closer to home: should safety zones or self-defense zones be implemented on the Moon, but not in Earth orbits, especially when the latter is far more urgent to the well-being of humankind? This same logic should propel the United States and other nations to establish zones for Earth orbits. Moreover, these zones should be set up and enforced during peacetime to establish precedent and prevent ambiguity before a crisis.[30]

Space Policy Directive-3 directs the Department of Commerce to oversee STM but mandates that "the Secretaries of Defense, Commerce, and Transportation . . . shall develop space traffic standards and best practices, including technical guidelines, minimum safety standards, behavioral norms, and orbital conjunction prevention protocols related to pre-launch risk assessment and on-orbit collision avoidance support services."[31] These standards and practices should be specific, transparent, and unambiguous so that space users can easily understand and comply with STM regulations. Directive-3 also recommends that the United States establish a process for "transiting volumes used by existing satellites" (the legal description of self-defense zones).[32] To make the process enforceable, one needs to specify the shapes and sizes of the zone. For example, each zone in geosynchronous Earth orbit (GEO) altitude could be spheres with a 50 km radius.[33] Regardless of the actual size of each zone, the DOD must proactively engage STM efforts now and not wait. It must use its knowledge to ensure equitable standards and practices for all space users.

Bodyguard Spacecraft

Many, including Weeden, suggest creating a resilient satellite architecture.[34] Such an architecture is a good strategy but faces three major challenges. First, achieving resilience will take time. Replacing all vulnerable and critical satellite constellations will not occur until the 2030s. Particularly acute is the vulnerability of US legacy constellations composed of too few (e.g., a dozen), expensive (e.g., $1 billion a satellite), and large (e.g., the size of a school bus) satellites. Examples include the GEO-based Space Based Infrared System (SBIR) satellites for early warning or Advanced Extreme High Frequency (AEHF) satellites for communications in a nuclear-disrupted environment. Both systems have the vulnerable attributes of number, cost, and size. Because these satellites are critical for early warning and nuclear deterrence, the DOD should establish zones and bodyguards to protect them in the 2020s.[35]

Second, if the deployment of resilient constellations of proliferated smallsats is delayed, zones and bodyguards would still be needed well into the 2030s. Third, according to Christopher Scolese, National Reconnaissance Office (NRO) director, the NRO would continue to operate a mix of satellites of many sizes. There will be "some number of large satellites to address questions that only they can."[36] The need for legacy-style satellites will likely go beyond the NRO and the 2020s.[37] US legacy-style large and expensive satellites have a poor cost-exchange ratio for the cheap attackers and need to be defended with equally cheap bodyguard spacecraft.

The US should start a crash program now to develop smallsat bodyguards capable of defending against the mid-2020 ASAT threat.[38] The program should take advantage of its smallsat development, such as the low-cost Blackjack satellites.[39] The US has already indicated that smallsats will cost far less than $1 billion each. SpaceX indicates a cost of $1 million each;[40] Bank of America, $5 million;[41] Planet Labs, merely $100,000–200,000;[42] and Morgan Stanley, $500,000.[43] DARPA envisioned that the cost of each smallsat under its Blackjack program, including launch, would be less than $6 million.[44]

In November 2018, the *Economist* reported that Erwin Duhamel, then head of security strategy at the European Space Agency, "observes that officials in several places are now studying the idea of defending important satellites with 'bodyguard' spacecraft."[45] On 25 July 2019, France announced that it would implement bodyguard spacecraft to protect its critical satellites in 2023.[46] The United States has not made any public statement about whether it will use bodyguard spacecraft to protect critical satellites against robotic ASATs. It is currently deficient in defining self-defense zones and deploying bodyguard spacecraft in time to counter the emerging robotic threat.[47]

Protecting Satellites without Escalation

The US should design and operate self-defense zones and bodyguard spacecraft to protect our satellites without escalating any potential conflict. The following three guidelines will help. First, Article 51 in the UN Charter says that "nothing in the present Charter shall impair the inherent right of individual or collective self-defence."[48] The right of self-defense is never in contention but of great concern is the misuse of self-defense for offensive purposes. The US can minimize this problem by announcing that it will use self-defense zones to protect its satellites and declaring that its spacecraft, including bodyguards, will follow the same rules to respect another country's zones. We should also design all bodyguard weapons, including robotic arms, for short-range defense—to disable an invader inside our zone. Such short-range bodyguards would be adequate for self-defense within our zones but could hardly be used to attack other countries' satellites from outside their self-defense zones.

Second, to maintain crisis stability, we need to allow invaders to retreat from our zones without harm to any satellites. Thus, as soon as another country's spacecraft of any kind enters our zones without prior consent, we should immediately broadcast the incursion and demand immediate retreat. If the intrusion continues, the bodyguard should initially take defensive actions that will cause only temporary or reversible damage to invaders. Each bodyguard should host a suite of selected countermeasures—such as electronic jamming, laser dazzling, and decoys—to disable the invader without permanent harm. A bodyguard might also capture an invader and move it out of our zone.

Finally, once appropriate reversible countermeasures have been exhausted, a bodyguard would disable the invader without creating excessive debris. For example, a bodyguard can use its robotic arms to bend antennae, solar panels, or sensors of the invading robotic spacecraft to disable it with little or no debris.

The Legality of Zones in Western and International STM

The first fundamental space event—*Sputnik 1* circling the Earth—violated international air law that, at the time, extended a nation's sovereignty vertically into outer space over its territory.[49] Fortunately, this law was unable to restrain progress in rocketry that launched humankind into the space age. Today, should we consider only candidate solutions that meet all existing laws, or should we also consider solutions that are far more effective? The foreword to the 2002 United Nations collections of its treaties and principles on outer space states, "As is appropriate to an environment whose nature is so extraordinary, the extension of international law to outer space has been gradual and evolutionary—commencing with the study of questions relating to legal aspects, proceeding to the formulation of principles of a legal nature and, then, incorporating such principles in general multilateral treaties."[50]

This passage reflects the development of space law as gradual and evolutionary to ensure its relevance in guiding solutions to the challenges of the space environment. While our forefathers could not possibly know what new threats or opportunities would look like, they made provisions for us to amend articles to better manage the contemporaneous space environment. For example, Article XV of the Outer Space Treaty states, "Any State Party to the Treaty may propose amendments to this Treaty. Amendments shall enter into force for each State Party to the Treaty accepting the amendments upon their acceptance by a majority of the States Parties to the Treaty and thereafter for each remaining State Party to the Treaty on the date of acceptance by it."[51]

As to the proximity threat, Weeden claims that the space zones proposed in the past are "unlikely to have a strong legal footing."[52] Some argue "that a 'keep out' area like a safety zone could run afoul of the Outer Space Treaty's prohibition on appropriating space for one nation's sovereign use."[53] That is to say, space zones do not comply with Article II of the Outer Space Treaty where "outer space, including the moon and other celestial bodies, is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means."[54] However, the author has argued that "while the owner of the satellite does not have sovereignty over the self-defense zone, the United States can propose, according to Article IX of the 1974 Convention on Registration of Objects Launched into Outer Space, that this Convention be amended to automatically include the self-defense zone in the registration of the satellite to be launched or, retroactively, already launched into space."[55]

When the International Telecommunications Union assigns an orbital slot to a GEO satellite, the satellite owner does not have sovereignty over the slot. One can argue that Article II does not consider an assigned slot as claiming sovereignty because Article II must yield to a law of higher order—the law of nature. A law of physics dictates that two physical objects, such as satellites, cannot occupy the same spot at the same time. Consequently, when a law of man (i.e., Article II) conflicts with a law of nature, the former has no choice but to be waived.

Similarly, if a robotic spacecraft can legally pre-position itself arbitrarily close to a satellite before commencing an attack, the defender cannot possibly be fast enough to exercise Article 51's inherent right of self-defense within its legally assigned slot. It is illegal either for the attacker to stay so close or for the defender to exercise satellite self-defense. Clearly, the former should yield. Claiming that self-defense zones violate Article II disregards the purpose of the Outer Space Treaty—that being the peaceful use of space. As zones are needed to deter the proximity threat and keep the peace, Article II must yield.

For those who still believe that Article II should continue to reign supreme, they can seek comfort from the concept of warning zones, which are designed to meet existing laws. In June 2020, Michael Cerny et al. made an important observation of US maritime operational practices since at least 2006. They drew on Heinegg's analysis that zones merely served to protect vessels and found that

> much like Article I of the OST [Outer Space Treaty], international maritime law does not recognize any situation during which freedom of navigation on the high seas can be limited. However, warning zones are neither operational nor exclusionary, and instead "merely serve to protect the naval vessels from attack or from illegal activities. . . ."[56] Although these zones are historically established during wartime or national emergency, it is generally accepted that these zones can be established during peacetime under international law to protect naval vessels.[57]

Cerny et al. then applied the concept of maritime warning zones to space:

> The declaration of the zone itself is *not* understood—either implicitly or explicitly—to grant any right to the declaring state that it does not already possess. Instead, much like certain similar zones in the maritime domain, warning zones in space serve an information gathering function: "trespass" *per se* is not restricted, but can, upon meeting certain thresholds, provide increasingly certain evidence of hostile intent which would justify preemptive use of force in self-defense. Warning zones, would, therefore, provide an important—indeed, essential mechanism for clarifying intent, reducing the propensity for miscalculation by either side, improving signaling by both parties, and enhancing stability in crises (emphasis in original).[58]

Astutely, they took advantage of the boundary of a self-defense zone as a clear threshold for action against "increasingly certain evidence of hostile intent," which would justify preemptive self-defense. They conclude that "the unilateral establishment of warning zones around United States satellites presents a potential solution to the threat of co-orbital ASATs without violating Articles I and II of the OST [Outer Space Treaty]."[59]

Moreover, Rebecca Reesman and Andrew Rogers report that "to reduce the chance of collisions and to make the intent of nearby objects clear, the ISS [International Space Station] has a nominal approach ellipsoid around it in space. This ellipsoid extends four kilometers in front and behind the ISS path and two kilometers above, below, and beside it. The ISS also has defined a 200-meter 'keep-out' zone; external vehicles are only permitted to fly in this zone with approval and within a defined approach corridor."[60] Thus, zones have already been used in space to keep at least one satellite (i.e., the ISS) safe.

In retrospect, in the past four decades, space zones of different names—such as self-defense zone, keep-out zone, safety zone, and, most recently, warning zone—have been proposed. A self-defense zone is intended to provide a timely warning for initiating legitimate preemptive self-defense while a keep-out zone restricts traffic in an area to prevent potential attackers. A safety zone is established to keep other spacecraft at a distance to avoid collisions, while a warning zone serves to provide "increasingly certain evidence of hostile intent"[61] to justify preemptive self-defense. In any case, as the proximity threat is fast approaching, pragmatists would simply contend that we are far better off to have any of these roughly similar zones in the interim than to wait for the perfect zone at some future time.

Some space planners and experts with very different ideologies are also uncomfortable with self-defense zones. Why? They want to protect America's right to conduct close-up inspections of Chinese and Russian satellites, one satellite at a time. This is something the United States has done since 2016.[62] The desire of policy makers to preserve America's freedom of action to conduct close one-on-one inspections, however, comes with high risk. This policy unwittingly validates China's and Russia's right to threaten our key satellites at close range with an unlimited number of hostile robotic spacecraft. The Pentagon should study whether the US needs close inspection and if it would be acceptable to forgo inspections of another country's satellites from less than 50 km unless requested to do so.[63]

A compromise is limiting the number of simultaneous close inspections. The US could continue one-on-one inspections closer than 50 km but abide by a less stringent but still useful rule: no state should have more than one spacecraft close to any other state's satellites without prior consent.[64] This policy would allow continued close-in space inspections but deprive China and Russia of the right to simultaneously attack more than one of our key satellites at close range. Of course, the United States will observe the same rule toward another country's satellites. The key is to be willing to negotiate and agree to a threshold number of spacecraft in close proximity that applies to all countries equally and fairly. However, regardless of how low the threshold number of close-in spacecraft, we will always need bodyguard spacecraft to protect our critical but vulnerable satellites.

The Legality of Bodyguard Spacecraft in Western and International STM

The legality of bodyguard spacecraft hinges on the legality of preemptive self-defense. As far back as 1842, Secretary of State Daniel Webster viewed preemption as legal, provided certain conditions are met. Subsequently, jurists like Roberto Ago in 1980 came to a similar set of conditions: necessity, proportionality, and immediacy.[65] Thus, "pre-emptive self-defense against space stalkers is necessary because the US cannot defend with, as Ago stated, 'measures not involving the use of armed force.' It is proportional because . . . the pre-emption is not allowed to go beyond what is needed to disable this attack. It must take place immediately, as the attack is ready and can be imminent."[66] Cerny et al. also argue similarly.[67] Thus, bodyguards should be allowed to exercise the "inherent right"[68] of self-defense stipulated in Article 51 of the UN Charter, even preemptively when Ago's conditions are met.

A Dual-Track Approach to International STM

China and Russia want STM to focus on commercial servicing and not self-defense zones or bodyguards. The latter would prevent them from taking advantage of lax commercial STM rules, which do not prohibit stalking another country's satellites. Worse yet, they are not alone in their distaste for zones and bodyguards. Many others in the West feel the same. There is a powerful camp with similar views, including Weeden:

> We need to keep the military security discussion separate from the commercial servicing and RPO discussions. . . . We've got 35 companies as members . . . working on best practices and standards for commercial servicing. Their biggest concern is they're going to get lumped in with all the military stuff and all of their investment and insurance is going to evaporate. I think if we do have space traffic management, it has to be explicitly for commercial, civil activities[,] . . . but I don't think we should try and make civil space traffic management that applies to military space traffic.[69]

This view can have serious unintended consequences. Weeden does not want military security measures, such as zones and bodyguards, included in international STM. He considers that "the RPO [proximity] threat is misunderstood and overblown" and that STM contributes little to military security, such as preventing a proximity attack.[70] In a 2020 Global World Foundation report, Weeden and Victoria Samson state that "warning time of such a [Chinese RPO satellite's] close approach would likely be at least hours (for LEO) or days (for GEO), unless the attacking satellite was already in a very similar orbit."[71] Indeed, attacking RPO spacecraft are slow-flying. This warning of days long is useless because international rules currently allow the attacking satellite to remain arbitrarily close to its target for indefinite periods. Their statement of "unless the attacking satellite was already in a very similar orbit" would likely mean that if the attacking satellite were in the same orbit and arbitrarily close to our satellite as the current rules allow, there would be insufficient warning to take legitimate and timely actions to prevent the attack. Thus, the STM cannot simply focus on commercial and civil activities and should include a "military security discussion," such as how to prohibit the attacker from getting so arbitrarily close during peacetime or crisis. A key motivation of the States Parties to agree to the Outer Space Treaty was their recognition of "the common interest of all mankind in the progress of the exploration and use of outer space for peaceful purposes."[72] Clearly, using STM to prevent the proximity threat is for a critical peaceful purpose.

Viewing the proximity threat as overblown and STM as applying exclusively to commercial matters—and thus being dealt with only in international fora—aids China and Russia in two ways. First, they hope the West will continue to be ambivalent about the new danger. Second, they seek continued negotiations on STM matters via international fora, where agreements are typically made by consensus and they will have far better control of the outcome as they can just say no to the ones they do not like.

Unfortunately, if the West continues to think and negotiate as China and Russia expect, it will inadvertently live in the shadow of the proximity threat indefinitely. Naturally, China and Russia would encourage those in the West who want commercial activities in STM and not zones and bodyguards. Moreover, there are those in the West who consider any negotiation to be a failure without an agreement. Given such thinking, China and Russia would have the upper hand in any final STM framework. They could stall any deliberation or decision on zones and bodyguards, as they have already done in agreeing to the 21 guidelines only, further delaying rules that resolve the proximity threat. The status quo remains, as does the proximity threat. Since the current approach will have dire consequences, the US must devise a new tactic to create international STM that provides economic prosperity while preventing threatening proximity operations.

Pursuing an International STM

The United States should take the lead on a dual-track approach by proposing and pursuing a Western STM regime and an international

STM regime in parallel. The West's initial negotiating position will propose zones and bodyguards in both STM regimes. While negotiations may compromise in the details of the zones and bodyguard rules, they will never forsake zones and bodyguards or accept STM that cannot prevent the proximity threat.

Western countries will decide rules for Western STM while all participating countries will determine rules for international STM. International agreements are typically made by consensus of the negotiating State Parties. Thus, the key disadvantage of pursuing only international STM, as the United States is currently doing, is allowing China and Russia to block those Western measures they dislike. The West is forced to choose either having international STM that subjects itself to the proximity threat or reverting to the status quo, which allows arbitrarily close pre-positioning and makes proximity threat possible in the first place. Under a dual-track approach, Western STM can be completed quickly, setting up a fair model for international STM. The latter would follow in due time without any deadline.

The DOD's Defense Space Strategy refers to "allies" 32 times in the summary report of 18 pages. One needs to cite only a few passages to see how heavily the DOD relies on its allies and partners. First, "the strategy . . . moves with purpose and speed across four lines of effort," including "cooperat[ing] with allies, partners, industry, and other US Government departments and agencies."[73] Second, "in cooperation with allies and partners, DoD will . . . deter aggression in space . . . and support US leadership in space traffic management."[74] Third, "the United States has long maintained a robust and prolific arrangement of alliances and partnerships built on trust, common values, and shared national interests. This approach creates an important advantage for the United States and its allies and partners."[75]

The first point says that cooperation with allies and partners is one of four major efforts for the DOD to deal with space security issues. The second point makes explicit that deterring aggression in space and taking leadership in STM are two key national security issues. The third point implies that to negotiate more effectively with China and Russia, the United States needs to speak with one voice with other Western countries. In fact, it is easier to form a united front with our allies and partners because we share common ideologies, values, and interests. The dual-track approach capitalizes on these three points to wean China and Russia from the use of proximity threat.

Under the dual-track approach, China and Russia would clearly reject both STM proposals at the start. However, in the interim, before international STM is agreed upon, the West must develop and conduct its space operations according to its own STM. China and Russia would have little control over the Western STM agreement. The West could choose the type of zone—self-defense, keep-out, safety, or warning—garnering the most support from Western signatories. From the start, the West must design STM that keeps the peace and creates economic prosperity for all countries. This altruistic pursuit will attract adherents to Western and international STM. It should be noted that China and Russia are not prevented from doing space business with Western clients—the choice is theirs. However, it is common practice for companies doing business in a foreign country to abide by local regulations and laws. Thus, there is precedent for abiding by traffic rules in the vicinity of Western satellites. In doing so, China and Russia would not enter Western self-defense zones without prior consent.

Most importantly, the West can protect its critical space assets with zones and bodyguards through either international or Western STM. China and Russia could no longer pose the proximity threat whether they join either or neither STM agreement. In the case of joining an international STM regime that includes zones and bodyguards, they are prevented from posing a proximity threat by the zones and bodyguards already in international STM. In the case of joining Western STM that also includes zones and bodyguards, they are similarly prevented from posing a proximity threat. Even if they do not participate in either STM regime but try to get close to Western satellites, the West will still have zones to provide warning, the right of self-defense, and bodyguards to block the threat. Thus, under the two-track approach, the West would have no proximity threat and be far better off than under the current one-track approach. Its satellites would be protected regardless of the outcome of international STM.

A creative mind might wonder whether it would be far more straightforward to offer only Western STM. However, if just Western STM is offered, China and Russia would rightly complain of unfair treatment since they have no voting rights in Western STM. The dual-track approach offers international STM wherein decisions will be made by all participating State Parties. In the current approach, China and Russia have the right to disagree with what the West proposes. In the proposed international STM, the West has the right to disagree with theirs. The key difference between the current and recommended approaches is that, without an international STM agreement, the current approach will revert to the status quo of no zones or bodyguards. In the suggested approach, the West will have Western STM—with zones and bodyguards—to fall back on.

Essentially, our current approach is to negotiate with China and Russia in not threatening our satellites and trust them to keep their word so that we can relieve the need to protect these critical assets. However, even the best-negotiated outcome could not meet the desired purpose of keeping our satellites safe. Assume that the US were able to offer enough incentives to China and Russia to deter the proximity threat. They can still conduct a successful and damaging proximity attack at the opening of a war if such an attack would yield national security benefits greater than the costs of breaking the STM agreement. China and Russia could also withdraw from the agreement in advance (e.g., one-year prior notice in the Outer Space Treaty[76]) knowing that the West could not possibly ready a defense in the span from the countries' withdrawal to the proximity attack.

Under the dual-track approach, the West can negotiate international STM under the auspices of the United Nations, just as it now does under the single-track approach. Negotiating Western STM is a multilateral effort for establishing the rules for companies and countries, domestic or foreign, to conduct space operations for Western clients and countries. In the context of the Western space market and STM, China and Russia plan to serve Western clients for economic benefits, and the West plans to attract them for the same. Once the proposed approach makes the inclusion of zones and bodyguards nonnegotiable, the proximity threat is solved provided that zones and bodyguards are implemented. Interestingly, with military-security measures (zones and bodyguards) included in STM, the negotiation will rightly focus on economic terms. Specifically, these are the benefits for China and Russia doing business in the Western space market and the benefits for the West having China and Russia participating in the Western market. Now, the negotiation becomes similar to a trade agreement or foreign direct investment where the result is more likely than the current approach to be a positive-sum game or agreement.

Phil Schneider, president of Schneider Consulting, comments that "historically, most foreign companies investing in the United States have been primarily driven by a need to create or enhance access to new markets and customers."[77] Similarly, the key incentive for China and Russia is to keep, or gain far more, access to the Western space market. While

China, Russia, and the West are competitors in the global space market, the West is endowed with ample incentives to attract countries to participate in the Western space market. Since the rules in Western and international STM are essentially the same, once China and Russia agree to abide by Western STM rules, it would be a small step for them to join with international STM. Thus, the dual-track approach uses Western STM as a necessary detour, which ironically can make international STM more likely than the current single-track approach. The West's key incentives for attracting Chinese and Russian companies to the Western space market are to enhance a competitive environment, including breaking domestic monopolies to be more innovative for the long term. Doing so will help Western space firms maintain or expand their global market share. Moreover, the global space industry will produce cheaper or better space products and services. Regulatory barriers imposed on Chinese and Russian firms should focus on national security and not on protecting domestic firms' market shares for the short term. The West should add considerable incentives to attract China and Russia to join international STM: a common STM system will sow harmony and cooperation and reap peace and prosperity for all countries.

Incentives for China and Russia to Join STM

Better access to the West's space business and technical expertise is the greatest incentive for China and Russia to join Western or international STM. Morgan Stanley assessed that the revenue from the global space market or economy was $339 billion in 2016 and projects it to be $1.1 trillion annually by 2040.[78] The company lists 11 market segments (table 1). Three of these are selected for analysis here: space launch, satellite manufacturing, and satellite internet services. The first segment selected, space launch, is projected to account for only 1 percent of the global space economy by 2040. However, Chinese and Russian space launch services have been the strongest suit in their space business. If they lose their edge in their strongest sector, they may fare even worse in other space sectors. Second, satellite manufacturing, although projected at just 1.7 percent, is chosen for analysis because it is the most important capability that determines their competitiveness in the global space market. Finally, satellite internet services (i.e., access) is chosen for the obvious reason that, at 34.6 percent, it will be the largest segment of the global space economy by 2040.[79]

Table 1. Global space economy by 2040

Segment	Annual revenue in $billion	Annual revenue in %
Consumer TV	100.0	8.6
Consumer broadband	80.0	6.9
Mobile satellite services	20.0	1.7
Earth observation services	30.0	2.6
Ground equipment	215.0	18.6
Satellite manufacturing	20.0	1.7
Satellite launch	11.0	1.0
Government spending	180.0	15.6
Insurance	0.8	0.1
Internet services	400.0	34.6
Space freight transportation	100.0	8.6
Total	*1,156.8*	*100*

Source: Morgan Stanley, *Space: Investment Implications of the Final Frontier* (New York: Morgan Stanley, 12 October 2017), 10, http://www.fullertreacymoney.com/.

Space Launch Industry

Goldman Sachs reported that the US share of global launch revenues during 2006–16 was 19 percent.[80] It jumped to 47 percent largely because SpaceX quickly captured numerous launches due to its success in substantially reducing launch costs.[81] By 2040, Morgan Stanley projects that SpaceX will have about 60 percent of the global launch market.[82] At worst, it will likely form a duopoly with Arianespace, a subsidiary of ArianeGroup. The combined launch share of SpaceX and Arianespace will continue to be far higher than that of Russia and China together. SpaceX's achievement in space launch hinges on its pathbreaking innovation and willingness to risk huge sums of capital. Its prowess forces both longtime and start-up competitors, including those from China and Russia, to strive for lower prices and better quality.

Goldman Sachs indicates that while Chinese Long March rockets are competitively priced with low failure rates, regulatory barriers prevent US components from flying on Chinese rockets.[83] Since nearly all European satellites contain US components, Chinese rockets cannot be used to launch US or most European satellites.[84] This regulatory barrier exemplifies how strongly the United States can control access for China and Russia to the Western space market and technical know-how.

As to the next-generation launch vehicle, Russia counts on *Soyuz-5*—expected to make its inaugural flight in 2022. However, Vitaly Egorov, Open Space group manager on Facebook and PR specialist for a Russian aerospace company, remarks, "The Soyuz-5 is described as Russia's best bet at ensuring the nation's triumphal return to the launch vehicle market. It should be noted, however, that nearly all its launch characteristics are inferior to the current market leader [SpaceX], the Falcon-9. The only thing yet unknown is the price tag."[85]

For almost two decades, the United States has relied on the Russian RD-180 engine in Atlas 5 to power national security space launches. *Foreign Policy*'s Pentagon correspondent Lara Seligman recently noted that "the Defense Department is racing toward a congressionally mandated deadline of December 2022 to fly the first all-American rocket, powered by domestically produced engines, for US national security space launches."[86] Further, former Russian deputy prime minister Dmitry Rogozin, now the general director of Roscosmos, believes that it is not worth the effort for Russia to try to elbow SpaceX and China aside in the market for launch vehicles.[87] His statement signals that Russia may give up competing in the market to launch Western satellites.

The US and the West in general will continue to dominate the launch market. China's and Russia's launches of Western satellites will decline due to their deteriorating competitiveness with Western launch providers, such as SpaceX and Arianespace, and the US restrictions limiting or banning their launches.

Satellite Manufacturers

Goldman Sachs's list of 13 key satellite manufacturers worldwide includes nine in the US, two in Europe, and one in Brazil, with the China Great Wall Industry Corp. rounding out the list. Russia does not show up. This list is consistent with Goldman Sach's statement that "most satellites are built in the US or Europe."[88] The company also notes that "the nascent Chinese satellite manufacturers have yet to prove their technology over a meaningful period of time. Their oldest satellite is six years old, according to the Union of Concerned Scientists database as of June 2016."[89] Thus, China has too little experience in satellite manufacturing to capture sizable business from the West unless it focuses on some niche segments such as small satellites, where low prices can be a more critical consideration than better performance and reliability.

Egorov further indicates that "Russian navigation and telecommunication satellites suffer from low reliability and have an operational life twice as short as their European or American counterparts. Russia remote sensing satellites are 5–10 times the mass of their rivals and lag in terms of data quality."[90] While Russia will try to get into satellite manufacturing,[91] like China, it would need to partner with Western companies to access market and technical know-how.

Satellite Internet Service Market

Besides continuing space launch services, SpaceX plans to launch its Starlink small satellites (smallsats) in low Earth orbits (LEO) to provide global internet services. Morgan Stanley reports that SpaceX plans to launch 11,943 smallsats to LEO in two phases: from 2019 to 2024 and from 2029 to 2032 for full capacity—at a cost of $10 to $15 billion.[92] In October 2019, SpaceX asked the International Telecommunication Union to arrange a spectrum for 30,000 Starlink satellites. These are in addition to about 12,000 already approved by the US Federal Communications Commission.

Thus, SpaceX's 42,000 Starlink satellites alone (i.e., 12,000 plus 30,000) will be five times the total spacecraft previously launched by all countries. SpaceX's spectrum request for so many satellites will make it difficult for countries such as China and Russia to play catch-up. According to an Institute of Defense Analyses report by Irina Liu et al., representatives of several Chinese companies expressed concern that their companies will be unable to obtain the spectrum they need because the large international companies have already claimed the most desirable spectrum bands for satellite communications. Thus, Chinese commercial companies are forced to use the less desirable V and Q bands that are more expensive to operate in.[93]

According to SpaceX, while about 720 LEO satellites will serve the US, merely doubling the number will serve most of the world. Thus, business economics favors LEO satellite constellations that serve the world versus a region. For this reason, the lion's share of the satellite internet access segment will likely go to only a few providers worldwide. These providers can afford the huge capital expenditure, offer good services at competitive prices, and are able to capture a big chunk of the market first.

China is unlikely to be one of these few big winners. Its best bet is to form a partnership with major Western providers. Moreover, even China's lower-cost advantage is losing its edge in providing space products and services. Liu et al. relay that "our interviews and searches on Chinese job websites showed that salaries in the space sector in China are lower, but not significantly so, than those in the United States." Moreover, "salaries for talented Chinese researchers are rising. . . . Although skilled labor in the commercial space industry in China will likely remain cheaper than in the West for the foreseeable future, somewhat cheaper labor may be insufficient to make the Chinese commercial space sector competitive with that of the West."[94]

Choosing Incentives or Intransigence

The two-track STM approach can protect satellites against the proximity threat whether or not China and Russia agree to join Western or international STM. The two countries would have to recalculate their strategic choices. Should they forgo the Western space market and voice their objection to the "unreasonable rules"? Or should they face the new reality that they can no longer mount an effective proximity threat and, instead, focus on maximizing the benefits from participating in the lucrative Western space market? Without a proximity threat, they would have far less bargaining power with the West and might acquiesce to Western STM, leading to better economic, social, and diplomatic relations.

China and Russia may well prefer to participate in the Western space market and follow the Western rules of zones and bodyguards. On 22 May 2020, the *Wall Street Journal* reported that "China broke with more than a quarter-century of tradition by not issuing an economic growth target for 2020, a stark acknowledgment of the challenges facing the world's second-largest economy."[95] In the aftermath of the Covid-19 pandemic, China and Russia will likely view participation in the lucrative Western space market as essential to resuming robust economic growth.

China and Russia lag behind the West, particularly the US, in technical know-how, the ability to innovate rapidly, the attitude of risk-taking, and financial resources to launch another constellation to compete with SpaceX or other early movers into the huge ($400 billion per year as shown in table 1) satellite internet service realm. Their best alternative is to form partnerships or working relationships with Western space service providers to share Western business and profits. They could support Western providers by building and managing ground facilities and services, including acting as distribution partners.[96] In their domestic markets, they will continue to retain unbeatable home-court advantages including financial and other subsidies by their governments. They also have some competitive advantages in countries friendly toward them.

China and Russia could manufacture components or even smallsats, in addition to launching them, if the West did not set up barriers to ban or limit their services in these areas. Smallsats would be an excellent vehicle to provide space services, other than launching, to the West. Making smallsats is relatively low tech, and they will be widely used in many applications worldwide. Moreover, since smallsats are intended for more frequent re-placement and upgrade, they generally have a far shorter service life than large satellites. Buyers would be more willing to trade lower quality for a lower price for smallsat components or even for whole smallsats. The fact that the service life of Russia's satellites is around 50 percent that of their US counterparts might not be a deal breaker in the case of smallsats.[97]

Another potential business for China and Russia is Earth imaging and monitoring provided by companies such as Planet Labs, which operates the largest constellation of Earth observation satellites in the world. GIS Geography states that Earth remote sensing has hundreds of applications from farming to retail to urban growth.[98] Robbie Schingler, co-founder and chief strategy officer of Planet Labs, notes, "We run into challenges with predatory pricing by Chinese backed companies."[99] Although China or Russia would have some catching up to do, each has the potential—aside from strong subsidies from their governments—to compete in these services for Western and other commercial clients where lower cost is still a primary consideration.

Perhaps the most intriguing Western space segment for China and Russia is the use of robotic spacecraft to refuel, repair, move, and upgrade satellites in orbit and remove space debris. Getting into these peaceful services would be a perfect outcome for all parties involved. Their long-held claim of never wanting to pose a proximity threat would be vindicated by their joining international STM with zones and bodyguards or acquiescing to Western STM with the same measures. Accepting zone/bodyguard rules is the tradeoff China and Russia will make to acquire sales and technical expertise in the new space age—what they have been eagerly seeking from the West. Moreover, once they work more closely with the West in space, a better understanding of and improved relations with each other will enhance the atmosphere for reducing threats and keeping the peace.

In sum, the West, especially the United States, will continue to have most of the huge and growing global space market in the next two decades. Under the current single-track approach, China and Russia can continue to threaten the West with the proximity threat. In contrast, under the proposed dual-track approach, the West will have deterred the proximity threat from them and, later, North Korea, Iran, and others, regardless of whether these countries agree to STM rules. Most satisfying and important, the proposed approach harnesses the West's tremendous market power in space to create effective international STM.

Pursuing an International STM for Peace and Prosperity

STM is currently under early development. After analyzing the characteristics of the proximity threat and identifying the opportunities to counter it, three main actions emerge for developing a space traffic management regime that will resolve the proximity threat and provide economic prosperity for the West, China, Russia, and the rest of the world.

First, Western countries should unilaterally enact self-defense or warning zones to provide timely alerts that another country's spacecraft have entered the zones without prior consent. Collecting intelligence of hostile intent and preparing for self-defense would then be legitimately initiated to prevent invaders from reaching our vulnerable but critical satellites. Moreover, the US should pre-position bodyguard spacecraft, equipped with countermeasures, inside the zones to protect satellites.

Second, the United States should lead the way to pursue both Western STM and international STM in parallel, each having self-defense zones enforced by bodyguard spacecraft. Regardless of whether other countries, particularly China and Russia, join either STM arena, Western satellites will be protected by zones and bodyguards against the proximity threat. China and Russia will no longer be able to threaten the West's satellites in that way.

Third, during the next two decades, the global space market will grow to an annual revenue of $1.1 trillion by 2040, and the West will continue to have the preponderance of the global market. The West should offer China and Russia adequate economic incentives regarding access to the Western space market and technical know-how. Since the zones and bodyguards embodied in our proposed STM arenas will render their proximity threat ineffective, these countries are now left with two choices. One choice is not to participate in the Western market and voice their objection to the "unreasonable rules" of Western STM. The second choice is to participate in the Western space market and, as a common business practice, naturally follow Western STM, including rules for self-defense zones and bodyguard spacecraft.

China and Russia may well prefer the latter: participation in the lucrative Western space market despite the need to follow Western STM embedded with zone/bodyguard rules. Once they are willing to abide by these rules under Western STM, it could be a small accommodation to join the international STM because both STM systems will have essentially identical rules. Finally, countries will have fair international STM that resolves the proximity threat, helps keep the peace, and aids prosperity for all in the emerging second space age. SSQ

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Notes

1. U.S.-China Economic and Security Review Commission (USCC), *2015 Report to Congress of the U.S.-China Economic and Security Review Commission*, 114th Cong., 1st sess. (Washington, DC: Government Printing Office, November 2015), 16, https://www.uscc.gov/. See also Brian Chow, "Avoiding Space War Needs a New Approach," *Defense News*, 16 September 2015, https://www.defensenews.com/.

2. USCC, *Report to Congress*, 321.

3. The White House, "Remarks by Vice President Pence on the Future of the U.S. Military in Space," 9 August 2018, https://www.whitehouse.gov/.

4. They are Daniel R. Coats, director of national intelligence ("satellites . . . intended to advance counterspace capabilities"): see Daniel R. Coats, *Statement for the Record: Worldwide Threat Assessment of the US Intelligence Community* (Washington, DC: Office of the Director of National Intelligence, 13 February 2018), 13, https://www.dni.gov/; Office of the Secretary of Defense ("dual-use technologies in space that could be applied to counterspace missions" in 2018 and 2019; "orbiting space robots" in 2020): see Department of Defense, *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2018* (Washington, DC: Department of Defense, 2018), 40, https://media.defense.gov/; and the DOD's same-titled 2019 and 2020 reports, respectively, 51, https://media.defense.gov/; and 65, https://media.defense.gov/; Lt Gen Robert Ashley, director of the Defense Intelligence Agency ("enemy robot satellites"): see Patrick Tucker, "Pentagon Intelligence Chief: Russia and China Will Have Weapons in Space 'In the Near Future,' " *Defense One*, 27 June 2018, https://www.defenseone.com/; Dr. Yleem Poblete, former assistant secretary of state for arms control verification and compliance ("very abnormal behavior by a declared 'space apparatus inspector' . . . a very troubling development"): see Yleem D. S. Poblete, "Assistant Secretary Poblete Addresses the Conference on Disarmament," U.S. Mission to International Organizations in Geneva, 14 August 2018, https://geneva.usmission.gov/; the Air Force's National Air and Space Intelligence Center (NASIC) ("counterspace capabilities . . . to . . . grapple with a satellite"): see National Air and Space Intelligence Center, *Competing in Space* (Wright-Patterson AFB, OH: NASIC, December 2018), 24, https://media.defense.gov/; Defense Intelligence Agency ("robotic technology for satellite . . . but . . . used for military purposes"): see Defense Intelligence Agency, *Challenges to Security in Space*, January 2019, 10, https://www.dia.mil/; Gen John Hyten, commander, US Strategic Command ("kamikaze satellites"): see David Axe, "Pentagon Admits Plan to Launch 1,300 Satellites Might Not Prevent Chinese or Russian Attacks," *Daily Beast*, 10 April 2019, https://www.thedailybeast.com/; Dr. Scott Pace, executive secretary, National Space Council (quoted Vice President Pence's concern: "maneuver their satellites into close proximity of ours"): see "National Space Council's Pace on International Space Cooperation, Europe, China," 12 October 2019, https://www.youtube.com/; Gen John Raymond, the first chief of space operations, United States Space Force (" 'threatening behavior' in outer space"): see Sandra Erwin, "Raymond Calls Out Russia for 'Threatening Behavior' in Outer Space," *SpaceNews*, 10 February 2020, https://spacenews.com/; and Dr. Christopher Ford, assistant secretary of state for international security and non-proliferation ("concerns about Russia's ability to operate in close proximity to other satellites"): see Christopher Ford, "Whither Arms Control in Outer Space? Space Threats, Space Hypocrisy, and the Hope of Space Norms," *New Paradigms Forum*, 6 April 2020, http://www.newparadigmsforum.com/.

5. Michael Gordon, "U.S., Russia Hold Talks on Space Security," *Wall Street Journal*, 27 July 2020, https://www.wsj.com/.

6. Sandra Erwin, "U.S. SPACECOM nominee Dickson says countries must be held accountable for actions in space," *SpaceNews*, 28 July 2020, https://spacenews.com/.

7. *Spacecraft* and *satellite* are the same and used interchangeably. However, in this article, *spacecraft* tend to represent vehicles with high maneuverability and that frequently move considerable distances while *satellites* tend to stay in, and provide services from, the same assigned orbits.

8. The well-accepted Kessler Syndrome theory says that collisions between space objects could cause a chain reaction of further collisions, increasing the debris density to such a high level that it renders space activities in certain orbital ranges infeasible. Donald J. Kessler and Burton G. Cour-Palais, "Collision Frequency of Artificial Satellites: The Creation of a Debris Belt," *Journal of Geophysical Research* 83, no. A6 (1 June 1978): 2637–46, http://www.castor2.ca/.

9. Permanent Representative of the Russian Federation and the Permanent Representative of China to the Conference on Disarmament, "Draft Treaty on the Prevention of the Placement of Weapons in Outer Space, the Threat or Use of Force against Outer Space Objects," 12 June 2014, CD/1985, https://www.fmprc.gov.cn/.

10. The White House, Space Policy Directive-3, National Space Traffic Management Policy, 18 June 2018, https://www.whitehouse.gov/.

11. The White House, *Space Traffic Management*.

12. Department of Defense, *Defense Space Strategy Summary* (Washington, DC: DOD, June 2020), 8, https://media.defense.gov/.

13. Brian G. Chow, "Stalkers in Space: Defeating the Threat," *Strategic Studies Quarterly* 11, no. 2 (Summer 2017): 96–102, https://www.airuniversity.af.edu/.

14. This article uses a broad definition of the *West* (i.e., Western countries), which includes NATO member countries; Australia, New Zealand, Japan, South Korea, Taiwan, Israel; and the nonaligned Austria, Finland, Sweden, and Switzerland. See "Western countries," fact-index.com, accessed October 2020, http://www.fact-index.com/. It also builds on the self-defense zone/bodyguard spacecraft portion of a research report by Brian G. Chow, "Commercial Space: Space Controls and the Invisible Hand," which first appeared on the website of its sponsor, the Nonproliferation Policy Education Center, on 16 June 2019, http://npolicy.org/.

15. Committee on the Peaceful Uses of Outer Space, "Draft Guidelines for the Long-Term Sustainability of Outer Space Activities," A/AC.105/2018/CRP.21, 27 June 2018, Guideline 8 on p. 7, https://www.unoosa.org/.

16. Committee on Peaceful Uses, "Draft Guidelines," 7; and the Committee on the Peaceful Uses of Outer Space, "Guidelines for the Long-term Sustainability of Outer Space Activities," A/AC.105/2018/CRP.20, 27 June 2018, https://www.unoosa.org/.

17. Defense Intelligence Agency, *China Military Power: Modernizing a Force to Fight and Win* (Washington, DC: Defense Intelligence Agency, January 2019), 43, https://www.dia.mil/.

18. NASA defines a *smallsat* as a satellite with a mass less than 180 kilograms and about the size of a large kitchen refrigerator. CubeSats are smallsats and a class of nanosatellites that use a standard size and form factors. The basic unit or 1U measures 10x10x10 cms. A CubeSat takes different sizes such as 1, 1.5, 2, 3, 6, and 12U with a mass of 1-10 kilograms. See Elizabeth Mabrouk, ed., "What Are SmallSats and CubeSats?," NASA, 6 August 2017, https://www.nasa.gov/.

19. For further discussion on the US's horrific choices between warfighting with degraded space support and no intervention when necessary, see Brian G. Chow, "Space Arms Control: A Hybrid Approach," *Strategic Studies Quarterly* 12, no. 2 (Summer 2018): 117, https://www.airuniversity.af.edu/.

20. Joshua Philipp, "China Is Branding Anti-Satellite Weapons as 'Scavenger Satellites,' " *Epoch Times*, 5 May 2019 and updated 6 May 2019, https://www.theepoch times.com/.

21. Jacqueline Feldscher, "Chinese Small Satellites Threaten U.S. Industry," *Politico*, 26 April 2019, https://www.politico.com/.

22. Wayne Rash, "The Future of GPS," Hewlett Packard Enterprise, 16 July 2019, https://www.hpe.com/. The price of the first 10 satellites was estimated at $577 million each. The Air Force expected the remaining 22 satellites to cost $7.2 billion or $327 million each. However, the Government Accounting Office estimated the cost at $12 billion or $545 million each. See Dan Elliott, "US Air Force Set to Launch 1st Next-Generation GPS Satellite," *Air Force Times*, 16 December 2018, https://www.usatoday.com/story/.

23. Article X of the Convention on International Liability for Damage Caused by Space Objects says that a claim should be filed not later than one year following the date of the occurrence of the damage. Article XIV states, "If no settlement of a claim is arrived at . . . within one year from the date on which the claimant State notifies the launching State . . . , the parties concerned shall establish a Claims Commission." Article XV adds six months to appoint the Chairman of the Commission if the claimant State and the launching State cannot agree on the choice of the Chairman. Finally, Article XIX states that the Commission shall give its decision or award no later than one year from the date of its establishment. Thus, the total amount of time is up to three and a half years. See United Nations Office for Outer Space Treaties, *United Nations Treaties and Principles on Outer Space and Related General Assembly Resolutions* (New York: United Nations, 2002), 16–18, https://www.unoosa.org/.

24. Todd Master, "Consortium for Execution of Rendezvous and Servicing Operations (CONFERS)," Defense Advanced Research Projects Agency, accessed 30 April 2020, https://www.darpa.mil/.

25. CONFERS, "CONFERS Recommended Design and Operational Practices," 1 February 2019, https://www.satelliteconfers.org/.

26. "Transcript of a Discussion between Dr. Brian Chow and Dr. Brian Weeden on Space Zones and Bodyguards for Proximity Operations," moderated by Henry Sokolski, co-sponsored by the Nonproliferation Policy Education Center (NPEC) and the American Bar Association (ABA) Standing Committee on Law and National Security, Washington, D.C., 2 March 2020, http://npolicy.org/; ABA Standing Committee on Law and National Security and NPEC, "Working Smarter with America's Spacefaring Allies," Workshop Report, March 2020, 17, https://www.americanbar.org/; and Secure World Foundation, "SWF Discusses the Pros and Cons of 'Guardian' Satellites and Space Zones of Control," 2 March 2020, https://swfound.org/.

27. United Nations, *Treaties and Principles*, 6.

28. United Nations, 6.

29. NASA, "The Artemis Accords," May 2020, https://www.nasa.gov/.

30. Chow, "Stalkers in Space," 96, 100, 102.

31. The White House, *Space Traffic Management*.

32. The White House, *Space Traffic Management*.

33. While 50 km is a reasonable choice, the DOD should determine actual threshold distance after consultation with other agencies domestic and foreign. The use of specific numerical values in guidelines is common. For example, the Inter-Agency Space Debris Coordination Committee (IADC) Space Debris Mitigation Guidelines use 25 years as the post-mission orbital lifetime limitation. See also Inter-Agency Space Debris Coordination Committee, "IADC Space Debris Mitigation Guidelines," IADC-02-01 Revision 1, September 2007, 9, http://www.unoosa.org/.

34. American Bar Association and NPEC, "America's Spacefaring Allies," 19.

35. Brian G. Chow, "Nuclear Vulnerability: In-Orbit Bodyguards Would Help Protect NC3 Satellites from Attacks," *SpaceNews*, 1 April 2019, https://spacenews.com/.

36. Sandra Erwin, "Scolese: NRO Advancing Space Technology, Developing Tactics to Defend Satellites," *SpaceNews*, 3 December 2019, https://spacenews.com/.

37. For example, the Air Force's constellation of Next-Generation Overhead Persistent Infrared (Next-Gen OPIR) missile warning satellites will be deployed by 2029. However, it seems unlikely that they will be resilient enough against a proximity threat because the constellation has the three nonresilient attributes discussed earlier (number, cost, and size). See Sandra Erwin, "Northrop

Grumman Gets $2.3 Billion Space Force Contract to Develop Missile-Warning Satellites," *Space News*, 18 May 2020, https://spacenews.com/.

38. The author recommended in another article that "the United States should quickly initiate a crash program to develop cheap but effective bodyguards by using small satellites." Brian G. Chow, "Two Ways to Ward off Killer Spacecraft," *Defense One*, 30 July 2019, https://www.defenseone.com/.

39. The Defense Advanced Research Projects Agency plans to launch the first three experimental Blackjack satellites in late 2020 and early 2021, and as many as 20 satellites by 2022. Sandra Erwin, "DARPA to Begin Launching Blackjack Satellites in Late 2020," *SpaceNews*, 11 May 2020, https://spacenews.com/.

40. Morgan Stanley reported a cost of $10–$15 billion for SpaceX's deployment of 11,943 Starlink smallsats. This amounts to roughly $1 million per satellite for manufacturing and launch. Morgan Stanley, *Space: Investment Implications of the Final Frontier* (New York: Morgan Stanley, 12 October 2017), 9, 22, http://www.fullertreacymoney.com/.

41. According to the Organisation of Economic Co-operation and Development, "Satellites typically cost about US$1bn [billion] to build and launch but the rise of small satellites (CubeSats) means this cost has now been driven down to US$5mn [million] by some companies like Terra Bella/Skybox Imaging." Further, "the speed of manufacturing satellites is increasing too; in early 2015 it took Planet Labs just nine days to build two CubeSats." See Felix Tran et al., "Thematic Investing: To Infinity and Beyond – Global Space Primer," Bank of America Merrill Lynch Transforming World Thematic Research, 2017, 62, http://newspaceglobal.com/.

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