Strategic Choice and the Orbital Security Dilemma

LTC Brad Townsend, USA

Abstract

The current environment in space appears to have many of the traits of a security dilemma. Left unchecked, security dilemmas create unstable conditions and generate suboptimal arms racing, potentially leading to war. The growing orbital security dilemma is being fueled by the common perception that space is an offense-dominant environment. This misperception of offense dominance is ruling out viable reassurance strategies and forcing states to pursue self-defeating policies that are only intensifying the security dilemma in space. This article addresses the more nuanced reality of the offense-defense balance in space and its implications for the future of great power competition in orbit. It concludes that states should pursue a hedging strategy that favors robust defensive capabilities and a disaggregated space architecture due to a combination of a nearly neutral offense-defense balance and the persistence of some form of the security dilemma driven by borderless orbital geography.

*****

The common refrain from US political and military leaders is that space is now a war-fighting domain just like any other.[1] The casual frequency of this previously taboo statement highlights the rapid shift in US space policy from seeming complacency to proactive deterrence. As the US perceives an increasing threat to its space power by strategic competitors, its policies are reflecting a more aggressive military posture in space. This stance can fuel the possibility of an arms race in orbit as other states react to US efforts to safeguard its space assets in unpredictable ways. The behavior of the major space powers in orbit is creating the conditions for the classic action-reaction-overreaction cycle described by the security dilemma that drives arms races and can often lead to tragic and unintended outcomes, especially when the perception of the military conditions varies from reality.

A security dilemma arises when a state's attempts to increase its security threaten other states, leading to unnecessary conflict or intensified

security competition.[2] It is a relatively simple concept with complex outcomes. Since state behavior in space is beginning to resemble one of security seeking, the security dilemma can provide a framework for explaining and predicting future outcomes. But foremost, understanding the nature of the orbital security dilemma may facilitate determining a way to preserve the current fragile peace in the space domain, a condition that best suits the desires of all spacefaring states.

Among the many drivers of this security dilemma are the heightened dependence of conventional military capabilities on space support and the growing economic importance of space. This combination of factors has revived early space age fears of war in space that until recently were slowed by a combination of norms, technical limitations, and the relatively limited value of the domain both militarily and economically. These mitigating factors that once helped maintain stability in space are rapidly disappearing. Space has become vital to the economic well-being of developed nations as well as to the ability to project military power. As the cost of space access decreases, the connection between space power and national power will strengthen, bolstering the likelihood of intense military competition in orbit.

The perception of vulnerability in space is partly driving the severity of the security dilemma and the nature of military competition in orbit. This sense of vulnerability is a function of the common understanding that the offense dominates in space and that the purpose of space systems as offensive or defensive weapons is difficult or impossible to differentiate. These perceptions, accurate or not, create the conditions for a severe security dilemma but do not mean that all the negative consequences of a security dilemma–driven arms race will occur, particularly when the conditions for the dilemma are isolated to a single domain. However, they do point to the potential expansion of security competition into an entirely new physical domain for the first time in over a century—with dangerously uncertain consequences and outcomes. A clear understanding of the offense-defense balance in space and the conditions under which it changes will allow policy makers to more accurately assess threats and vulnerabilities while allowing for the development of viable reassurance strategies. The reality is that as more satellite constellations are launched, the balance will tilt in favor of the defense—creating more opportunities for cooperation that can moderate the orbital security dilemma and preserve peace.

This article addresses the perception of military conditions in space within the security dilemma. First, it reviews the relationship between the security dilemma and the offense-defense balance. It also addresses

methods for measuring the offense-defense balance and the degree of distinguishability of space weapons. Next, the article determines the offense-defense balance in orbit at different levels of warfare. It then addresses the challenge of distinguishing between offensive and defensive space systems. Finally, this article presents a brief analysis of effective national strategies in an environment increasingly driven by the dynamics of the security dilemma.

Security Dilemmas and the Offense-Defense Balance

The *security dilemma* is a term first used by John Herz, the influential international relations author and scholar, more than 60 years ago to describe a situation that arises in an anarchic environment where one individual or group's quest for security through the accumulation of power creates insecurity in neighboring individuals or groups.[3] In an effort to ensure their security, neighboring individuals or groups accumulate power in response. An action-reaction cycle then ensues, with each party attempting to ensure its security by accumulating more power than its neighbor. In an anarchic world where individuals or groups are chiefly concerned with ensuring their own security, the security dilemma provides an explanation for competition and conflict.

In his landmark article "Cooperation under the Security Dilemma," Robert Jervis lays out many of the challenges and conditions associated with understanding the severity of a security dilemma.[4] He highlights that there are two crucial drivers of the dilemma: the distinguishability of defensive from offensive weapons and "whether the defense or the offense has the advantage."[5] If defensive weapons are easily distinguishable from offensive weapons, then a state can arm itself without threatening the security of its neighbors. In addition, when the "defense has the advantage over the offense, a large increase in one state's security only slightly decreases the security of [its neighbors]."[6] The result of this insight is that the balance between offense and defense is a key determinant of the severity of the security dilemma. For instance, if the offense has the advantage and states cannot distinguish between the nature of weapons, then the security dilemma is "doubly dangerous."[7] Alternatively, if the defense has the clear advantage and weapons types and uses are distinguishable, then the situation is stable and the security dilemma ceases to be an issue (table 1). This offense-defense balance can drive status quo powers to act aggressively if offense dominance exists, or it can encourage cooperative behavior if defense dominates.[8]

Table 1. Impact of offense-defense distinguishability on security dilemma

Offense	Offensive Advantage	Defensive Advantage
Not distinguishable from defense	Doubly dangerous	Security dilemma
Distinguishable from defense	No security dilemma, though aggression possible	Doubly stable

Adapted from Robert Jervis, "Cooperation under the Security Dilemma," *World Politics* 30, no. 2 (1978): 211.

In *Causes of War*, Stephen Van Evera goes so far as to argue that the offense-defense balance can act as the centerpiece of a separate theory of international relations. The core of his argument is that shifts in the offense-defense balance, real or perceived, substantially affect the risk of war because these calculations drive "policymakers' estimates of relative power."[9] The result is that when conquest is easy, war is far more likely. A perception of power imbalance, coupled with the ease of conquest in an offense-dominant environment, creates fear. This fear forces states to seek increased security through alliances, arms control agreements, or the accumulation of arms.

According to Van Evera, another negative outcome of misperceptions of the offense-defense balance occurs when the offense is perceived to have the advantage. Under these conditions "states hold military secrets more tightly," allowing militaries "to monopolize information" and leaving inflated assessments of the threat unchallenged.[10] Van Evera's observation further reinforces the need for a clear understanding of the offense-defense balance in space. Given the highly secretive nature of military space programs and an accepted perception of offense dominance in space, his assessment has ramifications for understanding current state behavior. Is the near-monopoly by national militaries on information about actions and events in space driving a cycle of overreaction and helping to fuel the security dilemma?

The quest for power to provide security from others' power is central to Herz's original formulation of the security dilemma.[11] Jervis recognizes that a way to describe power is in terms of the offense-defense balance; Van Evera takes this thread to the extreme and tries to make it stand on its own as the independent variable in his own theory.[12] Charles Glaser, in *Rational Theory of International Politics,* argues that the offense-defense balance is still important but must be included in a broader theoretical framework to accurately capture the severity of the security dilemma.[13] He substantiates his argument by incorporating the offense-defense balance

into a grouping of material factors that influence the security dilemma. The material variable's impact on the severity of the security dilemma is a function of the state's power, multiplied by the offense-defense balance.[14] Glaser defines *power* as the "ratio of states' resources that can be converted into military assets."[15] This definition can be understood as referring to military capability versus purely military assets since many normally nonmilitary space assets have military capability, such as commercial communications satellites. The concept of material power as a driver for the security dilemma is not new. It is at the core of the offensive realism school of international relations, though Glaser's nesting of the offense-defense balance within the material variable does offer additional insights when combined with other aspects of his theory. Glaser also explicitly incorporates two additional variables in his theoretical formulation of the security dilemma—motive and information—that were only implicit in the security dilemma framework as defined by Herz and others. Motive captures the security desires of a state, which can be characterized as security seeking, greedy, or a combination of the two. Greedy states have nonsecurity reasons for expansion that can include a desire to increase "wealth, territory, or prestige."[16] In contrast, security-seeking states are focused on protecting their current territory or wealth. These categories are not black and white; security-seeking states can appear to have greedy motives for a variety of reasons. They might desire a buffer zone, or more strategic depth, and so might seize territory or actively pursue strategies to weaken a stronger adversary to increase their security.[17] Almost all states naturally have at least a basic desire for security, though some desire more based on multifarious factors. It is the uncertainty that states have over the nature of their neighbors' motives that leads to the second additional variable impacting the security dilemma—information.

According to Glaser, the other independent variable necessary in determining behavior under the security dilemma is information. In this context, it denotes "what the state knows about its adversary's motives and what it believes its adversary knows about its own motives."[18] This concept differs from other structural theories of international relations that treat the uncertainty about states' motives as a static assumption. Instead, this factor becomes a variable for both parties. This does not mean that uncertainty cannot be eliminated; if that were so, then the security dilemma would not exist. However, using the information variable, a state might be reasonably confident that an adversary is a security-seeking state and so influence it to pursue cooperative policies with only minor levels of hedging. In contrast, if a state were highly uncertain that an adversary was a

security-seeking state, then it might decide that pursuing cooperative policies was too risky.

The other half of the information variable is what a state believes its adversary knows about its own motives. This reversal is necessary because it can lead to reaction and overreaction under the security dilemma. If state A believes that it is obvious to an adversary that it is a status quo security seeker and the adversary, state B, continues to build up arms, then state A concludes that it must be a greedy revisionist state. However, the truth may be that state B does not see state A as a security seeker, or it has a high level of uncertainty about state A's true intentions and so pursues a competitive policy to protect itself. This sequence of misperceptions was described by Jervis, but Glaser fully incorporates it into a functional theory.[19]

The severity of the security dilemma is therefore determined by a combination of material, motive, and informational variables working together within the rational strategic choice framework developed by Glaser. The explicit combination of these three variables explains why states sometimes pursue what would otherwise be seen as irrational policies under traditional realist structural theories. Since more than material factors impact the security dilemma in Glaser's theory as independent variables, a state might pursue cooperative policies when the material factors alone would point to competition and vice versa.[20] These variables combined with the offense-defense balance influence the severity of the security dilemma (table 2).

Table 2. Severity of the security dilemma

Motives	Offense Advantage	Defense Advantage
State is likely greedy	Very severe	Moderate
State is equally likely greedy or security seeker	Severe	Mild
State is likely security seeker	Moderate	Essentially eliminated

Adapted from Charles L. Glaser, *Rational Theory of International Politics* (Princeton, NJ: Princeton University Press, 2010), 87.

Determining the type and severity of a state's security dilemma is valuable in deciding whether to pursue competition or cooperation in space. This choice is influenced by the three variables mentioned above, making it a complex and difficult decision not entirely confined to the space domain. Defaulting toward cooperation seems to be the best option for escaping the security dilemma, but this is not always the case. Competing by pursuing arms can sometimes be the optimal choice for preventing war

or at least of decreasing the probability of conflict. When facing a greedy state in an offense-dominant environment, the optimal choice for a state is to pursue arms and seek to deter its adversary.[21] Of course, war is still more likely when a security-seeking state is faced with a greedy one, but choosing not to arm would only further increase the likelihood of conflict by encouraging the greedy state to take advantage of weakness, and so the logic of deterrence becomes dominant. The pursuit of arms for security is then the optimal choice under these conditions because cooperation would be dangerous.

In contrast, a suboptimal arms race can generate the insecurity that a state is attempting to avoid when cooperation would be a better option.[22] Suboptimal arms races can create dangerous uncertainty and lead to conflict. At best, suboptimal arms races are a waste of resources that a state would be better off investing elsewhere, particularly in the space domain where changes in technology can rapidly offset the advantages gained through arms racing.[23]

The overall logic of choosing to pursue arms or cooperation is shown in table 3, below. Both the upper left and lower right quadrants are optimal choices. In the upper left, a state's best choice was to arm to deter a greedy adversary. In the lower right, both states sought cooperation and correctly did so. In the upper right quadrant is the classic security dilemma where a state chose to arm when it did not need to, with the attendant negative impacts on its security as other states responded. The other suboptimal choice is when a state chose not to arm even when faced with a hostile adversary, leaving the cooperating state dangerously vulnerable. War is always possible with or without arms races, though it is the uncertainty inherent in the security dilemma that drives these suboptimal choices that "make war unnecessarily likely."[24]

Table 3. Quality of arming decisions

		State Should Have Armed/Raced	
		Yes	No
State Armed/Raced	Yes	Optimal Arming: Necessary Races	Suboptimal Arming: Dangerous Races
	No	Suboptimal Restraint: Dangerous Cooperation	Optimal Restraint: Desirable Cooperation

Source: Charles L. Glaser, *Rational Theory of International Politics* (Princeton, NJ: Princeton University Press, 2010), 233.

Glaser's models for the security dilemma and arming decisions do have shortcomings when applied together. The first is a 2x3 matrix of possible outcomes while the second is a 2x2 matrix of arming decisions that prevent straightforward application. Considered independently, both models

are logically consistent, but there is significant underlap when they are applied together. If conditions are such that the offense-defense balance only slightly favors the defense and a state's adversaries are equally likely to be greedy or security seekers, then it is unclear from table 3 if a policy of restraint or arming is optimal. This unclear middle ground is also the most likely to occur in applications where motivations, intentions, and capabilities become clearly defined only after the fact, and likely not even then. A realm of hedging then exists between a policy of either optimal arming or restraint. Actions under these conditions depend on the degree of distinguishability in the offense-defense balance, something that neither of the structures proposed by Glaser explicitly considers.

In another approach, Evan Montgomery places the offense-defense balance in context with the degree of distinguishability and addresses the underlap in Glaser's two models.[25] The focus of Montgomery's model is providing a guide for how states can reveal their benign intentions—allowing other states to clearly identify them as security seekers—which under Glaser's model would either moderate or eliminate the security dilemma. Montgomery does this by using an approach similar to Jervis's model discussed above, but in addition to a different focus, he also includes the more ambiguous case of offense-defense neutrality. The resulting matrix does not explicitly identify whether cooperation or competition is the optimal strategy for a state under the conditions identified in the model. However, in determining the cost of pursuing a cooperative policy, it highlights the risks associated with choosing restraint over competition (see table 4, next page).

The models discussed above demonstrate the close relationship between the offense-defense balance and the security dilemma. They also show the importance of striving to determine the truth of a concept as subjective as the offense-defense balance. Understanding the nature of the balance and the degree of distinguishability can point to strategies for mitigating the severity of the security dilemma in space or determining if one exists at all. Even Jervis's simple 2x2 model can lead to complex outcomes and strategies that more recent models by Glaser and Montgomery attempt to clarify. The problem is that these complex outcomes are matched by the challenges associated with accurately measuring and determining the offense-defense balance.

Table 4. Offense-defense, reassurance, and vulnerability

	Offense-Defense Differentiation	
Offense-Defense Balance	**Yes**	**No**
Defensive advantage	• Large reductions in defensive forces are necessary to reveal benign motives. • Large concessions can still increase a state's vulnerability.	• Signals that decrease a state's ability to attack also decrease its ability to defend. • Large reductions necessary to reveal benign motives. • Large concessions increase a state's vulnerability.
Offense-defense balance neutral	Benign states can reveal motives without increased vulnerability because • Differentiation allows states to choose clearly defensive forces. • Defensive forces are as effective as offensive forces, so benign states are not at a disadvantage if they choose defense.	• Signals that decrease a state's ability to attack also decrease its ability to defend. • Moderate reductions in the number of forces will reveal benign motives. • Moderate concessions will also increase a state's vulnerability.
Offensive advantage	• Small limits on offensive forces sufficient to reveal benign motives. • Small concessions increase a state's vulnerability.	• Signals that decrease a state's ability to attack also decrease its ability to defend. • Small reductions in the number of forces will be sufficient to reveal benign motives. • Small concessions increase a state's vulnerability.

Adapted from Evan Braden Montgomery, "Breaking Out of the Security Dilemma: Realism, Reassurance, and the Problem of Uncertainty," *International Security* 31, no. 2 (2006): 169.

Measuring the Offense-Defense Balance in Space

The offense-defense balance is not an easy factor to measure despite the influence it can have on military behavior, especially as it is not the reality of the balance but the perception of it prior to conflict that impacts behavior. For this space-centric discussion, the *offense-defense balance* is the ratio of the cost of offensive forces versus the cost of successfully defending against those forces without significant degradation of capability.[26] This definition removes any troublesome references to territory, common in most definitions but irrelevant in the space domain. Using this relative method of measurement is not without subjectivity as the cost of attacking versus the cost of defending must be categorized in subjective

terms such as low, very low, or extremely high. Complicating this subjectivity, the process and methods of measuring the offense-defense balance are extremely controversial, with some arguing that it cannot be done.[27] Despite this ambiguity, the perception of offensive or defensive advantage plays a central role in determining states' arming choices and behaviors and remains a fixture of modern international relations theory.[28]

Two of the primary factors usually cited as determining the offense-defense balance are geography and technology.[29] Geography is usually the least controversial factor affecting the offense-defense balance between states.[30] If two states share a mountainous border that is difficult to cross or are separated by an ocean, then defense would have the advantage in any conflict between those states. In space, unlike on Earth, all states suffer from the same constraints imposed by orbital dynamics, so geography affects all nations equally.[31] Some might argue that access to launch sites near the equator—allowing larger masses to reach geosynchronous orbits for a given mass of fuel—represents a geographic limitation that may favor some states over others. However, the difference is small enough that it is not a significant strategic factor in the offense-defense balance. For example, there is only a 22 percent gain in mass to geosynchronous orbit for a Soyuz launching from Baikonur, Russia (46 degrees North latitude), versus launching from Kourou, Guiana (5 degrees North Latitude).[32] While this difference is undoubtedly economically significant, it is not enough to affect the balance of military power in space between great powers and so can be disregarded.

The second primary factor that affects the offense-defense balance is technology. Since geography in space is shared among states, it becomes the sole driver of the offense-defense balance in orbit. The challenge is that space technology's rapid evolution is shifting the envelope of the possible and altering the perception of threats in space. The last decade has seen remarkable developments in space technology and an accelerating pace of innovation. These changes can be most directly attributed to the paradigm-shifting decrease in launch prices combined with the development of mass-produced small satellites that can operate in constellations. These two trends are mutually reinforcing and will lead to a proliferation of satellites in orbit over the next decade. This surge in space platforms will create challenges for the other factor that influences an assessment of the severity of the security dilemma—the degree of distinguishability.

Determining the degree of differentiation between offensive and defensive weapons is becoming increasingly difficult in space. The inability to clearly differentiate weapons systems into categories of offensive and

defensive has always presented problems, especially to attempts at arms control. Salvador de Madariaga, a Spanish diplomat, famously said that "a weapon is either offensive or defensive according to which end of it you are looking at."[33] This statement highlights that the purpose of many weapons systems is dependent on how a state uses them and not on the intrinsic nature of the weapon. Even those that are explicitly defensive, such as fortifications, could be interpreted as supporting offensive purposes when they are used to free up mobile forces for duty elsewhere.

The space domain does not escape this confusion. Since space is primarily a domain for transmitting and gathering information, even a communications satellite could be construed as an offensive platform when used to support terrestrial offensive operations. To help alleviate this confusion of purpose, only the role of platforms in the space domain will be considered. Those systems that do not explicitly harm space assets are considered defensive while those designed to harm or interfere with space assets are offensive. For example, an antisatellite weapon (ASAT) or a ground-based laser is an offensive system, even if its use could be part of a defensive strategy—though this differentiation still does not entirely solve the problem of distinguishability.

The deployment of on-orbit repair and maintenance systems designed to service satellites or remove debris presents a dilemma. These systems are ostensibly designed for peaceful purposes, but a satellite with a repair arm or a net for catching debris could easily be used to damage or destroy a satellite. Unlike those explicitly offensive weapons categorized above, the purpose of these systems depends on how a state uses them. For the time being, this challenge is mitigated by the fact that only a handful of systems on orbit fall into this category. In the future, as more of these systems are launched, they will become a more pressing issue and represent a challenge to attempts at arms control agreements in space.

The issue that dual-use satellites create in determining the degree of distinguishability between space systems will be mitigated by two factors. First, the number of these systems on orbit must be constrained by the degree to which they are economically justified. The relatively small number of these platforms that could be economically justified would not allow one nation to rapidly dominate another in space. Launching a larger number of dual-use satellites than could reasonably be justified to perform their mission represents a clear provocation and an act that would clearly distinguish the specific capability as offensive. Second, while systems designed to perform commercial tasks such as repair, refueling, or debris removal can be used as weapons, they will be poor examples of them. An

analogous comparison is the military utility of commercial airliners. While airliners can be used to support military operations by transporting troops in permissive environments, they would be ineffective in comparison to dedicated military aircraft such as bombers or fighters. The technology on which commercial airliners are based could be used to develop dedicated weapons of war, but doing so requires time and experience. The fear of future dual-use commercial capabilities is largely driven by the lack of experience that humanity has with conflict in space and the implicit assumption that the offense-defense balance in space favors the attacker.

The Offense-Defense Balance in Space

If a nation misperceives the offense-defense balance, it will rule out reassurance strategies that might otherwise be possible and instead default to suboptimal arming policies. Such policies are being enacted now largely due to a misinterpretation of the overall offense-defense balance. The common belief is that offense has a distinct advantage in space and that the offense and defense are indistinguishable because of the dual-use nature of many space systems. These views of offense dominance and indistinguishability are ruling out viable reassurance strategies, forcing states to pursue self-defeating policies that are further intensifying the security dilemma in space.

In the space domain, it is generally accepted that offense has the advantage. This frequently cited "fact" appears in studies, newspaper articles, and treatises on strategy—often with little support.[34] RAND studies cite it, as do prominent strategists such as Colin Gray who argues with some equivocation that "offense may appear to be the stronger form of war in space, given the absence of terrain obstacles, the relative paucity of capital assets (and targets), and the global consequences of military success or failure."[35] Senior US policy makers also share Gray's opinion. James Finch and Shawn Steen, the former director and deputy director, respectively, for space policy and strategy development in the US Office of the Undersecretary of Defense for Policy, argue that the domain is offense dominant because "holding space targets at risk is far easier and cheaper than defending them."[36] With the notable exception of an article by Edward Ferguson and John Klein using a Clausewitzian-based premise, there are few serious attempts to refute the idea that space is offense dominant.[37]

It seems fairly obvious that space is offense dominant. After all, satellites are vulnerable machines. They travel in predictable orbits, and every kilogram of mass devoted to their defense leaves less available for its actual mission. The attacker is under no similar limitation and can devote all its

capabilities to defeating whatever safeguards the defender has available. Additionally, with many military satellites taking nearly a decade to design, their technology is already outdated upon launch.[38] During the expected 10 to 15 years of lifetime a satellite has on orbit, that technology deficit only grows with no realistic way for improvements or upgrades to occur. As a result, the attacking platform or system will almost always be newer and more capable. Even the traditional advantages of the defender do not apply. There is no terrain to leverage for a defending satellite's advantage. If orbits are terrain, then the defending satellite is essentially trapped in the orbit in which it is placed. Even if it had the fuel to move, it loses its very purpose once it changes orbit; thus, the attacker has achieved its objective merely by threating to attack. The attacker also chooses the time and place of the attack, which can occur when the defender has limited ability to observe or react.

Another traditional defensive advantage that fails in space is that of interior lines. Interior lines traditionally allow a defender to mass forces and reinforce faster than an attacker. In space, both the attacker and defender suffer from the same physical restrictions in achieving orbit, neutralizing any advantage to either side. Finally, the bullet is always cheaper than the target, assuming that the target is not another bullet. Whatever form the attacker takes, it is optimized for a single function: destroying or disabling its target. This approach will inevitably be cheaper than the target satellite.

With all of these disadvantages accruing to the defending satellite, how can any argument be made that does not favor the offense in space? Consider the fundamental military use of space. It lies not in the individual satellite but in the ability to transmit information through it and to collect information from it. True, the satellite is critical to this process; however, the paradigm is shifting. As recently as 15 years ago, the number of satellites on orbit with service to any one region in any particular band was relatively limited. Therefore, the ability to transmit information through space and the health of the satellite were inextricably linked. In December 2019, more than 2,218 active satellites were on orbit, up from around 500 in 2008, and we are on the cusp of the era when active small satellite constellations and reduced launch costs will cause these numbers to skyrocket.[39] The space between orbital slots in the geostationary belt also continues to shrink with multiple satellites now operating in the same slot. With so many satellites on orbit, a hostile entity looking to interfere with a signal will first have to contend with finding the signal. Once found, whether the attacker uses kinetic means to threaten the sat-

ellite or nonkinetic means to target the signal will not matter. The signal can move elsewhere in moments, and the attacker is again left hunting for a needle in a haystack. A competent defender will be ready for interference or attack and—just as is done with terrestrial radio interference—have a preplanned alternate frequency. A clever defender will take things one step further by having a plan, when threatened, to further complicate the attacker's search by switching bands or even moving from fixed to mobile satellite services.

The intermixing of military, civil, and commercial signals from a variety of sources on commercial platforms creates a further complication for an attacker. Attacking the wrong signal or satellite can involve a third party in any conflict, an undesirable situation for the attacking entity. The level of entanglement involved in commercial platforms varies, but it creates another issue that any attacker must consider. When the array of challenges involved in the actual mechanics of preventing the transmission of information through space is considered, the offense-defense balance is more neutral than commonly thought. While the sheer number of signals on orbit makes stopping the transmission of information extremely difficult, preserving the ability to gather information is even more complex.

Gathering information from space requires a platform. Thus, the loss of a satellite could create a catastrophic loss of information-gathering ability, although this situation is changing rapidly. In 2018, there were 684 active satellites on orbit whose primary purpose was Earth observation in a variety of spectrums—nearly double the number in 2016.[40] While much of the growth is coming from small satellites, there is significant growth in larger satellites as well. The US-based company Planet alone now offers three- to five-meter resolution of anywhere on the globe every day, with resolutions as low as .5 meters less frequently.[41] This is a capability that no one, civilian or military, ever had as recently as two years ago. It is becoming very challenging for a nation to hide anything and even harder to prevent someone from gathering information. There are simply too many commercial, scientific, and national systems imaging the Earth for any attacker to completely deny them the ability to image an area.

The one area where no commercial system can yet compensate for is in dedicated systems with no civilian application, such as missile warning. Satellites performing these missions are currently irreplaceable, though their specific association with nuclear deterrence provides them with their best protection. Any attack on these systems represents an attack on a country's nuclear deterrent, with attendant consequences. However, commingling these systems with non-missile-warning conventional missions

such as "battlespace awareness" represents a dangerous trend that makes these satellites legitimate targets in any conventional limited conflict.[42] Whether the intent behind an attack on these satellites is a prelude to nuclear conflict or an effort to deny an enemy information, a defender must assume the worst. Even unintentional damage by debris from another destroyed satellite could be misinterpreted as an intentional attack, given the inability to directly observe the damage. Protecting this handful of expensive, vital satellites is best done by avoiding a suboptimal arms race in space.

Fundamentally, the greatest threat to a nation's space control will be an adversary's ability to disrupt or deny the information flow provided by a nation's space assets, whether commercial or military. Since a larger presence on orbit makes this task more difficult, it benefits a nation to have the largest, most resilient space architecture possible. Resiliency is the ability of a nation's assets "to continue providing required capabilities in the face of system failures, environmental challenges, or adversary actions."[43] One of the easiest ways to achieve resiliency is by dispersing the capability to gather and transmit information across as many platforms as possible, commonly called disaggregation. Because the number of commercial satellites in orbit is increasing rapidly, a nation's ability to achieve resiliency through disaggregation will depend on the size of its commercial space industry. However, commercial providers are unlikely to offer the necessary level of conflict protection for their satellites due to the additional costs. This reluctance means that while the individual satellites may be more numerous, they are also more vulnerable to interference or other forms of attack.

Where then does the offense-defense balance lie? The individual satellite remains vulnerable to attack and nearly impossible to defend. Therefore, at the level of the individual satellite—the tactical level of space—the advantage does lie with the offense. At the level of a constellation of similar platforms, a signal can move or one platform can compensate for the loss of another, but the target set remains limited to a subset of satellites. A smaller constellation favors the attacker while a larger, more robust constellation can shift the advantage to the defender. The balance at this level—the operational level—is then generally neutral depending on the number of satellites and the ease with which they can be replaced. At the strategic level, where the balance is measured against the aggregate ability of a nation to transmit and gather information using space, the balance begins to shift in favor of the defender (table 5). As long as a nation can maintain access to a significant share of the commercial market, it is un-

likely that another nation can entirely deny it the use of space. Space is an environment where nations can always disrupt and degrade the capabilities of other nations. However, one nation cannot entirely deny another the ability to substantially leverage space as long as a neutral commercial market exists.

Table 5. Offense-defense balance in space

Level of War		Balance
Tactical:	Individual satellite	Strongly favors offense
Operational:	Constellation or specific architecture	Neutral depending on constellation size and architecture resiliency
Strategic:	Continued national access and ability to exploit space	Slightly favors defense

Distinguishability

Determining the need for competitive or cooperative policies in space also requires determining the distinguishability between the offense and the defense. This task is notoriously difficult as most weapons are not intrinsically either offensive or defensive. Instead, it is the intent behind the weapon that determines its nature. While some space systems are more easily distinguishable than their terrestrial counterparts, others suffer from the same degree of confusion. Space also has norms of behavior established at the outset of the space race that differ from any other domain and significantly affect distinguishability in space and the degree of uncertainty that comes from dual-use systems.

Before establishing the degree of distinguishability in space, clarification on degrees of space militarization is necessary. Since the very beginning of the space age, the US has publicly supported the peaceful use of space while at the same time quietly steering the definition of *peaceful* toward "the non-aggressive use of space."[44] The Eisenhower administration saw the unique benefits of space-based reconnaissance in verifying Soviet military capabilities and preserving the peace between the two superpowers. The precedent established of defining *passive military use* as peaceful has continued, even as the passive use of space moved beyond reconnaissance and treaty verification. Today, passive systems—such as satellite communications and GPS—actively contribute to offensive military actions on the ground, yet they remain classified as passive and therefore peaceful systems. Intentionally conflating *nonaggressive* with *peaceful* from the outset established a unique domain norm that remains in effect

today. In any other domain, a system that provides targeting data to weapons systems would clearly be a legitimate military threat, yet space maintains a definition of *peaceful* based on a precedent only tacitly agreed to during the Cold War.

The next degree of space militarization is ground-to-space weapons. These were among the first space weapons developed and have existed in one form or another since nearly the beginning of the space age, albeit in limited numbers. ASATs are the classic example of these type of systems, which can also include ground-based jammers and lasers designed to degrade or damage orbiting satellites. The current arms race in space is focused on developing these capabilities, and the further testing and development of these weapons is an area of significant concern.

The next level of space militarization is space-to-space weapons. This category includes satellites designed to destroy or disable other satellites. Satellites designed to protect other satellites through offensive action would also fall in this category, one that is only just beginning to develop. Weapons at this level of militarization would be a dangerous new development in space. Even so, they would be a threat only to other space systems and remain within the information-centric space power paradigm mentioned earlier.

The final and most dangerous level of space weaponization is the fielding of space-to-ground weapons (fig. 1). No nation has crossed this proverbial Rubicon, though if it does happen, it will create a dangerously unstable situation. The advent of space-to-ground weapons would invalidate information-centric space power theories because preserving the ability to gather and transmit information through and from space would no longer solely define the military utility of the domain. These space-to-ground weapons could provide nuclear effects without nuclear fallout from orbits low enough that they would give the defender minimal reaction time. Unlike ICBM launches that are easily detectable, space-to-ground weapons would most likely have much lower launch signatures.[45] These launch platforms would individually be vulnerable, and an opponent would no doubt develop ASATs designed to attack them. Both nations in this situation would enter a dangerous offense-dominant environment with extremely low crisis stability. In essence, if a situation developed that increased tensions, each nation may find itself in a use-it-or-lose-it quandary. This first-strike instability would pressure leaders "to strike first in a crisis to avoid the worst consequences of incurring a first strike."[46] Thankfully, this paradigm shift is not on the immediate horizon, though many believe it is inevitable.

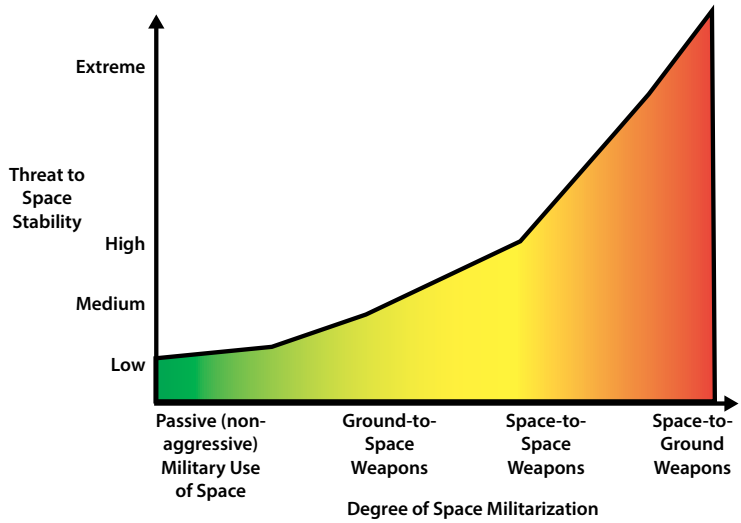

Figure 1. Degree of militarization and threat to space stability. (*Note*: Values are for illustrative purposes only and not based on empirical analysis.)

With the degrees of space militarization delineated, it is now possible to return to the issue of determining the degree of distinguishability. Established norms determine what constitutes the peaceful use of space, and since *peaceful/nonaggressive* and *defensive* are nearly synonymous terms in an environment dependent on information, anything designed to gather or transmit information is distinguishable as nonoffensive. This established norm of passive military use is stretched by the dependence that conventional offensive military capabilities have on space, yet it still holds. Nonetheless, the very dependence of conventional forces on these capabilities makes space capabilities a tempting target and drives nations to develop weapons designed to attack satellites. The next tier of militarization, ground-to-space, is where challenges of distinguishability begin. Antiballistic missiles (ABM) and ASATs are the most obvious examples of systems that suffer from distinguishability problems at this level. As discussed previously, a system designed to destroy or disable ballistic missiles can easily be retargeted to strike satellites in low orbit. A dedicated ASAT is only distinguishable from an ABM if it is designed to travel to altitudes beyond which ballistic missiles travel. Even if an ASAT and a missile defense system can be distinguished, the ASAT system might be a justified defensive system if there exists a legitimate reason to suspect that an adversary has placed weapons on orbit. The ASAT system then becomes indistinguishable in purpose from other weapons as it could be used defensively to deter enemy threats or offensively to attack peaceful satellites.

Other systems in this tier include ground-based lasers and jamming systems. These systems might have reversible effects, or they may cause permanent damage to the target. The intent of these systems could vary and may include causing interference with reconnaissance or navigation satellites assisting with enemy targeting. While this usage would be considered defensive in most contexts, any system designed to attack satellites for any reason can be classified as offensive. This simplistic categorization is only possible due to the established norms that passive satellites are peaceful. Therefore, any attack for any reason against passive satellites falls into the category of offense. This implicit understanding is present in US doctrine, which describes *offensive space control* as involving "measures [to] deceive, disrupt, degrade, deny or destroy space systems or services."[47] US doctrine makes no allowance for the intent behind why negation of enemy systems may be occurring, simplifying the categorization of ground-to-space weapons outside of ABMs as offensive.

The discussion of intent does enter into the equation when evaluating the distinguishability of defensive systems on orbit. The same US doctrine describes *defensive space control* as "all active and passive measures taken to protect friendly space capabilities from attack, interference, or unintentional hazards."[48] The inclusion of active defense in this description leads to confusion of intent. According to this doctrine document, *active space defense* "consists of those actions taken to neutralize imminent space control threats to friendly space forces and space capabilities."[49] In this definition, usage of the term "imminent" seems to clarify any confusion over what active defense is; however, what constitutes an imminent threat is not defined. Could a satellite belonging to a hostile nation sharing the same orbit be an imminent threat? Or does the satellite have to take aggressive action such as approaching within a given distance of a friendly satellite? If the friendly satellite possesses a defensive system capable of disabling the approaching satellite, could that system be used for offensive purposes? Lack of clarity with regard to defining imminent threats blurs the line between offensive and defensive space control.

It is under these conditions that the secrecy surrounding military satellite capabilities becomes an issue. While the orbits and designations of military satellites are generally known, the purposes of these platforms are impossible to verify. Unlike terrestrial weapons systems that can be easily imaged and observed in use, it is nearly impossible to verify that if a nation claims to launch a communications satellite, it is not instead launching a weapons platform or intelligence asset. The US Air Force recognized this problem and revealed a previously classified program in 2014 designed to

image satellites in geosynchronous Earth orbit (GEO).[50] The purpose of revealing this program, according to Gen William Shelton, was to "discern when adversaries attempt to avoid detection and to discover capabilities they may have which might be harmful to our critical assets at these higher altitudes."[51] Imaging adversary satellites can clarify a satellite's purpose, but the distance between two satellites in GEO may be tens of thousands of kilometers and thus prevent timely close inspection. Even if a close approach is made, the adversary satellite may possess the outward characteristics for its stated purpose while housing offensive weapons. Since military satellites are not available for general use, there is no way to verify that a particular satellite can, in fact, perform its stated mission even with visual inspection.

The ability to image satellites offers some reassurance, but space is large, and launch platforms can orbit multiple satellites simultaneously. The Indian space agency holds the current record for a multiple satellite launch, with 104 satellites of various sizes launched at once in 2017.[52] Each time a nation launches a military satellite, the possibility exists that the official payload is not the only payload on board. An exquisite level of space situational awareness is required to ensure that no additional satellites are on board. If they are small enough, these additional payloads may disguise themselves as launch debris to escape detection.

A Russian launch in 2014 attempted this trick of hiding in the debris. Following the launch of three Russian Rodnik military communications satellites, a piece of supposed debris from the launch began maneuvering.[53] The object was not part of the official Russian launch declaration, and speculation on its purpose and nature ranged from experimental repair vehicle to hunter-killer satellite. Whatever the cause, it demonstrated the ease with which nations can add additional payloads to launches without declaring them, hoping to evade detection. The US has the best space tracking network of any nation, and even it has substantial weaknesses that could easily allow something like this Russian action to go unnoticed.[54] Nations with much less robust tracking networks than the US can only rely on the data the US chooses to share about its satellites' purposes and capabilities, leaving significant room for suspicion and uncertainty of the type that fuel security dilemmas. With the rapidly growing number of satellites on orbit, it will be increasingly difficult to verify that every military satellite is what it is purported to be.

Military satellites are not the only ones that suffer from issues of distinguishability. While commercial communications, weather, and reconnaissance satellites create little suspicion because they are performing their

intended purpose daily for a variety of users, other commercial satellites, by their very design and nature, create suspicion. Commercial or civil ventures designed to refuel satellites, repair them, or remove debris can easily be used to damage or disable other satellites. For example, in 2018 Chinese researchers proposed a space-based laser designed to remove space debris from orbit.[55] This ostensibly civil research program would involve a satellite with a laser designed to heat targeted debris and deorbit it. A satellite mounting a laser designed to remove debris would have obvious dual-use potential and could serve as a test bed for future space-based weapons. This proposal is just one of many attempting to deal with the problem of space debris, and any of them could easily be used to destroy active satellites. The one mitigating factor is that at this time such satellites are only in the earliest stages of development and testing.

Among existing satellites and space systems, distinguishability is high relative to other fields of military endeavor. The establishment of norms early in the space era that information gathering and transmission, even in support of military efforts, are nonaggressive and peaceful greatly aids distinguishability in space. This differentiation makes ground-to-space weapons designed to interfere with satellites inherently offensive. Some confusion of intent does exist regarding active defenses on orbit and dual-use commercial systems. However, it is mitigated by the relative lack of known systems with these capabilities. One complicating factor is the uncertainty over the true purpose of military satellites. Distinguishability among military platforms is highly dependent on whether the satellite that a nation claimed it launched was in fact the one it did launch. The Russians have shown that hiding potential orbital weapons among launch debris is possible. Even with this caveat, distinguishability remains relatively high among existing space systems.

Cooperation or Competition

Returning to Jervis's interpretation of the impact of the offense-defense balance on the security dilemma leaves us with no clear answer for its current severity or a way to escape it. While distinguishability is relatively high among space systems compared to other military domains, the offense-defense balance is not nearly as apparent. It does not obviously favor the offense when an observer expands their viewpoint beyond the individual satellite to consider the capability provided by a constellation of platforms. The balance can best be described as generally neutral with a slight tilt in favor of the offense. This balance will shift to neutral with a

slight tilt in favor of the defense as more satellite constellations are launched into low Earth orbit over the next decade.

Relying on Jervis's 2x2 matrix of possibilities, this combination of offense-defense balance and distinguishability indicates that no security dilemma should exist in space but that aggression in space is possible. This conclusion does not seem to match current rhetoric or actions on orbit. Perhaps because the reality does not matter, the perception of the balance prior to conflict is the defining factor in determining behavior. The current perception of these factors places the great space powers in a doubly dangerous security dilemma according to the model developed by Jervis.

The usage of the offense-defense balance by Glaser to measure the severity of the security dilemma is more informative than Jervis's 2x2 model in that it provides for more gradations within the dilemma. If a minor offensive advantage exists, then some form of security dilemma also exists that can range from moderate to severe. As the advantage shifts toward the defensive, the security dilemma will moderate but is only eliminated if no uncertainty exists about the intentions of other states as security seekers. This event is unlikely to occur because space suffers from a multistate dilemma driven by the shared geography of space.

Orbital dynamics means that all states share a common border in space, so the actions of one state affect all states. The unique nature of the space domain means that the strategic choices that a state makes must be suitable for all the nations with a presence in the domain. In space, a state will find it difficult to pursue restrained arming policies centered on cooperation with one adversary while also deterring another potential adversary given the shared nature of orbits. The implication is that a state will find it increasingly difficult to determine if space-capable nations are security seekers based on the information it has about their motives and intentions. At best, a state can conclude that its potential adversaries are equally likely to be either greedy or security seekers. Using Glaser's model, this incertitude indicates that a severe or very severe security dilemma exists in space. Even if the balance shifts slightly in favor of the defense, a moderate or mild dilemma will persist due to the multistate dilemma in space.

States are not entirely passive actors subject to the conditions of the security dilemma. Understanding the offense-defense balance allows states to choose strategies that can help moderate the dilemma, as indicated by Montgomery's model. Using this model, current conditions in space can best be typified by a neutral balance with differentiation. This characterization implies that defensive strategies are as effective as offensive ones, so a state can choose a defensive strategy without leaving itself

too vulnerable. By choosing a defensive strategy, a state will signal benign intent and clearly identify itself as a security seeker. Doing so gives other states information that can help them more confidently determine that other states are security seekers and allows them to avoid suboptimal arming and moderate the security dilemma.

Conclusion

The perception of the balance and degree of differentiation can substantially impact the security dilemma and drive decisions on arming in space. Even with a more nuanced understanding of the balance, it is difficult to make a definitive recommendation against pursuing arms in space. Cooperation among states in space has significant benefits in that it avoids unnecessary suboptimal arming. However, the possibility that at least one space power has greedy motives is high, so pursuing a policy of restraint in space could leave a nation that is dependent on space dangerously vulnerable. If this uncertainty means that states default to competitive policies in space, then the real question is whether it is possible to pursue defensive capabilities and moderate the security dilemma in orbit. Given the status of the offense-defense balance and the ability to somewhat differentiate systems by function, a defensive posture on orbit seems to be the best compromise approach for preserving capability while promoting cooperation.

Relying on the limited number of factors considered in this article, it seems that the optimal policy is some form of defensive arming. During the Cold War, some degree of restraint and cooperation was possible due to fewer actors in space and less dependence of conventional military capabilities on space assets. As more nations enter the space domain, the ability to adopt cooperative stances on orbit will only grow more difficult. The combination of a nearly neutral offense-defense balance and the persistence of some form of security dilemma indicates the prudence of pursuing a hedging strategy in favor of robust defensive capabilities and a disaggregated space architecture.

A caveat to the conclusion above is that the offense-defense balance and the degree of distinguishability in space are not static. The ongoing proliferation of small satellite constellations will increasingly shift the overall balance in favor of the defense. This beneficial trend will be countered by decreasing distinguishability between offensive and defensive capabilities on orbit driven by the proliferation of dual-use systems designed for a variety of legitimate purposes. Decreasing distinguishability will create misperceptions of intent as defensive actions are far more likely to be mistaken as aggressive. As this trend continues, the value of pursuing

a robust defensive posture will increase. In the future, the likelihood of unintended conflict in space will grow even as the overall defensive shift in the offense-defense balance increases the possibility of successful multistate cooperation.

The danger is that without a clearer understanding of the true vulnerability of space systems among policy makers and military personnel, a cycle of action-reaction-overreaction is likely to occur in the current space environment. This cycle may generate an intensifying arms race that could lead to suboptimal arming, wasteful spending, and unnecessary tension between space powers. Understanding the nuanced nature of the offense-defense balance allows for a more constrained approach to arming in orbit, which can inform future strategy decisions and moderate the orbital security dilemma—decreasing the possibility of future conflict in space. SSQ

LTC Brad Townsend, USA

LTC Brad Townsend, US Army, is the author of the forthcoming book *Security and Stability in the New Space Age: Alternatives to Arming* (Routledge Press, 2020). He holds a PhD and MPhil in military strategy from the US Air Force's Air University School of Advanced Air and Space Studies. A 2002 graduate of the US Military Academy, he also earned an MS in astronautical engineering from the Air Force Institute of Technology and an MS in space operations management from Webster University. He currently serves as a space policy advisor on the Joint Staff.

Notes

1. Statements to this effect have been made in public forums by almost all senior administration officials from President Trump downward beginning with Air Force Secretary Heather Wilson's testimony to the SASC in 2017. Marcia Smith, "Top Air Force Officials: Space Now Is a Warfighting Domain," 17 May 2017, https://spacepolicyonline.com/.
2. Evan Braden Montgomery, "Breaking Out of the Security Dilemma: Realism, Reassurance, and the Problem of Uncertainty," *International Security* 31, no. 2 (Fall 2006): 151.
3. John H. Herz, "Idealist Internationalism and the Security Dilemma," *World Politics* 2, no. 2 (1950): 157.
4. Robert Jervis, "Cooperation under the Security Dilemma," *World Politics* 30, no. 2 (1978): 167–214.
5. Jervis, 186–87.
6. Jervis, 187.
7. Jervis, 211.
8. Jervis, 188.
9. Stephen Van Evera, *Causes of War* (Ithaca, NY: Cornell University Press, 1999), 13.
10. Van Evera, 13–14.
11. Herz, "Idealist Internationalism and the Security Dilemma," 157.
12. See Jervis, "Cooperation under the Security Dilemma"; and Van Evera, *Causes of War*.

13. Charles L. Glaser, *Rational Theory of International Politics: The Logic of Competition and Cooperation* (Princeton, NJ: Princeton University Press, 2010), 3.
14. Glaser, 78.
15. Glaser, 76.
16. Glaser, 36.
17. Glaser, 36.
18. Glaser, 3.
19. See Robert Jervis, *Perception and Misperception in International Politics* (Princeton, NJ: Princeton University Press, 1976), 62–86.
20. Glaser, *Rational Theory of International Politics*, 73.
21. Glaser, 236.
22. Glaser, 231–32.
23. Glaser, 232.
24. Glaser, 229.
25. Montgomery, "Breaking Out of the Security Dilemma."
26. Charles Glaser and Chaim Kaufmann attempted to develop a method of measuring the offense-defense balance in an effort to apply it as an independent theory as proposed by Van Evera. Before doing so, they had to first settle on a definition of the *offense-defense balance*. They defined it as the "ratio of the cost of the forces that the attacker requires to take territory to the cost of the defender's forces." Using this definition, they had some success in measuring the offense-defense balance, though they still encountered great difficulty. See Charles L. Glaser and Chaim Kaufmann, "What Is the Offense-Defense Balance and Can We Measure It?," *International Security* 22, no. 4 (Spring 1998): 64, https://www.jstor.org/. Their efforts faced significant criticism of methodology as well as of the territorial focus of their definition, given that many wars are won or lost based on a single battle or raiding strategy or through other means, rather than directly by the conquest of territory. The offense-defense balance as a stand-alone theory also required the assumption that states would act optimally so that military doctrine and force deployments would not impact the balance. While an important influencing factor in determining the severity of the security dilemma, the offense-defense balance is not the sole influencing factor on state behavior and, as a result, is too parsimonious to stand as an independent theory. However, it can still provide a useful way of measuring the severity of a security dilemma and point to potential reassurance strategies for escaping it.
27. James W. Davis, Jr., et al., "Taking Offense at Offense-Defense Theory," *International Security* 23, no. 3 (1998): 186–87, https://www.jstor.org/.
28. See Glaser, *Rational Theory of International Politics*.
29. Jervis, "Cooperation under the Security Dilemma," 194.
30. Glaser and Kaufmann, "What Is the Offense-Defense Balance and Can We Measure It?," 64.
31. This in effect removes one of the larger complaints by some (see Keir Lieber) about the nonsystemic nature of the offense-defense balance due to the fact that geography under traditional definitions impacts each state uniquely.
32. "R-7/Soyuz Data Sheet," Space Launch Report, accessed 23 August 2018, http://www.spacelaunchreport.com/.
33. Quoted in Jervis, "Cooperation under the Security Dilemma," 201.
34. See Forrest E. Morgan, *Deterrence and First-Strike Stability in Space: A Preliminary Assessment* (Santa Monica, CA: RAND Project Air Force, January 2010), 2, https://

www.rand.org/; James P. Finch and Shawn Steene, "Finding Space in Deterrence," *Strategic Studies Quarterly* 5, no. 4 (2011): 11, https://www.airuniversity.af.edu/; and Paul Scharre, "The US Military Should Not Be Doubling Down on Space," *Defense One* (blog), 1 August 2018, https://www.defenseone.com/.

35. Colin S. Gray, *Weapons Don't Make War: Policy, Strategy, and Military Technology* (Lawrence, KS: University Press of Kansas, 1993), 14–15.

36. Finch and Steene, "Finding Space in Deterrence," 11.

37. Edward Ferguson and John Klein, "The Future of War in Space Is Defensive," *Space Review*, 19 December 2016, http://www.thespacereview.com/.

38. Cristina T. Chaplain, Director, Acquisition and Sourcing Management, US Government Accountability Office, *Space Acquisitions: DOD Continues to Face Challenges of Delayed Delivery of Critical Space Capabilities and Fragmented Leadership; Testimony before the Subcommittee on Strategic Forces, Committee on Armed Services, U.S. Senate* (Washington, DC: US Government Accountability Office, 2017), 1, https://www.gao.gov/.

39. Union of Concerned Scientists (UCS), "UCS Satellite Database," 1 May 2018, https://www.ucsusa.org/.

40. "Earth Observation Satellites in Space in 2018?," Pixalytics, 5 September 2018, https://www.pixalytics.com/.

41. "Planet Imagery and Archive," Planet, accessed January 2020, https://www.planet.com/.

42. Lockheed Martin, "SBIRS: Missile Defense Early Warning Satellite," fact sheet, PIRA SSS201608034, 2017, https://www.lockheedmartin.com/.

43. Air Force Space Command, *Resiliency and Disaggregated Space Architectures*, white paper (Peterson AFB, CO: Air Force Space Command, 14 April 2016), 4, https://www.afspc.af.mil/.

44. Note that the administration did regularly have to tamp down on USAF enthusiasm for seizing the high ground. See "Draft Position Paper for UN Ad Hoc Committee on Peaceful Uses of Outer Space: Legal Problems Which May Arise in the Exploration of Space" (White House Office of the Staff Secretary: Records, 1952–61, 22 April 1959), 8, Box 24, Space Council (7), Eisenhower Library.

45. US Air Force, "Defense Support Program Satellites," fact sheet, 23 November 2015, https://www.af.mil/.

46. Glenn A. Kent and David E. Thaler, *First-Strike Stability and Strategic Defenses: Part II of a Methodology for Evaluating Strategic Forces* (Santa Monica, CA: RAND Corporation, October 1990), xviii, https://www.rand.org/.

47. Joint Publication (JP) 3-14, *Space Operations*, 2018, II-2, https://www.jcs.mil/.

48. JP 3-14, II–2

49. JP 3-14, II–3.

50. Amy Butler, "USAF Space Chief Outs Classified Spy Sat Program," *Aviation Week*, 21 February 2014.

51. Gen William Shelton quoted in Irene Klotz, "US Air Force Reveals 'Neighborhood Watch' Spy Satellite Program," Reuters, 22 February 2014, https://www.reuters.com/.

52. Samantha Mathewson, "India Launches Record-Breaking 104 Satellites on Single Rocket," *Space.Com*, 15 February 2017, https://www.space.com/.

53. Sam Jones, "Object 2014-28E – Space Junk or Russian Satellite Killer?," *Financial Times*, 17 November 2014, https://www.ft.com/.

54. Brian Weeden, "Space Situational Awareness Fact Sheet," Secure World Foundation, May 2017, https://swfound.org/.

55. Kyle Mizokami, "China Proposes Orbiting Laser to Combat Space Junk," *Popular Mechanics*, 20 February 2018, https://www.popularmechanics.com/.