NPEC Nonproliferation Policy Education Center

NPEC monograph, published August 13, 2020 (revised August 28, 2020)

What War in Space Might Look Like Circa 2030-2040?

Peter Garretson[1]

Introduction

This essay seeks to give the reader two distinct visions of space warfare circa 2030-2040. First, a conservative view presumes wars begin on Earth (over geo-strategic interests on Earth), and extend into space to maintain the advantages of continued overhead satellite sensing. The second view is expansionist. It presumes space wars begin in space over geo-strategic interests in space and proceed with relative independence of events and military activity on Earth. Actual conflict of course might very well see a mix of both, but they are presented as extremes, or ideal-type cases to help the reader to see the outlines of different causal logics driving each. At some point, circa 2030 (and perhaps even sooner), economic development activities in deep space will create a truly unprecedented situation: nation-states will have geo-strategic interests on other planetary bodies — the moon and asteroids. The degree to which the future resembles the expansionist view will depend on how much and at what speed activities are conducted in deep space and on the Moon in particular. Those who would dismiss the expansionist scenarios as 'too far out' should consider that already today a number of states are talking about Lunar mining, and that the United States, China, India, Russia, Japan, and Israel are already putting precursor missions on the Moon. A wholistic view of both has implications for military doctrine, concept design, force structure design, and international governance including arms control and the law of armed conflict, as well as for legislation and policy. This suggests that 1) military doctrine must anticipate that United States geo-strategic interests will likely encompass economic activities in deep space, and develop concepts for peacetime strategic offensives to maintain positions of advantage; 2) that design of a 2030-2040 force structure requires attention to the unique navigational, maneuver, logistics, and power projection needs for deep space vehicles; 3) consideration and anticipation of conflict may enable the community of nations to arrive at consensus on certain conflicts or types of conflict they mutually wish to avoid, and 4) a role for civilian leadership to ensure the U.S. DoD is prepared through legislation and policy to specify roles and missions to protect space commerce, to specify plans, and to specify the Area of Responsibility (AOR) as encompassing the entirety of the Cis-Lunar theater.

Below I provide scenarios for crisis and conflict. The conservative view sees space war taking place close to Earth, within the Earth's Gravity well in Low Earth Orbit (LEO) or the Geostationary belt (GEO). In contrast, the expansionist view considers conflict that might occur

in proximity to Earth's Moon, *approximately ten times as distant as GEO (See image 1 below)*. Readers curious how I arrived at these can consult the appendix.

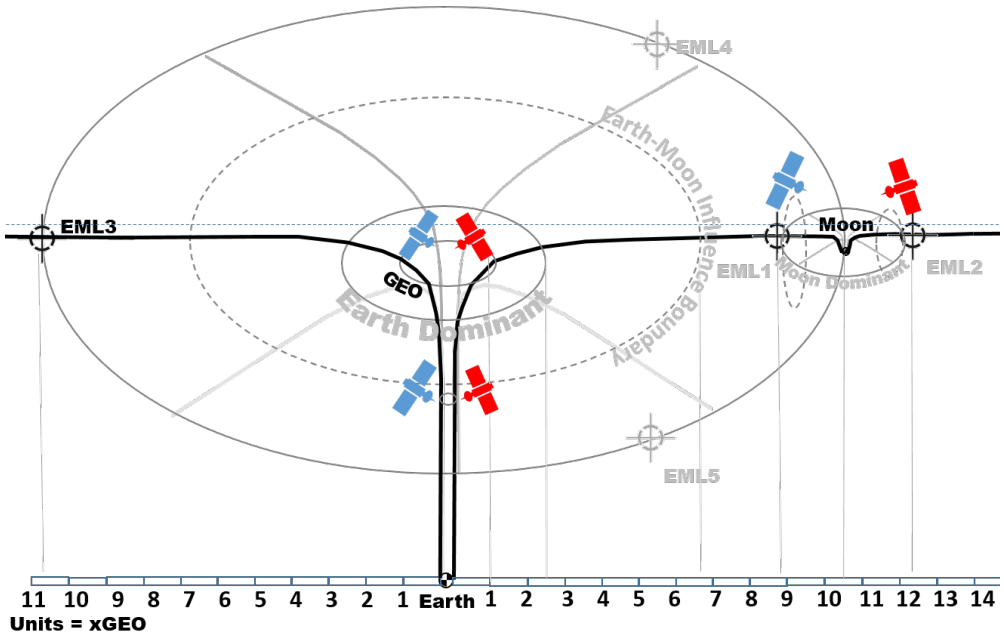


Image 1. Two Theaters of Space Crisis & Conflict (Source: Author)

Image 1 provides a basic 'terrain' map to orient the reader to the two theaters in which space conflict circa 2030-2040 might take place. The key features of this map are to-scale depictions of distance and the relative strength of gravity of the Earth and the Moon – depicted as gravity wells. Near the Earth, the Earth's gravity dominates spacecraft trajectory, labeled as *Earth Dominant Space*. Near the Moon, the Moon's gravity dominates, labeled as *Moon Dominant Space*. The region between the Earth and the Moon is an area of shared gravitational influence. Above the *Earth-Moon Influence Boundary* the gravitational influence of the Moon must always be taken into account. Also labelled are the Earth-Moon Lagrange (L) Points (EML1, EML2, EML3, EML4, and EML5) where gravitational and centrifugal forces balance such that spacecraft may be 'parked' at these points and maintain their relative position to the Earth and Moon, and may constitute strategic locations for commerce or control. The conservative scenarios take place entirely within *Earth Dominant Space*, and in fact GEO and below. In contrast, the expansionist scenarios take place beyond GEO, and mostly in *Moon Dominant Space*.

A conservative view of future space warfare: War Extends to Space

The conservative view of space warfare is that 'there is no such thing as a space war, there is just war'[2] and that a terrestrial 'war extends into space.'[3] Here the assumption is that the primary value of space assets is to support the terrestrial warfighter, and space control is a necessary activity to secure essential space information services (weather, missile warning, position, navigation, timing, blue force tracking, overhead surveillance, beyond line-of-sight

communications). Deterrence by punishment is assumed to be ineffective[4] since the U.S. has more to lose and the opponent can operate effectively in their near abroad without space. Because all military satellites are now held at risk, satellite protection and deterrence by denial is the key strategy. Therefore, the evolution of the architecture is toward a proliferated constellation of Low Earth Orbit (LEO) satellites, and better attribution and perhaps local bodyguards in GEO. The potential threats are manifold, with ground-based anti-satellite missiles and in-space robotic 'snugglers'[5] likely to multiply. Space-based terrestrial strike weapons[6] and through-space transportation and insertion remain of interest, but likely will not compete well against other power-projection mechanisms. Evolution of the order of battle is entirely military, though it likely leverages commercial launch and very large low-Earth Orbit (VLLEO) mega-constellation capabilities.[7] The architecture is entirely 'geocentric.' Deep space is conceptualized as the domain of NASA. Capabilities which we might expect to see in this time frame might include space-sensor layers to detect and track hypersonics,[8] and keep custody of other moving objects.

CONSERVATIVE CONSIDERATIONS IN CRISIS AND COERCION

Several considerations affect the lead-up and logic of how and why a crisis may escalate and embroil the participants in a difficult to exit spiral.

Escalation Route: The primary route to escalation is that an adversarial nation would take action with regard to a U.S. partner's equities which compromise the U.S. standing as a reliable partner or directly call into question U.S. treaty defense obligations. The U.S. would then posture to show the aggression is unacceptable.

Dominant Strategy: The adversary would then have to consider both crisis management and bargaining, the potential for a regional limited war, and escalation to general war where it was uncertain of U.S. restrictions on regime change. The dominant strategy in all cases for a U.S. adversary is to remove the force-multiplying effects of U.S. space infrastructure.

Raising the Costs of Intervention: The key action in a crisis is to raise the costs for the U.S. globally, and to signal its credible capability to hold at risk systems which might be perceived as more valuable than the U.S. interests in counter-intervention. We could expect then a series of postures that remind the U.S. of its vulnerability. Co-orbital platforms would snuggle in,[9] ground-based ASAT missiles would show increased readiness and mobility, laser systems would illuminate targets, denial of service of symbolically important channels via jammers[10] or cyber-attack,[11] and tests of new systems might be carried out. We might also expect an "accidental collision" or even a 'friendly inspection'[12] of a manned U.S. government or commercial space station. All to say, "we can touch you…back down." Some of this is likely to be done in ways not visible to the public, but in the U.S. system such private signaling is still likely to leak out. The U.S. could not be seen as publicly backing down from such threats, so it would have to counter-threaten in public while privately offering a de-escalatory program.[13] The U.S. is likely to take comparable measures, as well as to conduct horizontal escalation in an adjacent domain.

Fog and Uncertainty: The situation is likely to degrade further, as one or both sides attempt to mask their signatures through release of decoys, dazzling and jamming, and maneuver to change their orbital elements.

CONSERVATIVE SCENARIOS FOR SPACE WARFARE

Incentives to Escalate & Pre-empt: The problem with the adversary's threats to U.S. space systems is that the U.S. must take them seriously, and realize as well that an actual strike on U.S. space systems would so materially change conditions that it might feel it must pre-empt. It is not an exaggeration to think that a significant degradation of space could render the U.S. military a tenth to 100th as effective by which we mean that the U.S. would need to deploy 10 to 100x the level of activity to accomplish the same effect. For example, in WWII, it took an average of 100 sorties to destroy a single target while today one sortie can destroy four or five.[14] Numerous specific degradations are foreseeable. A loss of missile warning would make airbases and ships more vulnerable to missiles, enabling a potentially decimating first strike against forward-deployed (and perhaps even CONUS[15]-based) forces. A loss of timing signal[16] would remove the ability to reliably signal-hop or have secure communications. A loss of GPS would severely reduce the accuracy of U.S. missiles. A loss of beyond line-of-sight satellite communications would impede any coordination or update between dispersed forces or allow update of missiles. A loss of overhead sensing would severely reduce U.S. knowledge of enemy order of battle, and virtually eliminate the ability to prosecute mobile targets. Finally, most worrisome, the U.S. would have to take seriously that a loss of nuclear command and control or missile warning could facilitate or signal a surprise nuclear first strike and delaying retaliation sufficiently to further attrite U.S. nuclear forces.

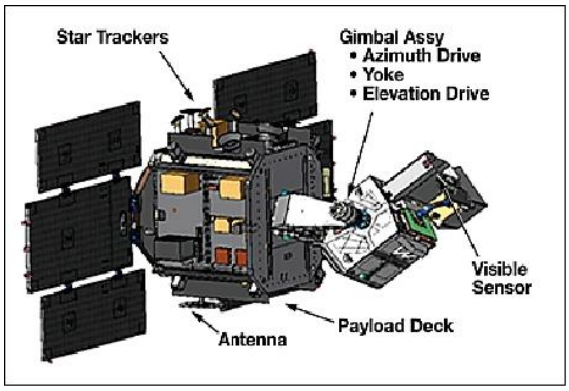
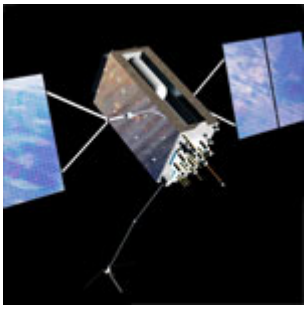


Image 2: Space-Based Surveillance System Spacecraft (SBSS-1) and its imaging sensor (image credit: Boeing Company)[17]

What are Attractive Targets?: Targeting of space systems relies on a belligerent's space domain awareness (SDA),[18] command and control systems, and anti-satellite weapons systems (an example of one SDA system is depicted in image 2 above). Military planners are likely to favor targets which provide the maximum effect, enable the greatest economy of force, can be struck with the highest likelihood of success, and generate the minimum collateral damage and inadvertent escalation. As both nations multiply their sensors, links, command posts, and weapons, what appears most attractive and most vulnerable can shift. In the conservative scenario, the most critical and central nodes are on the ground, and can be struck only by terrestrial forces: clandestine or special operations forces, naval forces, or air forces.

Moreover, the belligerent forces of both sides are threatened by the adversary's space-enabled reconnaissance strike system. For example, U.S. major power-projection legacy assets such as a carrier or combat aircraft are moving targets. Targeting them is greatly facilitated by overhead intelligence from sensors that might be optical (cameras), infra-red (heat signatures), radar, or passive Radio-Frequency (RF) mapping.[19]



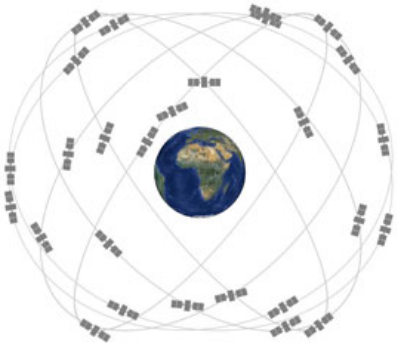


Image 3 & 4: An example of a global navigation satellite system (GNSS) Satellite (GPS Block III) and a full GNSS constellation of 24+ GPS satellites (source GPS.gov)[20]

Once observed, attacking platforms must be passed targets and updates via satellite communication, and must guide themselves where a global navigation satellite system (GNSS[21]) is a great aid. For these reasons, both sides have an incentive to target the enemy satellite system, for which it requires SDA,[22] and for which it must degrade adversary SDA to reduce their warning time and ability to take counter measures. Counter-space forces will be under severe pressure from terrestrial warfighters (naval, land forces, and air forces) to reduce their vulnerability by destroying space-based surveillance & reconnaissance systems.

Economy of Force Criteria: However, both sides are likely to face a scarcity of resources,[23] preventing all desired military targets from being simultaneously struck. Therefore, the logic of the situation dictates the priority for attack for the belligerents. Each belligerent must attack those enemy systems which most reduce their own ability, and defend those systems which maximize the belligerent's own ability to cumulatively prosecute enemy forces. If the opponent has multiple, resilient means of securing back-up services, you may leave those systems untouched. For example, the future ubiquity of target-quality overhead optical sensing, the ubiquity of global navigation systems, and perhaps even satellite internet may mean that attacking sovereign assets of these sorts are just wasted bullets in the initial volley.

Illustrated in extremely simple terms, if an opponent's reconnaissance strike complex for an anti-satellite missile consisted only of 1 ground-based sensor, one command center, one data-link, and 1 anti-satellite missile, striking any one of them would deny the opponent the ability to strike. If all of the targets could be attacked and destroyed with a bomb, and the attacking state had just one bomb, one might choose the target hardest to reconstitute. If on the other hand, the opponent had 1 ground-based SDA sensor, 2 command centers, 3 data-links, and 10 anti-satellite missiles, the most economical way to deny the system is to destroy the single point of failure, the SDA sensor. In reality, command posts are often very hard targets (hardened and deeply buried, deep within a belligerent's homeland), ASAT weapons are expensive (but may be mobile,

proliferated and difficult to track), uplink/downlink/crosslink datalinks can be proliferated at low cost; in contrast, Earth-based sensors are often fixed and visible, and space-based sensors are likely visible and jammable.

Counter-force, Counter-Value, and Astroeconomic 'guerre de course': Attacks on space systems may not be limited to military-only systems. As in nuclear thinking, we can make a distinction between counter-force attacks which target military systems to reduce military capability, and counter-value attacks which directly injure the broader society.[24] As a form of strategic attack or coercion, a belligerent could choose some level of guerre de course or astroeconomic warfare,[25] which injure the other belligerent or impose third party (allied or neutral) costs. Some military targets like GPS are also critical civilian and commercial infrastructure and would constitute astroeconomic targets.

Four Possible Outcomes: Four general outcomes appear possible: mutual denial, relative invulnerability, space supremacy, and space superiority. It is possible that both sides might have such terrestrial counter-space capabilities that neither side can enjoy the benefits of space, and the advantages accrue to the side whose force structure is better positioned to express military power in the relevant theatre without space information services. It is theoretically possible (though very unlikely given current trends) that both sides could attrite each other's ability to target satellite systems, or that satellite defenses were far more capable than attacking systems, leaving space a relative sanctuary.[26] It is possible that one side could succeed in destroying or denying an adversary's space information services and access to backups, and succeed in destroying the adversary's counterspace reconnaissance strike system to such an extent that it is possible to operate in space with impunity, in which case it would have space supremacy. The final possibility is a more limited and temporal degree of space control,[27] where there is sufficient advantage to enable sufficient survival and freedom of action to employ space information services not everywhere but locally for specific objectives in time and space.

Top Priorities in Space War: If space services can be secured for one side, then it allows full exploitation of those services. To attack an enemy's space-based reconnaissance strike complex,[28] you require your own SDA, and must deny them theirs so they cannot blunt your attack. Loss of SDA is the loss of one's eyes to see and target, and so its denial effectively denies all subsequent precision attack. Therefore, we can expect the primary target of both belligerents to be the SDA of the other. For belligerents actively engaged in terrestrial combat, arguing for equal priority will be the denial of sensors and data-links which enable precise targeting, especially of mobile targets. To the extent one's own offensive forces require space information services to function with precision, their sensors and datalinks are likely to be defended assets. To the extent the security of one's terrestrial forces depends heavily on advance warning of a strike (for example warning of incoming missiles or warning of incoming bombers), its sensors and datalinks are likely to be defended assets. Freedom of action for each side requires defense of their offense-enabling systems, and attack of adversary defense-enabling systems and their local defenses.

Technological Trends which May Alter these Scenarios: Over time, the capability and relative cost and economies of anti-satellite weapons may shift. Overall, such shifts are unlikely

to materially alter the overall logic of the situation except in one specific instance: the introduction space-based long-range direct fire anti-satellite weapons. The introduction of space-based, counter-space direct-fire weapons (such as lasers, neutral particle beams, or rail guns) could alter the situation such that these are the major impediment to freedom of action, and are fewer in number than the sensors that direct them, being both the most dangerous and most economical part of the system to attack. In such a case, they would become the primary first target to enable follow-on freedom of action, not unlike the contest between fighter aircraft for air superiority, or between battleships in WW1 and later carriers in WW2 for command of the sea.

How the War Unfolds

The war thus unfolds in one of four obvious ways.

Scenario 1 'He's too close' [in space]: At some point in crisis posturing, a belligerent gets too close to a capital asset in space, and the use-it-or-lose-it pressure becomes unbearable. It triggers self-defense and simultaneously broad-based offensive counter-space effort to prevent adversary counter-space activity.

Scenario 2 'Warning Shot': As part of the posturing, a warning shot or limited attack is fired to prove seriousness of intent. The receiver is likely to perceive this instead as a signal that this is the first indication of a more general war. Alternately, unsure that this is just a warning shot and not an actual attack, the receiver may attempt to ensure the safety of the targeted asset by interrupting the 'kill chain' by attacking supporting satellite infrastructure, whether reconnaissance, data-link, or navigation satellites. As part of such self-defense measures, it may also degrade SDA or attack in-space defending assets. Such actions would be perceived by the other side as an actual attack and escalation, triggering their own broad-based counter-space plan.

Scenario 3 'First Strike': As the intervening power (probably the U.S.) moves forces into the region to create a posture to signal seriousness, deter or compel, there will likely come a point that such a posture becomes too threatening. If the other side chooses not to be compelled but to escalate, their best chance to win requires an overwhelming first-strike to destroy the logistics and basing upon which the intervening force depends. For such a strike to be maximally effective, they must maximize surprise and ensure the space information services for precision strikes. As a result, the first move targets missile warning and space domain awareness (SDA) for destruction or suppression. This ensures that the intervening force will not have adequate warning to parry either missile or anti-satellite attacks. Moreover, deprived of SDA, the intervening forces cannot understand what has happened to them in space, nor can they target the navigation and reconnaissance satellites enabling the first-strike against their logistics and basing.

Scenario 4 'Pre-empting First Strike': Fearing, and seeing indications of scenario 3, and knowing that allowing the other side the first offensive strike would be game-winning, the intervener decides to pre-empt, and attack the enemy's SDA and space information services.

Of note, in all of the scenarios, we would expect very early attack of SDA and attack on space-based sensors and guidance to enable prosecution of mobile targets. Because SDA sensors are both on the ground and in-space, success requires a multi-domain coordinated counter-SDA campaign.

Terrestrial Components of the Counter-Space Campaign

In such scenarios, the bulk of the 'space war' is taking place on planet Earth, and most of the attacks on spacecraft are launched from planet Earth.

Therefore, any significant effort to protect satellite infrastructure requires attack of the enemy's ground-based ASAT system. While ground-based SDA sensors are likely to have a high priority, the ASAT systems themselves (lasers and missiles) are also likely to be targets. This is because they may actually be the weakest link in the ASAT chain. Destroying enough SDA sensors to nullify ASAT targeting might prove to be a futile effort if sensors are numerous, dispersed, and mobile, providing a high level of redundancy. The same problem may exist for communication links. Command and control facilities may be hardened and deeply buried. Attacking ground-based ASAT facilities becomes an additional priority.

For example, attacking all the sensors might mean you have disabled all the missiles. However, *any* surviving sensors might enable *all* missiles, whereas striking an ASAT facility means that the system has *one less effector* to complete the kill. Belligerents must assume that any fixed site or known-location ASAT facilities (ground based lasers,[29] ground based missile kinetic ASATS[30]) would also be targeted, so there is an incentive to 'go big early' and use such capabilities to their maximum until they are used up or lost to adversary action. Despite the likely location of such systems deep in a belligerent's homeland, the assumed 'deep magazine' of laser threats, and their ability to rapidly and continually attrite LEO satellites as they fly overhead could create extreme incentives to strike them very early in a conflict.

Denying Third Party Space Information Services: Because of the criticality of SDA to war outcomes, belligerents would likely find it unacceptable for third party states or commercial SDA services to provide SDA to one's opponent. Extremely timely and strong incentives would likely result in cyber-based 'blockades' of such services contributing to enemy action. Similar 'wars' for commercial access would play out across the range of space information services, resulting in cyber and electronic-warfare-based denial of services (even to neutrals[31]) and involve financial and legal coercion and strong political pressure if time allowed, and buying up services wherever possible. Insider threats and sabotage should also be expected.

Preventing Reconstitution: Once the decision has been made to deny space-based services, it could be unacceptable to allow the other side to reconstitute during the conflict. Therefore, both sides would have incentives to deny the other launch sites and launch opportunities through suppression, sabotage, or strike.

Cross-Domain Integration: What ought to be clear from this discussion is the high level of integration required by the supporting terrestrial forces (clandestine, SOF, air forces, naval) early in the campaign, and the high degree of coordinated war-planning required to take a large

diversity of counter-space actions quickly and in the right sequence. Without the equivalent of Strategic Air Command's Single Integrated Operational Plan (SIOP)[32] to attempt space supremacy, the ensuing fumbling is likely to leave the unprepared side at a significant disadvantage. This may prove difficult, and space services are relatively new, and may lack the necessary political clout to argue for priority, and establish themselves as the supported effort in the early phases of conflict.

Prompt Global Strike (PGS) and Spaceplanes: Since the Cold War militaries have considered the possibility of delivering conventional munitions from or sub-orbitally through space.[33] Like hypersonic weapons generally, the advantages are: range, speed of transit, and kinetic energy on arrival without nuclear fall-out. The low response time, difficulty to defend, and low collateral damage makes them attractive conventional first strike weapons, especially against timely and hard targets. Because of the high level of damage that an opponent's SDA-ASAT system can inflict--literally every minute may count--the incentive is to attack it with the fastest system available. An obvious first use of a PGS system is to attack the enemy's SDA system and capable ASAT systems (such as ground-based lasers) on the first volley. However, if the enemy also has such weapons, you likely need to strike them first to allow further freedom of action, or they are going to strike yours. This creates an "offense dominant" and destabilizing condition analogous to nuclear Intercontinental Ballistic Missiles (ICBMs) and Intermediate Range Ballistic Missiles (IRBMs): each side is vulnerable, warning times are short, and both sides have incentive to strike first.

Restraint & Unrestraint

How exactly belligerents choose to attack each other's counter-space reconnaissance strike complex depends on many factors.

Incentives to Global War: A key problem is that space constellations are not confined to a single theater but serve global interests. Therefore, an attack on space systems creates a very high probability that the war will be seen, at least by the U.S., as a general war affecting the totality of its global equities. Overall, the offense dominance of current systems creates an incentive for pre-emption on both sides.

Incentives Toward Restraint: The general undesirability of a general war may tempt actors toward self-restraint, as was seen in the politically constrained use of airpower in Korea, Vietnam, and India-China and India-Pakistan conflicts. At its most extreme, we could imagine a head-of-state to head-of-state phone call agreeing that space was off-limits to anything but ground-based jamming in the theater. We could also see extremely carefully choreographed movements akin to the Cuban missile crisis.[34] Escalation concerns (such as unwanted confusion regarding nuclear retaliation) could place certain Nuclear Command and Control (NC3) and missile warning satellites on the no-strike list,[35] However, this cannot be taken for granted,[36] since such systems may also support tactical users. If the attacker is willing to make a gamble that the other side 'knows' a conflict is a limited war and not a nuclear war, it might risk attacking these assets. Alternatively, it is also conceivable that both sides desire to keep war limited -- and sufficiently fear escalation – such that they restrain themselves from kinetic strikes

on terrestrial facilities within the adversary's homeland or their key allies. Such restraint depends on a high confidence that the other side also prefers to keep the conflict contained and will display similar restraint.

Dialectic Response

Even in a limited exchange involving kinetic antisatellite weapons, such as two sides each demonstrating they can attack the other, an enormous amount of space debris will be created. It is unlikely that humanity would abandon important orbital regions. Whatever might be the effect on arms control or the law of armed conflict weapons legality,[37] it is likely there would be a significant acceleration[38] in Active Debris Removal (ADR).[39] This has two perverse effects: first, that the future is more 'safe for kinetic ASATS' and second, that a future conflict begins with a broader proliferation of new counter-space capabilities both robotic and directed energy.

Any contingency involving destruction of in-space infrastructure is likely to resolve many uncertainties and incentivize diverse actions. Even the winner of space supremacy is likely to find that victory is ephemeral without a major series of new investments. The victor may be left with a capable on-orbit system while the loser may have none. But if the loser retains any meaningful economy and industry, they can rapidly set to work on a first-class space denial capability custom built against the now aging and static constellation of the winner. Unless the winner is willing to take consistent pre-emptive action risking war, they will not be able to stop the proliferation of counterspace capabilities or the reconstitution of orbital capabilities. To do so, they would need to have the will and capability to go 'full Dolman'[40]—that is to emplace both a space-based launch-interdiction capability, and a space-based strike capability to control access to space and rapidly suppress any terrestrial counterspace capabilities. Otherwise, over time, the losing nation could create a posture to deny space from planet Earth.

What is remarkable about the foregoing scenarios is the inversion of priorities. While space capabilities are of purely instrumental value to support entirely limited terrestrial objectives, their importance nevertheless necessitates prioritizing counter-space as first-strike objectives with substantial horizontal and vertical escalation risk. Moreover, the nearness of the Earth and its power projection advantages means that it is like naval warfare taking place within constant range of shore-based artillery, or like artillery spotting balloons within range of the artillery. Describing such action as 'littoral' space warfare within the cosmic coastline is a helpful analogy. Sun Tzu also developed a taxonomy of different types of terrain and battle situations.[41] Sun Tzu might categorize warfare in terrestrial space (approximately GEO and below as 'contentious ground' because of its great advantage to either side. However, he might also describe it as 'desperate' or 'hemmed-in ground' because these spaces provide no place of refuge, and ambush from Earth is easy.

In contrast, beyond GEO, space becomes 'accessible,' easily traversable by both sides, and relatively more easy to hide. But some places, such as the Lagrange points might be like narrow passes or 'constricted' ground, where if you are not the first to occupy, you should not enter. Other areas such as the poles of the Moon could be 'entangling ground,' proving hard or

impossible to return or re-occupy once the enemy has made preparations, and the best one can do is lay distant siege, blockade or attack with fire.

An expansionist view of future space warfare: War Begins in Space

The expansionist view is that there is an extant scramble for the vast wealth of the inner solar system[42] to win the geo-economic struggle[43] for global hegemony. Space is not merely instrumentally important to national power, but is in fact the central theater of great power conflict.[44] As such, it is not only that a 'war could extend into space' but rather that jockeying for relative geo-strategic advantage in space[45] constitutes its own spark of conflict, and escalation route.

Evolution of the Space Architecture and The Expected Order of Battle

The drive for space resources results in a different relevant force structure and different geostrategic pressures. The investments proceed along several lines of effort. The first is 'volume space access' and logistics, resulting in a tendency of all parties toward reusable and scheduled services. The second is in-space industrial capabilities such as robotic assembly,[46] 3-D printing,[47] vacuum spray deposition,[48] etc. The third is resource prospecting and extraction, or 'space mining.' The final is a push for more capable in-space electrical power systems.

Desires to achieve scale for broader industrial ambitions, seek markets with large and regular launch tempos such as satellite internet mega-constellations, suborbital[49] and orbital tourism,[50] commercial point-to-point transportation,[51] fuel depots,[52] and solar power satellites.[53] Pressures from industry move military constellations to be customers of in-space refueling,[54] in-space servicing,[55] and cargo delivery[56] to the Moon.

An awareness develops among the great powers / spacefaring states that the energy and material wealth of the solar system could decide geo-economic leadership[57] on planet Earth, and that space resources may be critical to their liberty and freedom of action.[58] Occupation of key positions and control of global rule-sets offer leverage to control shares of this broader wealth and developing order.

The Centrality of the Lunar Poles: The 'peaks of eternal light'[59] surrounding the crater rims of the South and North Poles of the Moon assume particular relevance. While there is an abundance of Near-Earth Asteroids, the Moon is close, very large, and contains very large quantities of water[60] and methane ice which acts as a logistics force multiplier. Structural materials available by processing of the Lunar regolith (surface dirt) also offer a substantial logistics force multiplier as they can be placed into orbit at roughly 22x lower energy cost,[61] enabling construction of in-space industrial facilities or habitats of previously unheard-of scales. The possibility of bootstrapping (robots building robots), could enable exponential industrial growth. The possibility of building a global system of orbital power plants (and potentially controlling close to 10% of the global economy) offers a market of astounding proportions.

Space Lines of Commerce: What emerges are space lines of commerce of geo-economic significance, or at least perceived as the critical pathways which imply future geo-economic significance and must be protected. The Moon becomes the source of raw materials and location

of some industrial processing. People travel to, and return from, the Moon -- moving from Low Earth Orbit (LEO) to Lunar orbit. Supplies which support industrial processes ('vitamins') flow from Earth to the Moon, while high-mass structural materials ('macro-nutrients') or finished goods flow from the Moon to various staging or profit centers, including lunar orbits, L1, L2, GEO, LEO, L4 and L5.[62] In this period, the primary profit centers remain in GEO and LEO.

Military Posture: Space militaries are called to assume a broader set of responsibilities, more similar to navies and coast guards. As civil and commercial operations begin in Cis-Lunar space beyond GEO, there is increased pressure to provide safety-of-navigation services: navigational aids, space domain awareness, rescue and tug services, active debris removal, safety inspections, and patrol.[63] There will be strong pressures for military services to base the designs of their patrol and logistics spacecraft on commercial counterparts -- both to minimize cost as well as to ensure compatibility with the larger civilian logistics systems. While generally cooperative, space militaries and their owning states constantly measure their posture versus one another. States may be averse to openly weaponizing, but capabilities required to perform safety-of-navigation services are dual-use and inherently have space control capabilities.

EXPANSIONIST SCENARIOS FOR SPACE WARFARE

The logic of these situations is largely consistent whether we are talking about the very first stages of mineral exploration with robotic landers and rovers or large-scale industrial activity and settlements. What is different about these scenarios is that they *begin* over equities in space, and military action takes place primarily in space. Because the interests at stake are in space, there is at least the possibility of space forces acting unilaterally and that such action by space forces could prove 'decisive' for the encounter.

Interdicting 'Unacceptable' Behavior: With people in space come questions of political expression, symbolism and different standards of behavior. There are any number of scenarios where the mere presence of a symbolically important person or group, or their activities could incentivize a rival power to interdict their communications or movement. Things that might not seem problematic to the U.S., might appear problematic to another power such as the People's Republic of China (PRC). The presence of religious rights activists (such as the Dalai Lama[64] or Falun Gong[65]), or political dissidents could use in-space locations to militate for change, such as using a private space station for broadcast.[66] This could create interdiction of communications (jamming) or logistics (blockade) which could be seen as unacceptable. Other situations could involve the emplacement of capabilities deemed by the other to represent weapons or fortifications in disallowed zones, (for example: placing a mining laser on the Moon which can point up, or a mass driver that could direct-fire toward Earth). If one side became aware of an attempt to emplace on the Lunar surface an operational weapons system--an anti-satellite capability or Earth-strike -- the other side would almost certainly pre-empt. Such a preemption might take the form of an embargo (similar to the Cuban missile crisis[67]), sabotage (like StuxNet[68]), or military strike (such as the Israeli Operation Opera air attack on Iraqi nuclear facilities[69]).

Competing Claims: Because national interests are geo-economic, corporate interests are likely to be perceived as national interests. If disagreements arise about operating areas, safety, or harmful practices which interfere with another state's corporate interests, disagreements could arise. A non-state actor such as a corporation could impound or exclude other parties, or could convince their sponsoring state to do so. They might arrest or hold hostage people, equipment, supplies or valuables.

Sovereign Claims: A special case of both of the above would involve behaviors interpreted by the other as constituting a sovereign claim or appropriation, such as the announcement of a broad Exclusive Economic Zone,[70] a Defense Identification Zone,[71] or anything considered to be an excessive land grab, or land grab of a unique and special area. Although restrained claims of use and associated safety zones are likely to be tolerated, certain actions which might significantly alter the status quo and create a significant precedent or advantage might be interpreted as a failure of the Outer Space Treaty and necessitating self-defense.

Atrocity: Any of the above could involve or provoke some kind of atrocity by local actors. For example, corporate actors angry over some trespass might kill their competitors directly or do so via sabotage. Angry nationalists could do the same in response to the other side hosting dissidents.

Coercion & Counter-Coercion: In all such cases, there will be an attempt by one actor to compel behavior, and by another to compel the first to cease and desist. The crisis emerges as one state attempts to compel the other by creating a local superiority and signaling its seriousness, and the other side challenges that attempt at coercion. This might be triggered by the geo-economic or positional stakes involved. It might be triggered by an action which, unchecked, would allow the opposing actor to gain a decisive positional or logistical advantage. It might be triggered 'on principle' -- where an action is interpreted as an attack on one's identity, prestige, commitments or fundamental values. As a result, one side will use force to attempt to exact a direct concession, the other side will deploy force to break that coercion or liberate by force.

Therefore, we are likely to see military assets move into positions where they can threaten 'misbehaving' actors with direct force or interdiction of supplies, or to wage astroeconomic warfare by interdicting outbound commerce or threatening capital assets or profit centers to impose costs and force the offending side to capitulate. The objecting nation will move to counter-threaten the coercing fleet and/or counter-threaten a like asset as mutual hostage-taking.[72]

SCENARIOS: Warfare

While there is a constant background of competitive posture between militaries which position, inspect, and maneuver akin to Cold War submarine operations[73] -- which could result in 'dangerous activities at sea' -- this is not the primary route to escalation.

Incentives to 'Go Big': Both sides are likely to 'wish the other weren't there' seeing the adversary as a nuisance in daily operations, and feeling constantly on-guard that they will

overstep 'appropriate' boundaries, or are just waiting for an opportunity to eliminate the other. Therefore, it seems plausible that both sides are incentivized to develop war plans to 1) decisively eliminate the other's in-space military capability and to 2) wage astroeconomic warfare by holding the adversary's commerce and in-space profit centers at risk.

Counter-Force and Counter-Value: In these scenarios, military counter-force is concerned with removing all elements of military presence and force projection which can be used to coerce, raid or destroy commerce. Counter-value includes all portions of the in-space infrastructure and value chain for in-space industrial products and space services. A belligerent might target Lunar mines, mining equipment, launch infrastructure, propellant infrastructure, and factory infrastructure. They might also target any profit-generating infrastructure within 'Terran space' (GEO and below), such as satellite power plants,[74] data processing centers,[75] communication platforms[76] and human habitats.[77] Although conflict could begin over geo-economic or geo-symbolic considerations in GEO or LEO and might follow similar escalation routes, the most interesting scenarios take place in deep space.

Deep Space Considerations: The likely most important terminus of deep space commerce is the Moon. On the Moon itself are major resources, key positions, and potential fortifications. Unlike space itself, it may be possible to hide or harden on the Moon. As the geo-economic and geo-strategic hub of deep space transportation and commerce,[78] the Moon seems the most likely case to explore deep-space warfare in this period.

Significant choke points of Cis-Lunar commerce occur at EML1, Low Lunar Orbit (LLO), and the Lunar Poles. Traffic to and from the Moon likely will flow through these points. Therefore, to interdict positions, it is desirable to hold these positions. The difficulty of holding these positions depends on a variety of considerations. The viability of holding EML1 and LLO depend a great deal on whether there are ASAT capabilities on the Moon itself, and of what strength. If the Moon has a developed industrial capability, it might be able to hold at risk anything in its near abroad. On the other hand, if the Moon is undefended and its industrial base concentrated, then embryonic defenses may be crushed with conventional weapons from orbit, and such attacks would not be illegal under the OST since the arms are not stationed on the Moon and are not weapons of mass destruction.

Unlike in the earlier scenario, military space activities may no longer be dominated by the overwhelming influence of the Earth. Local advantage and long-distance power projection are likely to matter, *and fait accompli's* are possible. The Moon is approximately ten-times more distant than GEO. This, along with light pollution from the Moon's brightness mean that effective surveillance likely requires local sensors. Efficient transit between the Earth and the Moon requires approximately three days and significant energy expenditure. Therefore, repositioning or attack may not be timely. Defenders in the vicinity of the Moon may have warning and time to prepare. At some point, an industrial and logistical capability on the Moon may allow superior local logistics. The vastness of Cis-Lunar space combined with weak three-body gravitational interactions allow significantly increased possibilities for maneuver, hiding and surprise by military forces.

Space Cruisers: Very likely the vessels that service this area of space are general purpose and multi-use. They might have dedicated armaments such as guided missiles, rail-guns, or directed energy weapons, but they need not. Perhaps they have only robotic effector arms or merely the ability to maneuver and therefore block. Almost certainly, they will have some degree of SSA and autonomy, whether robotic or manned. Therefore, space warfare in this theater might most resemble naval battles at the far-reaches of empire.

Privateers, Reserve Forces & Preventing Self-Help: Of note, assets brought to bear might also be 'merchant marine' or repurposed commercial construction and transportation forces, perhaps even including authorization to act as privateers or private security firms (privateers). In fact, if states choose to focus on conservative scenarios as described in the previous section and neglect to maintain a presence apace with the private sector, the entire scenarios described below could in principle take place entirely between non-state actors using assets principally developed for industrial purposes. A key reason why states might wish to develop Cis-Lunar forces is to prevent a tendency of corporations toward 'self-help.'

Sequence of Events: The initiating coercer will move forces into the area to deny transit and directly threaten the locations in contest. Whatever was the initial balance, we can imagine that events might unfold as follows:

1) The coercer will principally move forces to apply direct coercion against the target and posture other forces to check a would-be responder.
    a. This may be in space, but it may also include actions on the Lunar surface, such as driving a robotic rover to block an opponent's landing pad or airlock.
2) The responder is likely to counter position forces against the coercer's forces (a vertical escalation) and the coercer's other forces (horizontal escalation).
3) If space remains an offense-dominant environment, there will be a strong incentive to pre-empt to enjoy the first mover advantage.
4) Each side will likely threaten each other's dedicated SDA assets to reduce the local SDA.
5) Each side will 'point their guns' at the most threatening asset—the assets which either most directly threaten their interests or which have the greatest capacity to create military losses.
6) GEO and LEO become additional theaters in their own right.
7) As long as both sides feel they can achieve greater advantage in waiting, both sides will reinforce and horizontally escalate.
    a. This may certainly include horizontal escalation on planet Earth itself, and not only against space infrastructure, but anything of value which may be threatened in trade.
    b. Both sides will be tempted to pre-empt or blockade further forces from leaving Earth to alter the balance of forces.
8) At some point in time the drawing up of forces will culminate for one power or the other, with it becoming clear that any delay merely puts them in a worse position.

9) At that point (in a disciplined situation), one side initiates conflict. At any point along this continuum of posturing, an individual asset might decide it must act in self-defense and trigger the same cascade.
    a. Unless the situation is extremely desperate, very likely the coercion itself will be neglected until the decision of battle.
    b. Because each side must respect the destructive power of the other, those platforms become the focus of effort to ensure follow-on freedom of action.
    c. If they are close enough to sense and shoot each other autonomously, then destruction of enemy reconnaissance and interdiction of logistics or follow-on forces become supporting efforts.
    d. If a principle threat is on the Lunar surface, it will either be:
        i. Struck immediately or
        ii. Local in-space forces must withdraw beyond the effective range of the threat to enhance their chances of survival.
    e. Whether or not capital assets such as a propellant depot or lunar fueling and landing facilities are struck depend a great deal on several factors:
        i. Do they materially contribute to the extant battle?
        ii. Will their destruction cause harm to one's own interests?
            1. For example, strike such targets might create collateral damage to one's own or neutral parties, creating debris which might foul orbits and threaten one's own capital facilities, commerce and spacecraft.
        iii. Can they be captured either to be held hostage to exact future concessions or to add to one's forces?
10) Either through attrition or paralysis one side will gain sufficient advantage to remove the other or put them in such an un-tenuous position as to negotiate a cease fire.

Direct-Fire vs Swarms: Long-range direct-fire weapons within the theater are likely to be the primary initial focus of action because of their reach and deep magazines. Very likely their destruction will be affected by a combined arms approach involving swarms of attackers overwhelming its self-defense capacities. The principle early threat to all platforms will be co-orbital 'snugglers'[79] which would need to be 'de-loused' early. The realities of orbital maneuver are likely to mean that the timing of such operations is unlikely to be well coordinated in time, leading to significant fog and friction.

Restraint & Unrestraint

Restraint: States will likely wish to avoid the audience costs of being seen either as the aggressor or as weak. Although locations on and around the Moon are likely to have significant strategic value, belligerents will wish to avoid overt military conflict unless they can clearly assert 'self-defense.' They may also prefer to steer clear of conflict to exploit absolute gains, especially if they believe that the time to pursue relative gains is yet in the future.

The problem of also maintaining supply lines for one's personnel at a lunar facility would also loom large, and perhaps constrain the barbarism or 'salt the Earth' strategies that are possible.

Unrestraint: The lure of a decisive victory creates an incentive for a broad scale offensive. If the configuration is such that a successful offensive could 'wipe the opponent' from the board, and leave the attacker in possession of the entire theater and sole actor capable of exploiting its wealth, this creates a strong economic motive for such an offensive.[80]

The considerations of restraint when one has isolated personnel would go away if they were eliminated, and could result in an escalation to reprisal or fouling of the local environment through area-weapons and/or large amounts of space debris.

Dialectic Response

Several outcomes are possible which would condition the system for future geo-political conflict:

Coercer Achieves Small Wins: If the coercer's succeeds and are appeased, this conditions them to seek further appeasement. Success conditions them to engage in 'salami-slicing' -- successive coercions which change the facts-on-the-ground in favor of the coercer. Such actions however will create resentments, setting the stage with tectonic forces for the next confrontation.[81] Crisis or limited war are 'teachable moments' where the coercer learns and is conditioned to seek or avoid future coercion.

Coercer Achieves Big Wins: If the coercer wins in a wider war, it is now likely to exclude its adversary from its closed economic empire, or to extract such concessions as to only allow it the weakest of interactions.[82]

Restrained Responder Wins: If the winning power had up until the battle been restrained in its weaponization and expression of military spacepower, it is likely to see such unpreparedness as unacceptable. Convinced that the adversary has a demonstrated character as an aggressor, and the taboo of space warfare having been broken, the winning power, previously restrained, is likely to make an attempt at all-out space supremacy (go 'full Dolman') -- attempting to establish and maintain military dominance and overwhelming presence generally, or at least in the vicinity of the Moon.

Implications

The significant divergence between the conservative and expansionist scenarios suggest that the United States might be preparing, planning and equipping for the wrong war, or at least not the full spectrum of possible wars. This could leave the United States, its allies and their respective businesses open for coercion. Preparation for the full spectrum of space crisis and conflict requires early attention to military doctrine, concept design, force structure design, and international governance including arms control and the law of armed conflict, as well as for legislation and policy.

Military Doctrine: Military doctrine must anticipate that United States geo-strategic interests will likely encompass economic activities in deep space, and develop concepts for peacetime strategic offensives to maintain positions of advantage.

Concept Design: Conceptual design of military campaigns and crisis planning need to anticipate the full range of scenarios to include the distant defense of geo-strategic economic, symbolic,

positional and citizen interests, and consider how such counter-coercion and defense would take place.

Force Structure Design: Military space vehicles capable of defending U.S. interests in the vicinity of the Moon differ in important ways from satellites designed to support terrestrial forces. Design of a 2030-2040 force structure requires attention to the unique navigational, maneuver, logistics, and power projection needs for such vehicles to be effective.

International governance including arms control and the law of armed conflict: Consideration and anticipation of conflict may enable the community of nations to arrive at consensus on certain conflicts or types of conflict they mutually wish to avoid. As a clearer picture can be painted of harm to be avoided, there may be opportunities to avoid certain conflicts through bilateral or multi-lateral agreements which:

- reduce ambiguity regarding claims and provide forums to adjudicate would-be conflicts;
- make certain acts or weapons illegal;
- agree to limit the type and number of weapons which could endanger broader interests.

Prospects for restraint may be more likely if there is an early conditioning shock which generates sufficient horror and offers few benefits. Such shocks might include:

- a limited ASAT exchange between states;
- a rogue state or actor attempting to hold the world hostage or exact costs through a disproportionate or terror weapons such as:
    - Electro-magnetic Pulse (EMP),
    - High Altitude Nuclear Detonation (HAND), or
    - deliberate collision.

Legislation and Policy: Because the conservative view is so firmly established in the U.S. Department of Defense, there is a significant possibility that left to its own devices, it will be underprepared for expansionist scenarios. This suggests a role for civilian leadership to ensure the U.S. DoD is prepared through legislation and policy to specify roles and missions to protect space commerce, to specify plans, and to specify the Area of Responsibility (AOR) as encompassing the entirety of the Cis-Lunar theater.

Conclusion

In this essay, we have explored two visions for space warfare which might manifest in the 2030-2040 timeframe. The conservative view postulated scenarios where war begins over Earth-bound geostrategic interests but extends into space to maintain advantage for the terrestrial warfighter. The expansionist scenarios anticipate that nations may have reason to fight over geo-strategic interests' resident in space -- and over Lunar commerce in particular. Circa 2030 (and perhaps even sooner), as the economic development activities in deep space establish geo-strategic interests on other planetary bodies (starting with the Moon), the possibility for the expansionist view of crisis and conflict becomes more likely. While some may wish to dismiss the expansionist view, they should consider that even at the time of writing, 10-20 years in advance of the scenarios, a number of nations are already sending landers to the Moon (United

States, China, India, Russia, Japan) as precursors to economic development. Being prepared for the full spectrum of space crisis and conflict requires early attention to military doctrine, concept design, force structure design, and international governance including arms control and the law of armed conflict, as well as for legislation and policy.

APPENDIX

This appendix explores in greater detail the factors which condition the specific shape of space conflict.

Why Consider Space Warfare?

Since the 2007 Chinese ASAT test,[83] there has been significant public interest in threats to space systems. With the formation of China's People's Liberation Army Strategic Support Force,[84] the subsequent formation of a USSPACECOM[85] and U.S. Space Force[86] and corresponding assertion by the U.S. that its adversaries had transformed space into a warfighting domain, there is broad interest regarding what a 'space war' might look like.

The essay is of course a speculative work. In it I have attempted to explore the trends and causal pressures which might shape conflict in space. I have no crystal ball. None of us can know the future—tremendous surprises have occurred in a span of two decades. Moreover, *at times the role of speculation is sometimes not to predict but to prevent*, because foresight offers early feedback loop to shape present choices. The value of foresight work is to anticipate the range of possible futures to reduce surprise to enable early recognition and adaptation.

Literature Review

The conservative view and expansionist view are roughly equivalent to two main school.

Although there is a diversity of spacepower theory and taxonomies by which to divide them, for the purposes of this paper, the conservative view of spacepower and the expansionist view of spacepower are roughly equivalent to the main divergence in current spacepower thought, between the 'brown water thinkers' and the 'blue water' thinkers, [87] each of which emphasize different theaters of competition and conflict.

'Brown Water' Schools of Spacepower: On the one side are the 'brown water' thinkers, who see the primary analogy as continental seapower. Particularly coherent are Brad Townsend[88] and Bleddyn E. Bowen[89] who have explored space warfare within Earth orbital space where Earth-based counter-space is a dominant influence. They focus principally on how military spacepower supports terrestrial conflict. Paul Szymanski[90] also appears to fall primarily in this camp, as does John Klein.[91]

'Blue Water' Schools of Spacepower: On the other side are the 'blue water'[92] thinkers who have advanced theories of how the space domain itself can be used in the contest for political primacy, using the analogy of the deep blue oceans which carry trade. These thinkers include Carl Everett Dolman,[93] Simon "Pete" Worden & John Shaw,[94] Brent Ziarnick,[95] Chris Stone,[96] and Joshua Carlson.[97]

Avoiding those conflicts: While not a school of military spacepower per se, a third school of thinkers spend their energies attempting to avoid conflict. These are the arms controllers. They are less concerned with the conduct of space war but rather develop thinking on the inherent danger of space conflict to terrestrial equities, and are associated with arms control or environmental security. These include, Joan Johnson-Freese,[98] Clay Moltz,[99] and Dan Deudney.[100] A key difference between arms controllers and other schools is their certainty that a space conflict would generate negative gains for all parties. They are also optimistic that rational actors can create binding regimes in advance of both crisis and capability.

In contrast, the other two schools of thought question the certainty of absolute losses (holding out positive outcomes for one side either in warfare or coercion), and assert the irrationality of restraint, saying "nobody does arms control with somebody who doesn't have the arms."[101]

Visions of Space Warfare

I am not alone in imagining space conflict. The reader can find other imaginative scenarios for conflict or space warfare treated in non-fiction, including Worden & Shaw's *Whither Space Power,* [102] Fred Kennedy's "A failure of vision," [103] Charlie Dunlap's "How we lost the high tech war of 2007,"[104] George Freedman's *The Next 100 Years,*[105] Andrew Krepinevich's *7 Deadly Scenarios,*[106] Tangredi's *All Possible Wars*[107] *and Organization for Economic Cooperation and Development (OECD)'s Geopolitical Developments and the Future Of The Space Sector.*[108] While aimed principally at applying a geopolitical determinist theory to space, Dan Deudney's Dark Skies[109] provides a thoughtful examination of a number of space conflict scenarios.

Fiction written specifically to offer strategic insight has also examined space warfare, including Peter Singer's *Ghost Fleet*[110], and William Scott's *Space Wars*,[111] and *Counter Space.*[112] The most comprehensive and imaginative treatment of space warfare would be found in the corpus of science fiction literature. Such a survey of space warfare as depicted in science fiction is beyond the scope of this work, but is something which would be an instructive undertaking by organizations concerned with space warfare.

What is known about space weapons development?

Space Weapons of great variety were explored in the Cold War, especially during the Strategic Defense Initiative (SDI) time period,[113] after which, in the 'unipolar moment'[114] strategic thinking about space weapons atrophied, and the United States treated space as a sanctuary. However, it became clear to the world that U.S. conventional military power was heavily reliant on space. States whose vision of the global order diverged from the U.S. -- most notably China and Russia – perceived that space constituted an unprotected rear area for the U.S., and began to develop anti-satellite weapons. A number of public threat assessments have described both the general state of affairs[115] as well as specific adversarial threats.[116] They detail broad lines of anti-satellite and counter-space efforts known to be explored by adversaries of the United States including threats electronic warfare (EW) such as jamming, ground-launched KE-ASATS (even able to reach GEO), directed energy weapons such as high-power lasers, cyber-attacks, and ground-launched high-altitude nuclear detonations (HAND), as well as orbital threats including radio frequency jammers, kinetic kill vehicles (KKVs), chemical sprayers, robotic mechanisms,

high power microwaves (HPM), and Lasers.[117] Moreover, many lines of counter-space effort may be concealed or justified under dual-use purposes, such as Active [Space] Debris Remediation (ADR), Satellite Servicing, or experiments to develop new space services. It can be expected that these lines of effort will create a cascade of counters and security dilemmas checked primarily by limited resources and competing problems.

Key drivers of change

While I attempted to provide an outline of the basic logic of space warfare, there are a range of complexities which will give it shape. Below are trends I judge to have significant impacts on military space competition and conflict.

Increasing Nationalism. Nationalism is likely to be the single most significant factor accelerating military space capabilities. Since the beginnings of the first Space Race,[118] space has been the most public of arenas to showcase national strength, pride and vigor to internal and external audiences. Like a bird's plumage, it is a proxy for the strength and status of a nation. With the current trend in de-globalization,[119] return of great power competition,[120] nations are likely to measure each other based upon their relative positions in space. Lack of agreement over relative strength might create incentives for conflict.[121]

Increasing Militarism. With the rise of nationalism comes the desire to showcase relative strength, and to be able to respond to threats to interest or slights to status with posture, saber-rattling or decisive action. That in turn leads to incentives to arms race.

Increasing Environmental Concerns. There is an ongoing attempt to frame space issues as environmental concerns,[122] and to limit economic development[123] or weaponization based upon concerns for the space environment.[124] Significant events such as debris-causing tests[125] or collisions[126] might create disincentives for certain types of space warfare.

Increasing Volume of Activity. Two revolutions – low-cost reusable commercial launch and proliferation of large-production-run space hardware – provide the possibility of much larger scales of space activity, and new commercial locations and markets.[127] Larger scale of activity means much more frequent access to space[128] and within-space by logistical vehicles which in turn enable still larger markets.

Expansion of Information Services. Expanding global demand for bandwidth and computation will seek solutions anywhere it can sustain growth. One possibility is that this will drive new global utilities. Most likely are expansions of already extant capabilities: daily commercial Earth imaging,[129] commercial synthetic aperture radar,[130] and commercial radio-frequency signal tracking.[131] Next likely is the extension of space services to un-modified cell phones,[132] and broad-band space-based internet.[133] We could also expect space-based full motion video, real-time space-based radar for traffic control for air, land and sea. It might also prove advantageous to host data-centers and computation centers in space.[134]

Increased Perceived Value of Space Resources. A key unknown is the speed at which space resources (lunar and asteroid mining) become important to national economies. Of note, space resources do not need to actually be productive to influence strategic behavior—the mere

perception that they will be important is enough to initiate a logic of moves and counter-moves to secure or deny advantage.[135]

Increased Space Access. The scope and scale of conflict depend greatly on the cost and reach of space access. Lower launch costs enable greater scale of activity[136]—higher launch tempos, more assets on orbit or on planetary bodies. Lower cost in-space transportation allows greater mobility, logistics, force extension and spatial extension of economic activity. The current trend suggests a lowering in the cost of space access to enable greater levels of economic and military activity.

Key variables

In general, we can be confident that all of the above variables are increasing, the scale of change matters for the world we can expect in 1-2 decades. The range of such variables is discussed below.

Domain Ideology: A key variable is the understanding among the would-be belligerents about the place of space and the aims and limits of space warfare, as well as their differences. Different visions of space warfare and its ends drive different investment and posture strategies. Prescriptions for brown-water and blue-water acquisitions, organization, force structure, force posture, force employment and training diverge.

Economic importance of space: Space is already important and integral to the U.S. and global economy, but the space sector itself is about $400B,[137] or less than half a percent of global GDP. At present, there is an expectation of an expanding cislunar econosphere[138] with a value in this time epoch to be between $1Trillion (T)[139] and $10T. [140] The economic importance of space might continue to rest (as it does today) on space information services. Alternately, one to two decades is enough to see the emergence of markets for space-based power[141] and space-based resources,[142] each undergoing rapid growth.

Technological Progress in Access: NASA estimates that commercial launch lowered the cost of access by a factor of 20 versus (vs) the space shuttle ($54,500/kg vs $2,720/kg Falcon 9).[143] Falcon 9 recently demonstrated the feasibility of human-rated commercial launch. Falcon Heavy is now $1411 per kilogram[144] (a factor of 38 better than the Space Shuttle). It is possible that launch costs could remain above $1000/kg for this epoch. Some allege that $1000/kg is already low enough to enable space-based solar power. SpaceX Starship, now in development, is expected to provide a combination of full reusability and 100MT+ payload. Estimates suggest it might reduce the cost from $1000/kg to as low as $10/kg to LEO, and perhaps $30/kg to the lunar surface.[145] Previous estimates suggest that emplacing as little as 12MT on the lunar surface is sufficient to begin industrial 'bootstrapping' and an exponential increase in industrial activity.[146]

Military Readiness: There appears to be a general trend toward the militarization of space likely with some level of anti-satellite weaponization. Investments in military space readiness will be a function of ideology, threat, available budget and competing priorities. Either

belligerent might underprepare for the 'right' space war, or could miscalculate the actual theater and be prepared for the 'wrong' space war.

Implications for Great Power Competition: The Will to Prepare and Shape

This paper has attempted to leave the reader with two distinct images of warfare. The first presumes that a space war is an extension of Earthly terrestrial geo-strategic concerns and extends to space to preserve overhead advantage. The second presumes that states have geo-strategic concerns in the space domain itself which generate conflict. A strategist's or policy maker's assumptions about the reasons for war, the object of such a war, strongly affect one's planning, preparation and force structure. A focus on one to the exclusion of the other may result in incomplete preparation.

Theory shapes Reality -- States will Prepare along Lines of Expectation. The Thomas theorem states, "if men define situations as real, they are real in their consequences."[147] Visions of astrostrategic competition and what is considered 'strategic' – even if it proves not to be -- will shape state action. Visions of space warfare – even if it does not happen – will shape state action. The contours of competition are shaped by what is defined as inherently valuable within space, and what is defined as instrumentally valuable in space to secure, protect, defend, or attack. Almost all 'inherently valuable' objects are themselves instruments as part of broader means-ends chains. Today, satellites in LEO and GEO can be said to be inherently valuable because they provide valuable services economically and militarily on Earth. Space control assets are instrumentally valuable because they can secure or deny such value. If, on the other hand, one focuses on the ice deposits on the poles of the Moon and certain asteroids as inherently important resources -- and on the locations which enable their efficient exploitation (key landing locations, well-illuminated crater rims), the Earth-Moon Lagrange points – then you shape your strategy around accessing and securing these. In short, you end up with a very different military space architecture and set of military and commercial strategies.

Astrostrategic Terrain: The main new competition will be to enable or avoid coercive advantage in the astrostrategic terrain beyond GEO to enable freedom of action and acquiescence to one's will. This is a competitive posture game likely to escalate from simple presence to space information services, space domain awareness, dual-use logistics systems, self-defenses, and perhaps 'snugglers,' soft-mission-kill capabilities (jamming, dazzling) and even long-range direct-fire systems.

Dynamics Incentivizing Competition: Several additional factors seem likely to accelerate military competition in space. These include commercial actors militating for the 'flag to follow trade' and provide security services for them, as well as provocative action on their part to embroil their state in activities which create private benefit. Such provocative action could be self-help or the threat of self-help should they not receive government security services. A second is a classic security dilemma where the actions by one party to make itself more secure make other parties less secure. Efforts to deter the other by increasing the cost of intervention may just as easily result in greater military investments. A third is the lack of a clear military order in space which parties may seek to solve through investment or resolve through battle.[148]

A fourth incentive are audience costs for reputation or strength which transfer to other theaters where perceived pre-eminence and power affects bargaining and access to spoils. A special case of the above may concern public or treaty commitments to third parties (such as an allied nation) whose geo-economic or personnel might be the subject of coercion.

Prospects for Arms control or Restraint in Arms Conflict

Prospects for restraint appear more likely if there is an early conditioning shock which results in costs with few benefits, horror, or naturally conditions cooperation and good will. Examples of the former might include a limited ASAT exchange by spacefaring states (perhaps India-Pakistan or even India-China) which shocks the major powers, or an attempt by a rogue state, polity or lone actor to hold the world hostage through deliberate use of a collision, space debris or an Electro Magnetic Pulse (EMP) delivered by a High Altitude Nuclear Detonation (HAND) (perhaps by Iran or North Korea).[149] A successfully negotiated crisis de-escalation is likely to result in a series of 'Détente'[150] measures to live together and reduce provocations to conflict as well as agreements on 'dangerous practices at sea.' In all cases, such a direct encounter with a general war in space could reduce the appetite for competitive and escalation under the sentiment 'too rich for me!'

Arms control in expansionist scenarios may be more likely if both parties see themselves in a precarious position both logistically and with their domestic audience. This might encourage mutually respected safety zones and protocols for safe interaction. Early efforts to limit a cycle of retaliations could focus on deliberate exercises to provide emergency aid in distress, and as much precision and clarity on boundary lines and coordinate systems as is possible. Further, while dual-use infrastructure may impact warfare in both conservative and expansionist scenarios, at the extremes of logistical reach, very tiny influences may enable exclusion, and dual-use infrastructure may present strong concerns.[151] The inability to limit dual-use infrastructure because of its critical functions may force arms control to focus less on numerical limits and more on inspection, verification and multi-lateral controls.

---

[1] DISCLAIMER: *This is a speculative work by the author. The reader should not construe these speculations to represent positions or policy of the United States. While the author spent part of his career in the U.S. Department of Defense, his views diverge significantly from current DoD views on these matters.*

[2] Steve Hirsch, "There is no 'War in Space'," *Air Force Magazine*, May 29, 2018, accessed June 30, 2020, https://www.airforcemag.com/article/there-is-no-war-in-space/

[3] Marcia Smith, "U.S. Space Command Reestablished After 17-Year Hiatus," *Space Policy Online*, August 29, 2019, accessed June 30, 2020, https://spacepolicyonline.com/news/u-s-space-command-reestablished-after-17-year-hiatus/

[4] John Klein, "Towards a Better U.S. Space Strategy: Addressing the Strategy Mismatch," *Strategy Bridge*, September 9, 2019 Accessed June 30, 2020, https://thestrategybridge.org/the-bridge/2019/9/9/towards-a-better-us-space-strategy-addressing-the-strategy-mismatch

[5] Brian G. Chow, "Stalkers in Space: Defeating the Threat," *Strategic Studies Quarterly*, Summer 2017, accessed June 30, 2020, https://www.airuniversity.af.edu/Portals/10/SSQ/documents/Volume-11_Issue-2/Chow.pdf

[6] Staff Writers, "US Project Thor would fire tungsten poles at targets from outer space," *Space Daily*, November 12, 2018, accessed June 30, 2020,

https://www.spacedaily.com/reports/US_Project_Thor_would_fire_tungsten_poles_at_targets_from_outer_space_999.html ; Blake Stilwell, "These Air Force 'rods from god' could hit with the force of a nuclear weapon," *We are Mighty*, May 22, 2020, accessed June 30, 2020, https://www.wearethemighty.com/articles/these-air-force-rods-from-god-could-hit-with-the-force-of-a-nuclear-weapon

[7] Casey Handmer, "The SpaceX Starship is a very big deal," *Casey Handmer Blog*, October 29, 2019, accessed June 28, 2020, https://caseyhandmer.wordpress.com/2019/10/29/the-spacex-starship-is-a-very-big-deal/#:~:text=Starship%20is%20not%20just%20a,This%20is%20a%20big%20deal. ; Casey Handmer, "Starlink is a very big deal," *Casey Handmer Blog*, November 2, 2019, accessed June 28, 2020, https://caseyhandmer.wordpress.com/2019/11/02/starlink-is-a-very-big-deal/

[8] Peter Garretson, "U.S needs a space sensor layer to protect against hypersonic missiles," *Washington Times*, June 22, 2020, accessed June 30, 2020, https://www.washingtontimes.com/news/2020/jun/22/us-needs-a-space-sensor-layer-to-protect-against-h/

[9] Brian G. Chow Space, "Nuclear vulnerability: In-orbit bodyguards would help protect NC3 satellites from attacks," *Space News*, April 1, 2019, June 30, 2020, https://spacenews.com/op-ed-nuclear-vulnerability-in-orbit-bodyguards-would-help-protect-nc3-satellites-from-attacks/

[10] Trevor English, "U.S. Space Force's First Offensive Weapon Is a Satellite Jammer: The Space Force is ready for battle," *Interesting Engineering*, April 22, 2020, accessed June 30, 2020, https://interestingengineering.com/us-space-forces-first-offensive-weapon-is-a-satellite-jammer#:~:text=The%20new%20weapons%20system%20delivered,in%20a%20matter%20of%20minutes.

[11] Zak Doffman, "U.S. Military Satellites Likely Cyber Attacked By China Or Russia Or Both: Report," *Forbes*, July 5, 2019, accessed June 30, 2020, https://www.forbes.com/sites/zakdoffman/2019/07/05/u-s-military-satellites-likely-cyber-attacked-by-china-or-russia-or-both-report/#4679ea02dd32 ; William Akoto, "Hackers could shut down satellites -- or turn them into weapons," *GCN*, February 12, 2020, July 30, 2020, https://gcn.com/articles/2020/02/12/hackers-satellites.aspx

[12] By Chelsea Gohd, "2 Russian satellites are stalking a US spysat in orbit. The Space Force is watching," *Space.com*, February 11, 2020, accessed June 30, 2020, https://www.space.com/russian-spacecraft-stalking-us-spy-satellite-space-force.html

[13] As was the case with Cuban Missile Crisis.

[14] Martha Harbison, Emily Elert, Clay Dillow, "Infographic: Horses and Bayonets? Guns And Butter? Is our Navy really the smallest it's been since 1916? And what does that mean, anyway?," *Popular Science*, October 23, 2012, accessed June 28, 2020, https://www.popsci.com/technology/article/2012-10/horses-and-bayonets-guns-and-butter/

[15] CONUS = The Continental United States

[16] "Timing," GPS.GOV, n.d., accessed June 28, 2020, https://www.gps.gov/applications/timing/#:~:text=GPS%20receivers%20decode%20these%20signals,economic%20activities%20around%20the%20world.

[17] "Space Based Space Surveillance," Mission Brochure, Boeing Company, URL: http://www.boeing.com/defense-space/space/satellite/MissionBook.pdf cited in: "SBSS (Space-Based Surveillance System)," EOPortal, n.d., accessed July 25, 2020, https://eoportal.org/web/eoportal/satellite-missions/content/-/article/sbss#foot37%29

[18] For an in-depth discussion of Cis-Lunar SDA, see Sean McClain, "Celestial Sentinels: A Framework For Cis-Lunar Space Domain Awareness In 2035," (masters thesis), Air University, March 2020, accessed June 30, 2020, https://www.linkedin.com/posts/namratagoswami_celestial-sentinels-by-sean-mcclain-activity-6664614183398629376-K-IH

[19] Of note, all of these have some level of commercial availability.

[20] "Space Segment," GPS.gov, n.d., accessed August 11, 2020, https://www.gps.gov/systems/gps/space/#IIIF

[21] Gps.gov, Other Global Navigation Satellite Systems (GNSS), n.d., accessed June 30, 2020, https://www.gps.gov/systems/gnss/

[22] The U.S. Space Force defines SDA as the "identification, characterization and understanding of any factor, passive or active, associated with the space domain that could affect space operations and thereby impact the security, safety, economy or environment of our nation" per Sandra Erwin, "Air Force: SSA is no more; it's 'Space Domain Awareness'," *Space News*, November 14, 2019, accessed June 30, 2020, https://spacenews.com/air-force-ssa-is-no-more-its-space-domain-awareness/

[23] It is almost always the case that you have more targets than you have munitions, though it is also common for states to underfund munitions:
Aaron Mehta, "The US is running out of bombs — and it may soon struggle to make more," *Defense News*, May 22, 2018, June 30, 2020, https://www.defensenews.com/pentagon/2018/05/22/the-us-is-running-out-of-bombs-and-it-may-soon-struggle-to-make-more/

[24] See Encyclopedia Britannica, "Counterforce doctrine: nuclear strategy," n.d., accessed June 29, 2020, https://www.britannica.com/topic/counterforce-doctrine
[25] This phrase appears to have been coined by Bleddyn E. Bowen, *War in Space: Strategy, Spacepower and Geopolitics*, (Edinburgh: Edinburgh University Press, 2020), p. 124
[26] Brian Weeden, "The End of Sanctuary in Space," *War is Boring*, January 7, 2015, accessed June 29, 2020, https://medium.com/war-is-boring/the-end-of-sanctuary-in-space-2d58fba741a
[27] See official definition and discussion of Space Control: Department of Defense, *Joint Publication 3-14 Space Operations*, April 10, 2018, accessed June 30, 2020, https://www.jcs.mil/Portals/36/Documents/Doctrine/pubs/jp3_14.pdf
[28] Barry Watts, *The Maturing Revolution in Military Affairs*, June 2, 2011, accessed June 30, 2020, https://csbaonline.org/uploads/documents/2011.06.02-Maturing-Revolution-In-Military-Affairs1.pdf
[29] Bill Gertz "China may deploy anti-satellite laser weapons next year able to destroy U.S. military satellites," *Washington Free Beacon*, February 18, 2019, https://www.militaryaerospace.com/trusted-computing/article/16711585/china-may-deploy-antisatellite-laser-weapons-next-year-able-to-destroy-us-military-satellites "Russia Lasers," *Global Security*, n.d., accessed July 1, 2020, https://www.globalsecurity.org/space/world/russia/lasers.htm; Bart Hendrickx, "Peresvet: a Russian mobile laser system to dazzle enemy satellites," *The Space Review*, June 15, 2020, accessed July 1, 2020, https://www.thespacereview.com/article/3967/1;
[30] U.S. Space Command Public Affairs, "Russia tests direct-ascent anti-satellite missile," April 15, 2020, accessed July 1, 2020, https://www.spacecom.mil/MEDIA/NEWS-ARTICLES/Article/2151611/russia-tests-direct-ascent-anti-satellite-missile/; Doug Messier, "DIA: China Has Ground-based ASAT Missile, Likely Working on Laser Weapon," *Parabolic Arc*, February 18, 2019, accessed July 1, 2020, http://www.parabolicarc.com/2019/02/18/dia-china-groundbased-asat-missile-working-laser-weapon/ ; Jeff Foust, "India tests anti-satellite weapon," *Space News*, March 27, 2019, accessed July 1, 2020, https://spacenews.com/india-tests-anti-satellite-weapon/;
[31] For an excellent discussion of the likely violation of neutrals in space war, see Bleddyn E. Bowen, *War in Space: Strategy, Spacepower and Geopolitics*,
[32] See Encyclopedia Britannica, "Single Integrated Operational Plan: United States warfighting plan," n.d., accessed June 29, 2020, https://www.britannica.com/topic/Single-Integrated-Operational-Plan
[33] Staff Writers, "US Project Thor would fire tungsten poles at targets from outer space," *Space Daily*, November 12, 2018, accessed June 30, 2020, https://www.spacedaily.com/reports/US_Project_Thor_would_fire_tungsten_poles_at_targets_from_outer_space_999.html ; Blake Stilwell, "These Air Force 'rods from god' could hit with the force of a nuclear weapon," *We are Mighty*, May 22, 2020, accessed June 30, 2020, https://www.wearethemighty.com/articles/these-air-force-rods-from-god-could-hit-with-the-force-of-a-nuclear-weapon
[34] Editors, "Cuban Missile Crisis," *History.com*, January 4, 2010, accessed June 29, 2020, https://www.history.com/topics/cold-war/cuban-missile-crisis
[35] In fact some authors think the US should deliberately disaggregate its NC3 from other systems: From Sanctuary to Battlefield: Elbridge Colby, *A Framework for a U.S. Defense and Deterrence Strategy for Space*, CNAS January 27, 2016, accessed June 30, 2020, https://s3.amazonaws.com/files.cnas.org/documents/CNAS-Space-Report_16107.pdf?mtime=20160906081938
[36] Brian G. Chow, "Nuclear vulnerability: In-orbit bodyguards would help protect NC3 satellites from attacks," *Space News*, April 1, 2019, accessed June 30, 2020, https://spacenews.com/op-ed-nuclear-vulnerability-in-orbit-bodyguards-would-help-protect-nc3-satellites-from-attacks/
[37] David Stuckenberg and Peter Garretson, "Updating the Laws of War for the 21st Century: Time to Reconsider, and Ban, Modern Nation-Killing Acts," The Mitchell Institute, April 2, 2019, accessed July 1, 2020, https://www.mitchellaerospacepower.org/single-post/2019/04/02/Updating-the-Laws-of-War-for-the-21st-Century-Time-to-Reconsider-and-Ban-Modern-Nation-Killing-Acts
[38] In the wake of a significant increase in debris, incentives might exist to create a new regime:
Peter Garretson, Alfred B. Anzaldúa, and Hoyt Davidson, "Catalyzing space debris removal, salvage, and use Maritime lessons and a proposal for a space salvage entity and pollution credit system," *The Space Review*, December 9, 2019, accessed July 1, 2020, https://www.thespacereview.com/article/3847/1
[39] C. Priyant and Mark Surekha Kamath, "Review of Active Space Debris Removal Methods," *Space Policy* Volume 47, February 2019, Pages 194-206.
[40] This is a reference to the prescriptions of Dr. Everett Dolman in *Astropolitik* to command space, and seek a position of hegemony by controlling access to space.

[41] Sun Tzu's six terrain configurations are: 1. Accessible (easily traversed both sides); 2. Entangling / suspended (hard to re-occupy; return impossible—attack if unprepared, don't attack if prepared; 3. Temporizing / stalemated (nobody gains by occupying); 4. Narrow passes/constricted (occupy first or don't enter); 5. precipitous heights; and 6. positions a great distance from enemy / Expansive. Sun Tzu's Taxonomy of Nine Battlegrounds / Situations / Terrain are: 1. dispersive ground (home territory; want to go home—do not engage the enemy); 2. Facile/Light ground (slight penetration want to run back)—don't stop; 3. Contentious Ground (decisive point great advantage to either side—don't attack, hurry up rear forces); 4. Open Ground/traversable (liberty of movement to both sides—don't block enemy, vigilant eye on defenses; do not allow your forces to become isolated); 5. Intersecting Highways /focal (easy control of 3 states—joint with allies; unite and form alliances with nearby lords); 6. Serious Ground/ Heavy terrain (deep penetration supply lines in danger—plunder and ensure continuous supplies); 7. Difficult Ground / entrapping terrain (forests, steeps, marshes hard to traverse—keep marching; move through quickly); 8. Hemmed in Ground / encircled terrain (easy to ambush with small numbers—resort to Stratagem [trickery] use strategy, block any retreat); 9. Desperate Ground / fatal terrain (no place of refuge at all, saved from destruction only by fighting—Fight/engage in battle). Adapted from: http://classics.mit.edu/Tzu/artwar.html

[42] For an extensive documentation of this claim, see: Namrata Goswami and Peter Garretson, *Scramble for the Skies: The Great Power Competition to Control the Resources of Outer Space* (Landham, Maryland: Lexington Books, 2020)

[43] Michael Brown, Eric Chewning, And Pavneet Singh, *Preparing The United States for the Superpower Marathon With China, Brookings*, April 2020, accessed June 30, 2020, https://www.brookings.edu/wp-content/uploads/2020/04/FP_20200427_superpower_marathon_brown_chewning_singh.pdf

[44] See in particular, Joshua Carlson, *Spacepower Ascendant: Space Development Theory and a New Space Strategy*, Independently Published via Amazon, June 27, 2020, https://www.amazon.com/Spacepower-Ascendant-Development-Theory-Strategy/dp/B08BWGPR8V/ref=tmm_pap_swatch_0?_encoding=UTF8&qid=1593376321&sr=8-1

[45] This view was recently expressed by Chinese Space expert Guoyu Wang, who stated, "This is bound to initiate a new round of competition about exploitation and utilization of the resources on the Moon and other celestial bodies among states and private entities. Exploitation of the resources on the Moon and other celestial bodies could become the spotlight of a new round of the space race and a new 'battlefield' among space powers. For a long time, space competitions and contests have been mainly supported by technology, engineering, and science, and are mainly in the fields as launch, space applications, space science, human spaceflight, and deep space exploration…In the last ten years, those trends appear have extended both in depth and breadth. First, the competition in space diplomacy, space rules, and space economy have become increasingly fierce. Second, three new directions or fields of space development, including on-orbit servicing (OOS), planetary defense, and exploitation and recovery of space resources, have become increasing clear."; Guoyu Wang, "NASA's Artemis Accords: the path to a united space law or a divided one?," *The Space Review*, August 24, 2020, accessed August 28, 2020, https://www.thespacereview.com/article/4009/1; it is also consistent with several U.S. assessments, including the *Space Futures 2060 Report*, the *State of the Space Industrial Base 2020 report*, and the *U.S.-China Economic and Security Review report*, and AFPC's Defense Technology Program Brief: Steven J. Butow, Thomas Cooley, Eric Felt, Joel B. Mozer, STATE OF THE SPACE INDUSTRIAL BASE 2020: A Time for Action to Sustain US Economic & Military Leadership in Space, Department of Defense, July 2020, accessed August 28, 2020, https://cdn.afresearchlab.com/wp-content/uploads/2020/07/27223753/State-of-the-Space-Industrial-Base-2020-Report_July-2020_FINAL.pdf
; U.S.-China Economic and Security Review Commission, "Section 3: China's Ambitions In Space: Contesting The Final Frontier," in 2019 Report to Congress of the U.S.-China Economic and Security Review Commission, USCC, November 14, 2019, accessed August 28, 2020, https://www.uscc.gov/sites/default/files/2019-11/Chapter%204%20Section%203%20-%20China%E2%80%99s%20Ambitions%20in%20Space%20-%20Contesting%20the%20Final%20Frontier.pdf
; Lamont Colucci, The Case for Space Development (Defense Technology Program Brief), AFPC, August, 2020, accessed August 28, 2020, https://www.afpc.org/uploads/documents/Defense_Technology_Briefing_-_Issue_20.pdf

[46] Mike Wall, "Incredible Technology: Spiderlike Robots Could Build Giant Space Structures," *Space.com*, April 06, 2015, accessed July 1, 2020, https://www.space.com/28846-spiderfab-space-structures-incredible-technology.html; Mike Wall, "Archinaut, a Construction Robot for Space, Could Launch a Test Flight in 2022," *Space.com*, July 13, 2019, accessed July 1, 2020, https://www.space.com/made-in-space-archinaut-flight-test-2022.html

[47] Lucie Gaget "3D printing in Space: The Next Revolution?, " *Sculpteo*, November 29, 2017, accessed July 1, 2020, https://www.sculpteo.com/blog/2017/11/29/3d-printing-in-space-the-new-revolution/; "Return to the moon?

3D printing with moondust could be the key to future lunar living," *The Conversation*, August 2, 2019, accessed July 1, 2020, https://theconversation.com/return-to-the-moon-3d-printing-with-moondust-could-be-the-key-to-future-lunar-living-121265; Bahar Gholipour, "3D Printing on Mars Could Be Key for Martian Colony," *Space.com*, October 03, 2013, accessed July 1, 2020, https://www.space.com/23059-3d-printing-mars-colony.html

[48] "Air Force Selects Lunar Resources and Rhea Space Activity for Next Generation USAF Space Capabilities," *PR Newswire*, October 31, 2019, accessed July 1, 2020, https://www.prnewswire.com/news-releases/air-force-selects-lunar-resources-and-rhea-space-activity-for-next-generation-usaf-space-capabilities-300949528.html

[49] Miriam Kramer, "Space tourism gets ready for launch," *Axios*, February 25, 2020 accessed July 1, 2020, https://www.axios.com/space-tourism-reshaping-industry-2bc34677-6fc1-4b5c-b81b-d1e0f69efcc4.html

[50] "Orbital Space Tourism," *Space Ventures Investors*, n.d., accessed July 1, 2020, http://www.spaceventuresinvestors.com/space-tourism.html#:~:text=was%20about%20300.-,Orbital%20Space%20Tourism,prototype%20orbital%20accommodation%20in%20orbit.

[51] Dave Mosher, "Elon Musk: 'SpaceX is building floating, superheavy-class spaceports' for its Starship rocket to reach the moon, Mars, and fly passengers around Earth," *Business Insider*, June 16, 2020, accessed July 1, 2020, https://www.businessinsider.com/elon-musk-spacex-starship-ocean-spaceports-offshore-engineer-job-posting-2020-6

[52] John K. Strickland, Jr., "Orbital Propellant Depots: Building the Interplanetary 'Interstate Highway'," NSS, August 5, 2011, accessed July 1, 2020, https://space.nss.org/orbital-propellant-depots-building-the-interplanetary-interstate-highway/ ; "Why Build Big Rockets at All? It's Time for Orbital Refueling," *Universe Today*, August 16, 2019, accessed July 1, 2020, https://www.universetoday.com/143178/why-build-big-rockets-at-all-its-time-for-orbital-refueling/

[53] Department of Energy, "Space-Based Solar Power," March 6, 2014, accessed July 1, 2020, https://www.energy.gov/articles/space-based-solar-power

[54] NASA, "Robotic Tool Operations Bring In-Space Refueling Closer to Reality," August 16, 2019, accessed July 1, 2020, https://www.nasa.gov/feature/robotic-tool-operations-bring-in-space-refueling-closer-to-reality

[55] Mike Wall, "First-of-Its-Kind Satellite Servicing Spacecraft Launches on Russian Rocket," *Space.com*, October 09, 2019, accessed July 1, 2020, https://www.space.com/mev-1-satellite-servicing-spacecraft-launch-success.html#:~:text=MEV%2D1%20is%20the%20first,servicing%20craft%20to%20take%20flight.&text=The%20era%20of%20commercial%20satellite,Russian%20Proton%20rocket%20today%20(Oct.

[56] NASA, "Commercial Lunar Payload Services," n.d., accessed July 1, 2020, https://www.nasa.gov/content/commercial-lunar-payload-services

[57] Peter Garretson, "The Future of the Asian Order Will Be Decided in Space: Space Resources could Determine Which Country Winds up Dominating the 21st century," *The Diplomat*, July 3, 2019, accessed June 29, 2020, https://thediplomat.com/2019/07/the-future-of-the-asian-order-will-be-decided-in-space/

[58] The importance of freedom of action, protecting commerce, and the anticipation of U.S. interests expanding beyond GEO are all found in the recently released Space Force Doctrine. The importance of U.S. interests in space resources, and the role of the U.S. Space Force to protect it are likewise articulated in the White House's new Deep Space Strategy: United States Space Force, *Spacepower: Doctrine for Space Forces* , Spaceforce.mil, August 2020, accessed August 28, 2020, https://www.spaceforce.mil/Portals/1/Space%20Capstone%20Publication_10%20Aug%202020.pdf; The White House, *A New Era in Deep Space Exploration and Development*, Whitehouse.gov, July 23, 2020, accessed August 28, 2020, https://www.whitehouse.gov/wp-content/uploads/2020/07/A-New-Era-for-Space-Exploration-and-Development-07-23-2020.pdf

[59] Martin Elvis, Tony Milligan, Alanna Krolikowski. "The Peaks of Eternal Light: A Near-term Property Issue on the Moon," (Postdoctoral NSF Grant#1066293), 2016. https://arxiv.org/ftp/arxiv/papers/1608/1608.01989.pdf

[60] Loren Grush, "Why mining the water on the Moon could open up space exploration: 'Water is the oil of space'," *The Verge*, August 23, 2018, accessed July 1, 2020, https://www.theverge.com/2018/8/23/17769034/nasa-moon-lunar-water-ice-mining-propellant-depots

[61] Mark Evan Prado, "Moving around in the Earth-Moon system," *Permanent.com*, accessed June 29, 2020, https://www.permanent.com/space-transportation-earth-moon.html#Earth-Moon-energy

[62] For an in-depth discussion of the Cis-Lunar 'Celestial Lines of Commerce' see Sean McClain, *Celestial Sentinels: A Framework for Cis-Lunar Space Domain Awareness In 2035*, Air Command and Staff College (Air University), March 2020.

[63] See for example: Brent Ziarnick, "The US Space Guard: Institutional Support to Space Commerce" Chapter 20 in Langdon Morris and Kenneth Cox (editors) *Space Commerce: The Inside Story by the People who are Making it Happen* (Aerospace Technology Working Group, 2010), p. 351; M.V. Smith, *The Space Corpsman's Handbook*,

unpublished, January 1, 2019; Sean McClain, *Celestial Sentinels: A Framework For Cis-Lunar Space Domain Awareness*.

[64] Matthias Williams, "India rejects Chinese protest at Dalai Lama trip," *Reuters*, September 30, 2009, accessed June 29, 2020, https://in.reuters.com/article/india-china-dalai-lama/india-rejects-chinese-protest-at-dalai-lama-trip-idINDEL53581420090930

[65] Rick Rojas, "Falun Gong followers protest Chinese President Xi in Desert Visit," *Los Angeles Times*, June 8, 2013, accessed June 29, 2020, https://www.latimes.com/local/lanow/la-me-ln-falun-gong-xi-protest-20130607-story.html

[66] For example, see the case of the PRC's strong-arm tactics to prevent the Voice of America from airing an interview of political dissident, Chinese billionaire Guo Wengui.
Evelyn Cheng, "How an Interview with One Chinese Billionaire Threw a US broadcaster into turmoil," *CNBC*, June 9, 2017, Accessed June 27, 2020, https://www.cnbc.com/2017/06/09/interview-with-guo-wengui-throws-voice-of-america-into-turmoil.html

[67] Editors, "Cuban Missile Crisis," *History.com*, January 4, 2010, accessed June 29, 2020, https://www.history.com/topics/cold-war/cuban-missile-crisis

[68] Kim Zetter, "An Unprecedented Look at Stuxnet, the World's First Digital Weapon," *Wired*, November 3, 2014, accessed June 29, 2020, https://www.wired.com/2014/11/countdown-to-zero-day-stuxnet/

[69] Anthony D'Amato, "Israel's Air Strike upon the Iraqi Nuclear Reactor," Faculty Working Papers (2010), Paper 76. http://scholarlycommons.law.northwestern.edu/facultyworkingpapers/7

[70] Christopher Woody, "This New Defense Department Map Shows How China says One Thing and Does Another with its Military Operations at Sea," *Business Insider*, August 17, 2018, accessed June 29, 2020, https://www.businessinsider.com/defense-department-map-shows-chinas-naval-operations-in-maritime-eezs-2018-8

[71] Jun Osawa, "China's ADIZ over the East China Sea: A "Great Wall in the Sky"?," Brookings, December 17, 2013, accessed June 29, 2020, https://www.brookings.edu/opinions/chinas-adiz-over-the-east-china-sea-a-great-wall-in-the-sky/

[72] "Capture" is a neglected consideration in air and spacepower thinking. Various forms of "active control" including Defeat, Capture, Containment, and Conversion are discussed in Jeremy L. Renken, "Airpower for Irregular Warfare: Reconciling USAF Theory and TACAIR Design with the Demands of Irregular Warfare and Special Operations," (master's thesis), National Defense Intelligence College, July 2012.

[73] Jon Bowermaster, "The Last Front of the Cold War: You think the Cold War is over? Think again. Russian and American forces are still challenging each other in the Arctic," *The Atlantic Online*, November 1993, accessed June 29, 2020, https://www.theatlantic.com/past/docs/politics/foreign/front.htm; Owen R. Cote, Jr., "Cold War Struggle with Soviet Submarines," FAS, March, 2000, accessed June 29, 2020, https://fas.org/man/dod-101/sys/ship/docs/cold-war-asw.htm

[74] Kirk Nankivell , "Why the Future of Solar Power Is from Space," *Singularity Hub*, Dec 31, 2018, accessed July 1, 2020, https://singularityhub.com/2018/12/31/why-the-future-of-solar-power-is-from-space/ ; Daniel Oberhaus, "How to Get Solar Power on a Rainy Day? Beam It From Space," *Wired*, December 2, 2019, https://www.wired.com/story/how-to-get-solar-power-on-a-rainy-day-beam-it-from-space/ ; Eric Rosenbaum and Donovan Russo, "China plans a solar power play in space that NASA abandoned decades ago," *CNBC*, March 17, 2019, accessed July 1, 2020, https://www.cnbc.com/2019/03/15/china-plans-a-solar-power-play-in-space-that-nasa-abandoned-long-ago.html

[75] DSM, "Is the Future of Data Centers in Space?," *DSM*, November 6, 2018, accessed July 1, 2020, https://www.dsm.net/it-solutions-blog/is-the-future-of-data-centers-in-space ; Michael Sheetz, "Satellite start-up raises $100 million to put cloud data storage in space," *CNBC*, December 20 2018, accessed July 1, 2020, https://www.cnbc.com/2018/12/19/cloud-constellation-raises-100-million-to-store-cloud-data-in-space.html

[76] B. Edelson, R. Lovell and C. Cuccia, "The Evolution of the Geostationary Platfom Concept," *IEEE Journal on Selected Areas in Communications* (Volume: 5, Issue: 4 , May 1987)

[77] Hanneke Weitering, "6 Private Deep Space Habitat Concepts That May Pave the Way to Mars," *Space.com,* October 11, 2016, accessed July 1, 2020, https://www.space.com/34357-private-deep-space-habitat-concepts-for-nasa.html ; Kate Baggaley, "Huge Space Hotel Promises Fake Gravity and 'Supersized Basketball: The Planned Von Braun Station Could be Open as Soon as 2027," *NBC News*, accessed July 1, 2020, https://www.nbcnews.com/mach/science/huge-space-hotel-promises-fake-gravity-supersized-basketball-ncna1051596

[78] Dennis Wingo, *MoonRush: Improving Life on Earth with the Moon's Resources* (Ontario, Canada: Apogee Books, 2004); Paul D. Spudis, *The Value of the Moon: How to Explore Life and Prosper in Space Using the Moon's Resources* (Washington, DC: Smithsonian Books, 2016).

[79] Brian Chow, "China's new space threat and the justification of US pre-emptive self-defense," *The Space Review*, January 18, 2016, accessed July 1, 2020, https://www.thespacereview.com/article/2903/1
[80] I recommend the valuable: Explore, Expand, Exploit, Exclude space development theory of Joshua Carlson. See: Joshua Carlson, *Spacepower Ascendant: Space Development Theory and a New Space Strategy*, Self-Published, 2020.
[81] Examples include the subordination of Germany after WW1, or the counter-reaction to appeasement after Nazi Germany successively took territory.
[82] An example of such an outcome is illustrated in Worden & Shaw's *Whither Space Power*, see the Asian Hegemony scenario beginning page 57.
[83] Leonard David, "China's Anti-Satellite Test: Worrisome Debris Cloud Circles Earth," *Space.com*, February 02, 2007, accessed June 29, 2020, https://www.space.com/3415-china-anti-satellite-test-worrisome-debris-cloud-circles-earth.html
[84] John Costello and Joe McReynolds, *China's Strategic Support Force: A Force for a New Era, Center for the Study of Chinese Military Affairs*, Institute for National Strategic Studies China Strategic Perspectives, No. 13, NDU Press, October 2019, accessed June 30, 2020, https://ndupress.ndu.edu/Portals/68/Documents/stratperspective/china/china-perspectives_13.pdf
[85] DoD, "Department of Defense Establishes U.S. Space Command," *Defense.gov*, August 29, 2019, accessed June 30, 2020, https://www.defense.gov/Newsroom/Releases/Release/Article/1948288/department-of-defense-establishes-us-space-command/
[86] USSF, "About U.S. Space Force," n.d., accessed June 30, 2020, https://www.spaceforce.mil/About-Us/About-Space-Force
[87] The distinction between Blue and Blown Water schools of space power was first advanced by Dr. Brent Ziarnick: Brent D. Ziarnick, "The Battle for the Soul of the Space Force," *The Hill*, August 23, 2019, accessed July 1, 2020, ; Brent D. Ziarnick, "The Space Force Strategic Vision Emerges," *The Hill*, September 9, 2019, accessed July 1, 2020 https://thehill.com/opinion/national-security/460469-the-space-force-strategic-vision-emerges
[88] Brad Townsend, "Space Power and the Foundations of an Independent Space Force," *Air & Space Power Journal*, Winter 2019, accessed June 10, 2020, https://www.airuniversity.af.edu/Portals/10/ASPJ/journals/Volume-33_Issue-4/F-Townsend.pdf
[89] Bleddyn E. Bowen, *War in Space: Strategy, Spacepower and Geopolitics*, (Edinburgh: Edinburgh University Press, 2020).
[90] Paul Szymanski's various products can be found in his online collection here: http://www.space.forces.space/
[91] John Klein, *Space Warfare: Strategy, Principles, and Policy* (London & New York: Routledge, 2006); John Klein, *Understanding Space Strategy: The Art of War in Space (Space Power and Politics)* [London & New York: Routledge, 2019].
[92] Dr. Brent Ziarnick is the first to call this collection of thinkers "the blue water school of spacepower"; Dr. Simon "Pete" Worden, Brig Gen, USAF-Ret was the first to my knowledge to assert US space forces must focus on blue water objectives.
[93] Everett C Dolman., *Astropolitik: Classical Geopolitics in the Space Age*.
[94] Simon P Worden and John E. Shaw, *Whither Space Power? Forging a Strategy for the New Century* (Maxwell Air Force Base: Air University Press, 2002).
[95] Brent Ziarnick, *Developing National Power in Space: A Theoretical Model*. Jefferson (NC: McFarland & Company, 2015).
[96] Christopher M. Stone, *Reversing the Tao: A Framework for Credible Space Deterrence* 1st Eds (Scotts Valley, California: CreAte Space Independent Publishing Platform, 2016).
[97] Joshua Carlson, *Spacepower Ascendant*, (Kindle Self-Publish, 2020).
[98] Joan Johnson-Freese, *Space as a Strategic Asset* (New York: Columbia University Press, 2007).
[99] James Clay Moltz, *Asia's Space Race: National Motivations, Regional Rivalries and International Risk*.
[100] Daniel H Deudney, *Dark Skies: Space Expansionism, Planetary Geopolitics, and the Ends of Humanity* (New York: Oxford University Press, 2020).
[101] My thanks to Lt Col Jeremy Renken who made me aware of this phrase.
[102] Simon P Worden and John E. Shaw, *Whither Space Power? Forging a Strategy for the New Century* (Maxwell Air Force Base: Air University Press, 2002).
[103] Fred Kennedy, Rory Welch, Bryon Fessler, "A Failure of Vision Retrospective," *Airpower Journal*, Summer 1998, accessed June 10, 2020, https://apps.dtic.mil/dtic/tr/fulltext/u2/a530286.pdf

[104] Charles J. Dunlap, Jr, "How We Lost The High-Tech War Of 2007: A Warning from the Future," *The Weekly Standard*, January 29, 1996, accessed June 10, 2020, https://www.washingtonexaminer.com/weekly-standard/how-we-lost-the-high-tech-war-of-2007
[105] George Friedman, *The Next 100 Years: A Forecast for the 21st Century* (NY: Anchor, 2010).
[106] Andrew Krepinevich, *7 Deadly Scenarios: A Military Futurist Explores the Changing Face of War in the 21st Century* (NY: Bantam, 2010).
[107] Sam J. Tangredi, *All Possible Wars? Toward a Consensus View of the Future Security Environment, 2001–2025*, Institute for National Strategic Studies, National Defense University, Washington, D.C., 2000.
[108] Michel Andrieu, *Geopolitical Developments and the Future Of The Space Sector,* OECD, Friday, 7th May 2004.
[109] Daniel H Deudney, *Dark Skies: Space Expansionism, Planetary Geopolitics, and the Ends of Humanity* (New York: Oxford University Press, 2020).
[110] P. W. Singer and August Cole, *Ghost Fleet: A Novel of the Next World War* (New York: Eamon Dolan/Mariner Books, 2016)
[111] Michael J. Coumatos, William B. Scott, William J. Birnes, *Space Wars: The First Six Hours of World War III, a Wargame Scenario* (NY: Forge Books, 2010).
[112] William B. Scott, Michael J. Coumatos, William J. Birnes, *Counterspace: The Next Hours of World War III* (NY: Forge Books, 2009).
[113] See for example, Collins, John M. *Military Space Forces: the next 50 years*. Vol. 4. Brassey's Incorporated, 1989, available online at: https://www.spacefaringamerica.com/wp-content/uploads/2020/05/military_space_forces_collins_1989_csr_report.pdf; Robert Preston, Dana J. Johnson, Sean JA Edwards, Michael D. Miller, and Calvin Shipbaugh. *Space Weapons Earth Wars*. RAND Corporation, 2002.
[114] Charles Krauthammer, "The Unipolar Moment: America and the World 1990," *Foreign Affairs*, September 18, 1990, accessed June 30, 2020, https://www.foreignaffairs.com/articles/1990-01-01/unipolar-moment#:~:text=The%20unipolar%20moment%20means%20that,now%20in%20the%20Persian%20Gulf.
[115] Todd Harrison, Kaitlyn Johnson, Thomas G. Roberts, Tyler Way, and Makena Young, *Space Threat Assessment 2020*, CSIS, March 2020, accessed June 30, 2020, https://csis-website-prod.s3.amazonaws.com/s3fs-public/publication/200330_SpaceThreatAssessment20_WEB_FINAL1.pdf ; Brian Weeden and Victoria Sampson, *Global Counterspace Capabilities: An Open Source Assessment*, Secure World Foundation, April 2020, accessed June 30, 2020, https://swfound.org/media/206970/swf_counterspace2020_electronic_final.pdf
[116] NASIC, *Competing in Space*, December 2018, accessed June 30, 2020, https://media.defense.gov/2019/Jan/16/2002080386/-1/-1/1/190115-F-NV711-0002.PDF ; Defense Intelligence Agency, *Challenges To Security In Space*, January 2019, accessed June 30, 2020, https://www.dia.mil/Portals/27/Documents/News/Military%20Power%20Publications/Space_Threat_V14_020119_sm.pdf ; Mark Stokes, Gabriel Alvarado, Emily Weinstein, and Ian Easton, *China's Space and Counterspace Capabilities and Activities* (Prepared for: The U.S.-China Economic and Security Review Commission), March 30, 2020, accessed June 30, 2020, https://www.uscc.gov/sites/default/files/2020-05/China_Space_and_Counterspace_Activities.pdf; Eric Heginbotham, Michael Nixon, Forrest E. Morgan, Jacob L. Heim, Jeff Hagen, Sheng Tao Li, Jeffrey Engstrom, Martin C. Libicki, Paul DeLuca, David A. Shlapak, David R. Frelinger, Burgess Laird, Kyle Brady, and Lyle J. Morris, *The U.S.-China Military Scorecard Forces, Geography, and the Evolving Balance of Power*, 1996–2017, RAND, 2015, p. 227-241, https://www.rand.org/content/dam/rand/pubs/research_reports/RR300/RR392/RAND_RR392.pdf
[117] As broad as this list is, early Cold War thinking (before the Outer Space Treaty of 1967 and Partial Test Ban treaty) was far more expansive, including strategic orbital bases, orbital and suborbital space bombers capable of nuclear and strategic strikes, Moon bases, manned orbiting laboratories, fully-reusable spaceplanes for logistic access, and nuclear thermal and nuclear pulse-powered spacecraft.
[118] "The Space Race," *History.com*, February 21, 2020, accessed June 30, 2020, https://www.history.com/topics/cold-war/space-race
[119] Andrew Browne, "How the Coronavirus is Accelerating Deglobalization," *Bloomberg*, February 29, 2020, accessed July 1, 2020, https://www.bloomberg.com/news/newsletters/2020-02-29/why-deglobalization-is-accelerating-bloomberg-new-economy
[120] Says the US National Security Strategy, "after being dismissed as a phenomenon of an earlier century, great power competition returned. China and Russia began to reassert their influence regionally and globally"; the National Defense Strategy, "The central challenge to U.S. prosperity and security is the reemergence of long-term, strategic competition by what the National Security Strategy classifies as revisionist powers. It is increasingly clear that China and Russia want to shape a world consistent with their authoritarian model—gaining veto authority over other nations' economic, diplomatic, and security decisions"; the National Military Strategy, "These trends,

especially those posed by the reemergence of great power competition with China and Russia, represent the most difficult challenges facing the Joint Force" see: *National Security Strategy of the United States of America*, The White House, December 2017, accessed July 1, 2020, https://www.whitehouse.gov/wp-content/uploads/2017/12/NSS-Final-12-18-2017-0905.pdf ; Summary of the 2018 National Defense Strategy of the United States, Department of Defense, 2018, https://dod.defense.gov/Portals/1/Documents/pubs/2018-National-Defense-Strategy-Summary.pdf ; *Description of the National Military Strategy 2018*, Joint Staff, 2018, https://www.jcs.mil/Portals/36/Documents/Publications/UNCLASS_2018_National_Military_Strategy_Description.pdf

[121] James D. Fearon, "Rationalist explanations for war." *International organization* 49, no. 3 (1995): 379-414.

[122] Rebecca Reesman, Michael P Gleason, Colleen Stover, and Layla Bryant, *Slash the Trash: Incentivizing Deorbit*, Aerospace Corp, April 2020, accessed June 29, 2020, https://aerospace.org/sites/default/files/2020-04/Reesman_SlashTheTrash_20200422.pdf

[123] Susanna Kohler, "Astronomy Impacts of Satellite Megaconstellations," *AAS NOVA*, April 13, 2020, accessed June 30, 2020, https://aasnova.org/2020/04/13/astronomy-impacts-of-satellite-megaconstellations/

[124] Secure World Foundation, Space Sustainability: A Practical Guide, 2018, accessed June 29, 2020, https://swfound.org/media/206407/swf_space_sustainability_booklet_2018_web.pdf ; Joan Johnson-Freese· *Heavenly Ambitions: America's Quest to Dominate Space* (Philadelphia, PA: University of Pennsylvania Press, 2009); James Clay Moltz, *Asia's Space Race: National Motivations, Regional Rivalries and International Risk* (New York: Columbia University Press, 2011).

[125] Brian Weeden and Victoria Samson, "India's ASAT test is wake-up call for norms of behavior in space," *Space News*, April 8, 2019, accessed June 29, 2020, https://spacenews.com/op-ed-indias-asat-test-is-wake-up-call-for-norms-of-behavior-in-space/ ; Leonard David, "China's Anti-Satellite Test: Worrisome Debris Cloud Circles Earth," *Space.com*, February 02, 2007, accessed June 29, 2020, https://www.space.com/3415-china-anti-satellite-test-worrisome-debris-cloud-circles-earth.html

[126] Loren Grush, "As Satellite Constellations Grow Larger, Nasa Is Worried About Orbital Debris: The space agency argues that these probes need to be de-orbited — reliably," *The Verge*, Sep 28, 2018, accessed June 29, 2020, https://www.theverge.com/2018/9/28/17906158/nasa-spacex-oneweb-satellite-large-constellations-orbital-debris

[127] Ivan Bekey, "Chapter 9: The Long-term Outlook for Commercial Space," in Charles D. Lutes, and Peter Hays, eds, *Toward a Theory of Spacepower: Selected Essays*, Figure 9–12. Potential Number of Annual World Launches, p. 196.

[128] Casey Handmer, "The SpaceX Starship is a very big deal," *Casey Handmer Blog*, October 29, 2019, accessed June 28, 2020, https://caseyhandmer.wordpress.com/2019/10/29/the-spacex-starship-is-a-very-big-deal/#:~:text=Starship%20is%20not%20just%20a,This%20is%20a%20big%20deal.

[129] "Planet Labs Imagery: The Entire Earth, Everyday," *GIS Geography*, April 26, 2020, accessed July 1, 2020, https://gisgeography.com/planet-labs-imagery/

[130] Rachel Jewett, "Capella Space Becomes First Commercial SAR Provider to Work With NRO," *Satellite Today*, December 12, 2019, accessed July 1, 2020, https://www.satellitetoday.com/government-military/2019/12/12/capella-space-becomes-first-commercial-sar-provider-to-work-with-nro/

[131] Annamarie Nyirady, "HawkEye 360 Releases 1st RF Signal Mapping Product," *Satellite Today*, April 4, 2019, accessed July 1, 2020, https://www.satellitetoday.com/imagery-and-sensing/2019/04/04/hawkeye-360-releases-1st-rf-signal-mapping-product/; Cortney Weinbaum, Steven Berner, and Bruce McClintock , "SIGINT for Anyone: The Growing Availability of Signals Intelligence in the Public Domain," RAND, 2017, accessed July 1, 2020, https://www.rand.org/content/dam/rand/pubs/perspectives/PE200/PE273/RAND_PE273.pdf

[132] Loren Grush, "Space startup Lynk uses satellite to send text message to unmodified Android phone: The company says it paves the way for its mega-constellation of satellite 'cell towers'," *The Verge*, March 18, 2020, accessed July 1, 2020, https://www.theverge.com/2020/3/18/21184126/lynk-mega-constellation-text-message-android-smartphone-cell-towers-space

[133] Casey Handmer, "Starlink is a very big deal," *Casey Handmer Blog*, November 2, 2019, accessed June 28, 2020, https://caseyhandmer.wordpress.com/2019/11/02/starlink-is-a-very-big-deal/

[134] Andrew Donoghue, "The Idea of Data Centers in Space Just Got a Little Less Crazy: Critical Thinking: SpaceX's latest launch raises the potential for all kinds of new space-based infrastructure, including data centers," *Data Center Knowledge*, February 09, 2018, accessed July 1, 2020, https://www.datacenterknowledge.com/edge-computing/idea-data-centers-space-just-got-little-less-crazy

[135] The Thomas Theorem States, "if men define situations as real, they are real in their consequences." Robert K. Merton., "The Thomas Theorem and The Matthew Effect," *Social Forces*, 74/2 (1995): 379-424,

available at http://garfield.library.upenn.edu/merton/thomastheorem.pdf

[136] Ivan Bekey, "Chapter 9: The Long-term Outlook for Commercial Space," in Charles D. Lutes, and Peter Hays, eds, *Toward a Theory of Spacepower: Selected Essays*, National Defense University Press, 2011, Figure 9–12. Potential Number of Annual World Launches, p. 196.

[137] Timothy Taylor, "How Big is the Space Economy," *The Conversable Economist*, December 19, 2019, accessed June 28, 2020, https://conversableeconomist.blogspot.com/2019/12/how-big-is-space-economy.html

[138] Ken Murphy, "The cislunar econosphere (part 1)," *The Space Review*, February 20, 2012, accessed June 28, 2020, https://www.thespacereview.com/article/2027/1

[139] There is broad consensus that the space economy is poised to grow significantly. Major banks have provided forecasts circa 2040 (Goldman Sachs $1.1T Morgan Stanley $1.1T, U.S. Chamber of Commerce $1.5T) and circa 2050 (Bank of America Merrill Lynch $2.7T). Reflecting this optimism, the U.S. Secretary of Commerce gave a speech at the World Economic Forum in Davos where he said, "*Current industry projections place the 2040 global space economy at between $1 and $3 trillion*. And I think we will certainly get to a trillion before 2030." See: "Space: Investing in the Final Frontier," *Morgan Stanley*, November 7, 2018, accessed January 30, 2019, https://www.morganstanley.com/ideas/investing-in-space; Rich Smith, "The $1.1 Trillion Space Industry Prediction You Can't Afford to Miss," *The Motley Fool*, February 16, 2018, accessed https://www.fool.com/investing/2018/02/16/the-11-trillion-space-industry-prediction-you-cant.aspx; Brian Higgenbotham, "The Space Economy: An Industry Takes Off," U.S. Chamber of Commerce, November 11, 2018, accessed January 30, 2019, at https://www.uschamber.com/series/above-the-fold/the-space-economy-industry-takes; Michael Sheetz, "The space industry will be worth nearly $3 trillion in 30 years, Bank of America predicts," *CNBC*, October 31, 2017, accessed January 30, 2019, https://www.cnbc.com/2017/10/31/the-space-industry-will-be-worth-nearly-3-trillion-in-30-years-bank-of-america-predicts.html; Wilbur Ross, "A New Space Race: Getting to the Trillion-Dollar Space Economy World Economic Forum, Davos, Switzerland," Commerce Department, January 24, 2020, accessed February 21, 2020, https://www.commerce.gov/news/speeches/2020/01/remarks-secretary-commerce-wilbur-ross-new-space-race-getting-trillion-dollar

[140] See discussions of China's "Cislunar Economic Zone (地月空间经济区 dì yuè kōngjiān jīngjì qū), or Moon-based economic sector" expected to return $10 trillion in annual economic benefit for China by 2050: Editors, "A Chinese Economic Zone In Space", *Sup China*, November 4, 2019, March 3, 2020, https://supchina.com/2019/11/04/a-chinese-economic-zone-in-space/; Andrew Jones, "From a farside first to cislunar dominance? China appears to want to establish 'space economic zone' worth trillions," *Space News*, February 15, 2020, accessed March 3, 2020, https://spacenews.com/from-a-farside-first-to-cislunar-dominance-china-appears-to-want-to-establish-space-economic-zone-worth-trillions/

[141] Research and Markets, "Global Space-Based Solar Power Market Study, 2020: An Emerging Industry with Unlimited Potential," *PR Newswire*, Feb 14, 2020, accessed July 1, 2020, https://www.prnewswire.com/news-releases/global-space-based-solar-power-market-study-2020-an-emerging-industry-with-unlimited-potential-301005179.html

[142] Leonard David, "The US Geological Survey Is Getting Serious About Space Resources and Mining," *Space.com*, September 04, 2018, accessed July 1, 2020, https://www.space.com/41707-space-mining-usgs-resource-survey.html

[143] Harry W. Jones, "The Recent Large Reduction in Space Launch Cost," NASA, 8-12 July 2018, accessed June 22, 2020, https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20200001093.pdf

[144] Brian Wang, "Reusable SpaceX Falcon Heavy will make highly cost competitive space based solar power", *Next Big Future*, February 5, 2018, accessed June 22, 2020, https://www.nextbigfuture.com/2018/02/reusable-spacex-falcon-heavy-will-make-highly-cost-competitive-space-based-solar-power.html#:~:text=A%20SpaceX%20Falcon%20Heavy%20will,will%20be%20%241411%20per%20kilogram.

[145] Ramish Zafar, "SpaceX Could Bring Starship Launch Costs Down To $10/kg Believes Musk," *WCCFTech*, May 8, 2020, accessed June 22, 2020, https://wccftech.com/spacex-launch-costs-down-musk/#:~:text=These%20are%20military%20payloads%2C%20with,is%20certified%20to%20deliver%20them.&text=Returning%20to%20the%20moon%20missions,kg%20for%20delivering%20lunar%20payloads.

[146] Metzger, Philip T., Anthony Muscatello, Robert P. Mueller, and James Mantovani. "Affordable, rapid bootstrapping of the space industry and solar system civilization." *Journal of Aerospace Engineering* 26, no. 1 (2013): 18-29, accessed June 28, 2020, https://arxiv.org/abs/1612.03238

[147] Robert K. Merton., "The Thomas Theorem and The Matthew Effect," *Social Forces* 74, no. 2 (1995): 379-424, available at http://garfield.library.upenn.edu/merton/thomastheorem.pdf

[148] James D. Fearon, "Rationalist explanations for war." *International organization* 49, no. 3 (1995): 379-414.

[149] David Stuckenberg and Peter Garretson, "Updating the Laws of War for the 21st Century: Time to Reconsider, and Ban, Modern Nation-Killing Acts," The Mitchell Institute, April 2, 2019, accessed July 1, 2020, https://www.mitchellaerospacepower.org/single-post/2019/04/02/Updating-the-Laws-of-War-for-the-21st-Century-Time-to-Reconsider-and-Ban-Modern-Nation-Killing-Acts

[150] "Détente," *History.com*, October 27, 2009, accessed June 29, 2020, https://www.history.com/topics/cold-war/detente

[151] Consider for example that early battles which decided the contours of French and Spanish interests in North America involved very small military contingents. While the French and Spanish militaries were on the order of 300,000 soldiers, important events such as the battle of Fort Caroline involved fewer than 700 on all sides. For approximate size of total armies, see, Pierre Bienaimé and Armin Rosen, "The World's Largest Armies From Antiquity To The Present," Business insider, November 26, 2014, accessed August 28, 2020, https://www.businessinsider.com/this-ambitious-graphic-shows-the-size-of-standing-armies-from-antiquity-to-the-present-2014-11; For the battle of Ft Caroline, see: National Parks Service, "The Massacre of the French," NPS.gov, n.d., Accessed August 28, 2020, https://www.nps.gov/foma/learn/historyculture/the_massacre.htm