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CHAPTER 4

Vulnerable frontier: militarized competition in outer space

Michael Haas

Critical dependencies on space-based infrastructure have grown dramatically in recent decades, and now extend to small states and the global economy as a whole. However, as geopolitical rivalries re-emerge in more traditional domains of interstate conflict, the prospects for future stability in space appear increasingly dim. While the consequences of a great-power clash in space could be ruinous, a shared understanding of the perils involved has yet to take hold. Strategic interaction along the 'final frontier' is set to enter a period of considerable danger.

An SM-3 interceptor modified for the anti-satellite mission is launched from the guided-missile cruiser USS *Lake Erie* during *Operation Burnt Frost,* 20 February 2008.

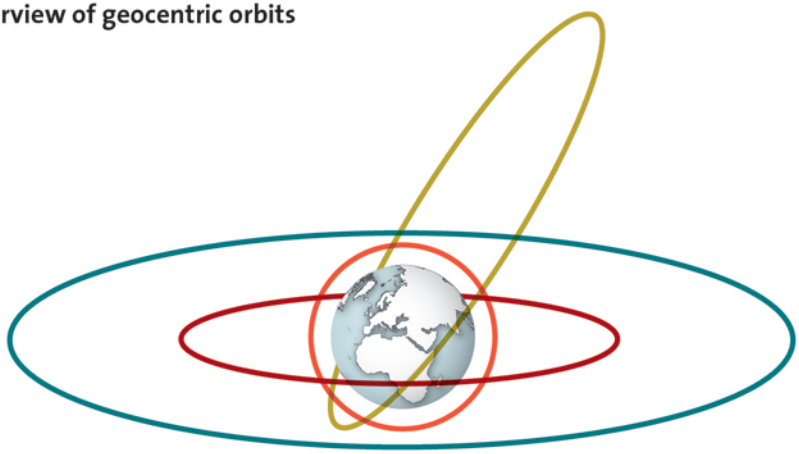
Among the various environments into which humans have expanded their economic, military, and scientific activities, outer space is easily the most unwelcoming and inhospitable. Impossible to access except through massive expenditures of energy per unit of mass to be placed into orbit, and utterly hostile to human life as well as to many types of man-made machinery, the maintenance of a permanent presence outside Earth's protective atmosphere remains a highly ambitious undertaking. Despite various complications, however, this presence – which, in most cases, has entailed the placement of unmanned artificial satellites in earth-centric orbits – has become an essential pillar of the global economic and security systems in the late 20th and early 21st centuries. From highly specialized scientific and commercial services to everyday applications of information technology (IT), space-based infrastructures now form part of the life-support system of a civilization that has tied its economic well-being and, indeed, its very survival to global connectivity.

However, while the economically most developed societies in particular have come to accept this state of dependence on space-based systems as fairly natural and unproblematic, the space domain is, in fact, highly vulnerable to the direct and indirect effects of reckless behavior on the part of both commercial and governmental entities. Instances of overcrowding are already in evidence within certain orbital planes, increasing the likelihood of serious accidents, such as the 2009 collision between the Iridium 33 and Cosmos-2251 communications satellites in low-earth orbit. Decades of ill-regulated activities in space have created millions of pieces of orbital debris, many of which have sufficient kinetic energy to permanently disable a satellite.

However, the most serious threat to the continued accessibility of the space environment by far is the prospect of a military confrontation, involving the use of kinetic anti-satellite (ASAT) weaponry by any of the growing number of states that now possess the technological wherewithal to field such capabilities.

As was rather vividly demonstrated by the Chinese test of a direct-ascent ASAT missile in January 2007, which is estimated to have created more than two million pieces of debris up to ten centimeters in size as well as 2,500 larger objects that can be routinely tracked by earth-based sensors, such a conflict would probably result in massive environmental damage. Depending on the number and position of satellites destroyed, the utilization of

Overview of geocentric orbits



LEO = Low Earth Orbit (≈ 200 – 2,000 km)
MEO = Medium Earth Orbit (≈ 2,000 – 35,000 km)
GEO = Geostationary Orbit (≈ 36,000 km)
HEO = Highly Elliptical Orbit (≈ 200 – 50,000 km)

Source: NASA Global Change Master Directory

affected orbital planes could be severely impaired. In a worst-case scenario, these orbits could become virtually unusable for extended periods of time, as most of the debris would remain in place for decades or even centuries, with serious implications for both commercial and military users.

Unfortunately, several trends point in the direction of an increased risk over the next 10 – 20 years of terrestrial conflict that may involve attacks on space systems, including the use of kinetic ASAT weaponry. These trends are primarily the results of the re-emergence of sustained strategic rivalries among some great and medium-sized powers – including the US and China in East Asia, the US and Russia in Eurasia, and potentially the China-India-Pakistan triangle in South Asia. With the exception of Pakistan, all of these states have already demonstrated a basic anti-satellite capability, and the US and China in particular are integrating space warfare scenarios into their military planning.

Moreover, the ongoing diffusion of underlying clusters of technologies – which include ballistic missiles and space launch vehicles (SLVs), advanced radar and seeker technologies, conventional and micro-satellites, solid-state or chemical lasers, as well

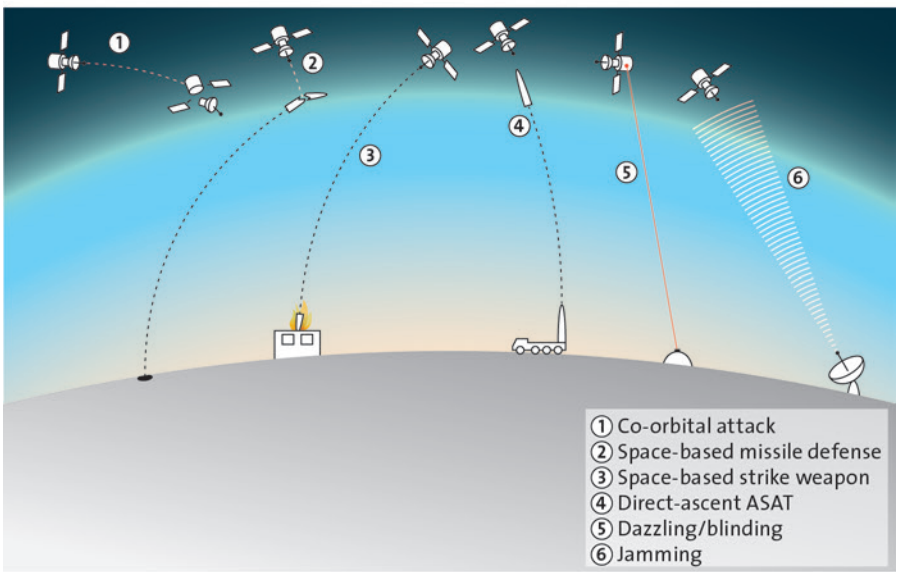
as battle management networks to coordinate attacks – will further increase the number of states with a latent anti-satellite potential. It is entirely possible that the pace of technology diffusion will accelerate further in the coming decades.

Against this backdrop of renewed strategic rivalry and continuing proliferation, the specter of space conflict will be a prominent feature of global politics in the coming decade and probably beyond. This chapter will first discuss the problematic, but largely irresolvable entanglement between civil and military activities in space, as well as the limited effectiveness of multilateral governance instruments in regulating these activities. It will then outline in considerable detail the current geostrategic and military trends that increase the likelihood of military confrontations and render space an ever more vulnerable domain. Finally, it will review several ways in which states can mitigate their dependence on vulnerable space systems and provide an assessment of their potential effectiveness.

Irresolvable entanglements

Over the last several decades, space-based services have become a critical component of the global economic system as well as of the civilian

Space and ASAT weapons



infrastructure of government. Long-range communications, public and commercial broadcasting, imaging and remote sensing, positioning and navigation, meteorology, and a host of specialized scientific applications are all highly dependent on the smooth functioning of satellites and their diverse payloads. Vital sectors of the globalized economy, including finance, shipping, and civil aviation, rely on these space-based infrastructures, as do agricultural planning, urban planning and surveying, disaster management, and environmental monitoring.

The provision of these various services is valued at over USD 300 billion per year, and has remained a growth industry even in the aftermath of the 2007–2008 financial crisis. The overall economic contribution of space-based infrastructure in terms of establishing global connectivity, reducing transaction costs, and providing unique sources of information about terrestrial activities is much more difficult to quantify. However, it undoubtedly makes a substantial contribution to the current gross world product of more than USD 74 trillion and thus likely exceeds the direct profits garnered by space-related industries many times over.

While space activities are still primarily conducted by a small number of advanced nations and private entities, the number of stakeholders has grown exponentially over the past 50 years. In its early stages, the utilization of space was the exclusive domain of the Cold War era superpowers. Today, only half of the more than 1,200 active satellites are still operated by the US or Russia, and in the case of the US almost half of those are owned by private businesses. Overall, more than 50 nations now have one or more satellites operating under their flag.

While the direct stakes of the leading spacefaring nations still exceed those of less capable or newly emerging actors, small states that are tightly integrated into the global economy are now nearly as vulnerable to disruptions of the orbital environment as are the great powers. At the same time, the capacity of most of these actors to unilaterally hedge against a loss of services without incurring unacceptable economic costs is rather limited.

This state of vulnerability, which is a product of states' dependence on space-based services and the current lack of viable alternatives to such services, is compounded by the fact that the infrastructures in question are inherently fragile. Due to the difficulty of placing them in orbit and keeping them in working order in the stringent conditions of the space

environment, space assets tend to be expensive, scarce, and difficult to replace. As a result of constraints in weight and size, they also typically lack physical robustness beyond what is absolutely necessary to keep them operational over their specified lifecycle. Consequently, the human foothold in the space domain is fundamentally less resilient than is our hold over other more easily accessible components of the global system, such as the maritime domain.

The situation is further complicated by the fact that any distinction between the civil and military spheres of space activity is at best porous, and in many cases non-existent. Not only are most space programs military in origin, they also tend to embody the very essence of dual-use technology, as their civil components are either direct corollaries of military services (as is the case with the US Global Positioning System, or GPS) or can be employed for military purposes with no, or only minimal, modifications (which is the case in many commercial communication and imaging applications). In fact, among some 500 satellites that are not directly related to a governmental or military agency, a substantial majority provide services that potentially have military applicability. As a result, debates about the perils of 'militarization' are largely moot – space is, and has been ever since the 1950s, a thoroughly militarized domain.

This entanglement of civil and military infrastructures in space has important implications as far as future security dynamics are concerned. On the one hand, in case of a serious confrontation, their potential military relevance may require that a large number of foreign-operated spacecraft be considered as targets. Otherwise, an opponent would be allowed to immunize essential services from attack by outsourcing them to commercial entities or third parties. On the other hand, attacks on such third-party satellites would likely be perceived as particularly escalatory, requiring that fragile and ambiguous distinctions be upheld during a crisis or conflict. This would seem to create considerable opportunity for miscalculation and miscommunication.

At the same time, entanglement also accentuates the fact that civil and military infrastructures are equally vulnerable to any large-scale environmental effects of kinetic space warfare. Even if distinctions between enemy and 'neutral', as well as between military and commercial, spacecraft could be upheld, attacks would inexorably entail some amount of collateral damage within that particular orbital plane. While some military satellites are

already designed to weather specific types of adversarial effects, such as the electromagnetic pulse (EMP) created by high-altitude nuclear explosions, and could perhaps be better protected against other effects as well, a comprehensive program of satellite hardening would almost certainly entail prohibitive costs. Therefore, the prevention of destructive anti-satellite warfare would seem to constitute the only viable course of action if major risks to the existing infrastructures are to be avoided.

The hollow promise of comprehensive governance

Among the options available to policy-makers to ensure that space does not become the scene of serious military confrontation, the institution of a framework of binding rules and norms that underwrite the status of space as a non-weaponized 'sanctuary' that is off-limits to any direct military interventions would seem to hold considerable appeal. If such a framework were embraced and collectively upheld by all the relevant space powers, the possibility of space conflict would almost certainly diminish, and access to the space environment would continue to be relatively unproblematic for decades to come. In fact, several initiatives with the declared goal of achieving such an end state are currently on the table, including a draft treaty proposed by Russia and China in 2008, which has recently been updated, and a non-binding code of conduct supported by the EU.

Unfortunately, hopes for a comprehensive scheme of governance that ensures the military inviolability of the space domain are largely based on extravagant extrapolations from the limited achievements of Cold War space diplomacy, or of more recent civil-commercial governance instruments. While the former were made possible by a specific set of political-military conditions that no longer apply, the latter fail to provide a workable template for regulating military activities in space, which are among the most sensitive and least transparent aspects in the military policies of the great powers. As a result, it is unlikely that multilateral governance will be able to effectively prevent terrestrial rivalries from spilling over into space. Far from offering any decisive solutions, it should be regarded as one of a number of mechanisms that may be able to make a limited contribution to a stable space environment.

Historically, space governance has enjoyed some success only where the great powers had a shared interest in preventing a further escalation of ongoing activities, notably where weaponization in the very narrow sense of permanently deploying specific types

of weapons in orbit, was concerned. This was laid down in the 1967 Outer Space Treaty, which remains to this day the most significant legal document regulating activities in space, and the now defunct Anti-Ballistic Missile (ABM) Treaty, ratified in 1972. While such partial achievements remain a possibility, trust in comprehensive multilateral governance would appear to be largely misplaced where military competition is perceived by one or both sides as providing important strategic or political advantages.

To the extent that effective governance remains elusive, space will once again become – and likely remain – a contested zone of influence, and potentially a zone of conflict, between the great powers. Governance efforts, in the form of confidence-building measures and arms control initiatives, could be instrumental in regulating the more escalatory or destabilizing aspects of militarized competition. The stationing of weapons in orbit, in particular, will remain a distinct and perhaps more manageable concern. That said, the re-emergence of strategic rivalries between several of the great powers and the persistence of rivalry in other settings indicate a heightening of competition in the near- and medium-term that any existing or proposed mechanisms of governance are unlikely to prevent.

The return of strategic rivalry and the rise of space denial

As the unrivalled military and economic predominance of the US, which has been the hallmark of the post-Cold War era, begins to wane, geopolitical competition with China in the Asia-Pacific and with Russia in Eurasia is inaugurating a new era of rivalry in an increasingly multipolar global system. Intermittent tensions in the East and South China Seas, which from a US perspective largely amount to confrontations by proxy over the future regional order, and the acute crisis in NATO-Russia relations over Ukraine are but the most visible crystallization points of these growing fault lines in great power relations. As scenarios of conventional or 'hybrid' interstate warfare begin to reshape the horizon of military planning, these rivalries are also increasingly finding their expression in outer space. But the strategic conditions under which the next round of militarized interaction in space will take place differ very considerably from those of the Cold War competition, and in ways that indicate a much greater potential for conflict escalation.

Of course, space has been an arena of geostrategic antagonism and jostling from the very inception of human orbital activities. Throughout the first half of the period since 1957, when

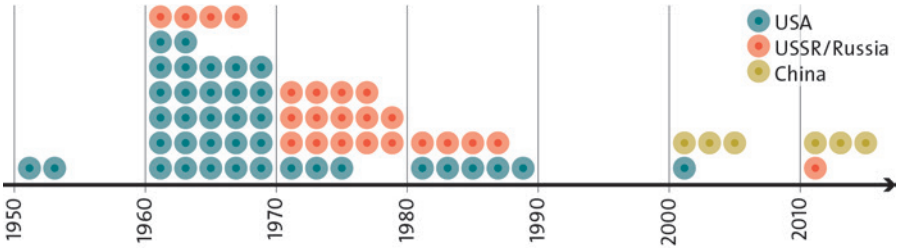
the civil and military utilization of space began in earnest, great-power relations were dominated by an entrenched militarized rivalry between two largely incompatible systems of government. However, alone among the environments into which humans have extended their economic and military reach, space has never seen a direct military clash between hostile political actors. This outcome might be seen as an encouraging sign of the great powers' ability to regulate their interactions even in the absence of comprehensive space governance or, at the very least, to successfully 'muddle through'. It appears increasingly unlikely, however, that this run of good fortune will hold indefinitely.

A strong case can be made to the effect that space conflict during the Cold War was of limited importance because it was viewed almost exclusively through the prism of space systems' intimate association with the strategic nuclear balance. Throughout the bipolar standoff, satellites were utilized mainly for strategic command and control (C2), early warning, and reconnaissance. As a result of this close integration of space and the nuclear sphere, attacks on spacecraft were generally seen as a corollary of, or prelude to, full-scale nuclear war, and considerably less attention was paid to space warfare as a serious issue during more limited conflicts. It was thus expected that, should attacks on spacecraft ever occur, they would almost immediately be eclipsed by far more serious events.

It was only during the 1991 Gulf War that the current paradigm of space operations in support of conventional force deployments began to take hold. In the quarter-century that followed, the contribution of space-based services to conventional military operations has increased to the point of becoming the chief *raison d'être* of space power, with other advanced military forces clearly seeking to emulate the US in this regard. As a result of these developments, the perspective of potential ASAT users on space denial operations has changed completely. Far from being a prelude to an all-out nuclear assault, space warfare is now seen primarily as a means of denying information support and C2 to the opponent's conventional forces, thereby depriving them of vital force multipliers. Such considerations are particularly prominent in the warfighting concepts of armed forces that view the highly space-enabled and space-dependent US military as a likely opponent.

As a matter of fact, concerns about US conventional military superiority have been the main driver behind the

Kinetic ASAT testing



Sources: Brian Weeden (2014), *Through a Glass, Darkly: Chinese, American, and Russian Anti-satellite Testing in Space*, Broomfield, CO: Secure World Foundation; Michael Krepon & Julia Thompson (eds.) (2013), *Anti-satellite Weapons, Deterrence and Sino-American Space Relations*, Washington, DC: Stimson Center.

renewed interest in anti-satellite capabilities. Attempts at offsetting the US advantage in space – and thereby diminishing the US armed forces' overall margin of superiority in a future conflict – are now quite prominent in Chinese and Russian conceptions of future warfare, and are manifesting themselves in a number of development programs and tests not seen since the 1980s. With space warfare gaining currency in the doctrinal debates of some of the world's most capable armed forces, other nations are beginning to take an interest in military counter-space options as well.

The remarkable rebirth of ASAT

In retrospect, the developments that placed space warfare back on the agenda of great power politics were the direction taken by the Chinese People's Liberation Army (PLA) in its modernization drive, which finally began to gather some steam in the early 2000s, and the US decision in 2002 to withdraw from the ABM Treaty. It was only in the aftermath of China's much-noted shoot-down of its Fengyun-1C weather satellite in early 2007, however, that the issue began to reenter the public consciousness. It was this rather dramatic event, which drew a thinly-veiled US riposte in the destruction of the defunct USA-193 reconnaissance satellite in an ASAT test known as *Operation Burnt Frost* in February 2008, which reestablished the prospect of space warfare as a prominent global security concern.

In the eight years that have passed since the Fengyung intercept, a wealth of evidence has emerged that points to renewed efforts by several of the great powers to develop a capacity for effective space denial by both kinetic and non-kinetic means. Of these, China's development of the direct-ascent missile system, known as the SC-19, which was first observed in two non-destructive tests in 2005

and 2006, and also employed in the 2007 destructive test, has understandably received the greatest amount of public attention. Four additional tests with a suspected ASAT background have been reported in 2010, 2013, and most recently in July 2014. According to one notable technical analysis, one of two tests observed in 2013 may have utilized a more advanced missile and reached much deeper into space than did earlier tests, with an apogee in excess of 10,000 kilometers. The same may have been true of the test reported in 2014. Should the PLA be able to consolidate such an extended-range capability, it will be able to threaten a much greater number of satellites than has hitherto been the case.

One significant feature of the SC-19 system is that it has been tested in a road-mobile configuration, which points to the development of an operationally credible and survivable capability that may already be deployed in small numbers with the Second Artillery Force (SAF), which also has responsibility for the land-based component of China's nuclear deterrent. Even a few SC-19s could do considerable damage to selected high-value military assets in low-earth orbits, and the same could be true of the extended-range system purportedly tested in 2013 and 2014 if it is targeted against relatively vulnerable constellations in geostationary orbits. Meanwhile, the GPS constellation in medium-earth orbits is generally considered relatively robust, due to its distributed nature. Bringing the system to its knees for an extended period of time would require the coordinated expenditure of perhaps a dozen or more weapons, which would almost certainly draw an extremely robust – possibly nuclear – response from the US.

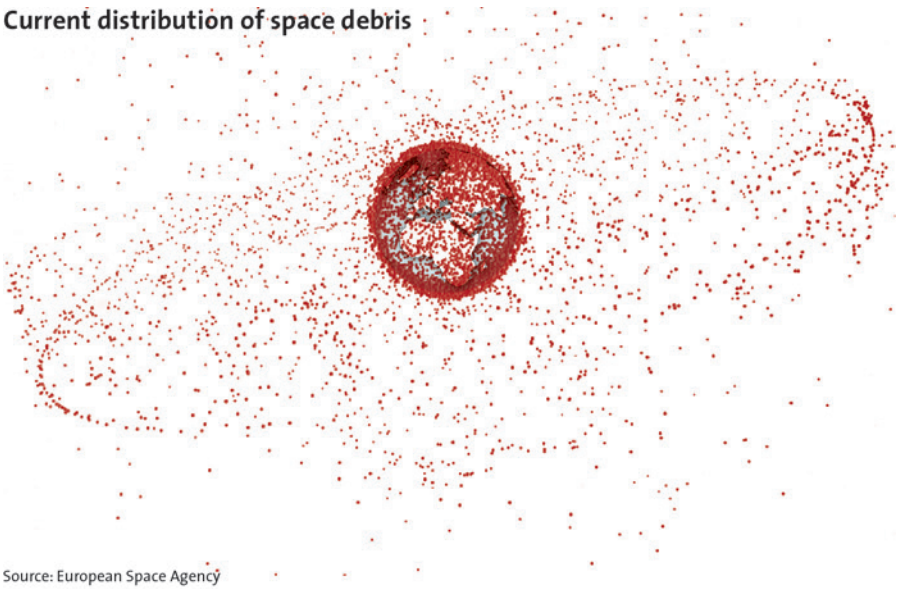
In addition to its direct-ascent, hit-to-kill system (or systems), China is also reported to be testing systems for co-orbital attack. This is based on the observation of a number of unusual maneuvers by satellites Shiyan-7, Shijian-15, and Chuangxin-3, which are thought to have begun in July 2013. The exact extent and implications of this additional path to an ASAT capability are currently difficult to fathom. Moreover, the PLA is known to also have engaged in the 'dazzling' or 'blinding' of US imaging satellites by means of terrestrial laser systems, and has likely acquired GPS jammers, which can be effective in protecting critical installations from certain types of precision-guided munitions (PGM). It may also be developing a range of other space warfare techniques based on microwave, electronic attack, and cyberspace capabilities. Given the considerable breadth and depth of its space warfare programs, the PLA's

activities are currently the main driver of a burgeoning arms dynamic in this area of strategic interaction.

The US, meanwhile, is not known to be operating or developing dedicated anti-satellite weapons, which is explained in part by the much lower dependence on space-based services of even the most capable among its potential opponents. The US military does, however, field several types of missile defense interceptors, some of which are inherently dual-use capable, as was successfully demonstrated in *Operation Burnt Frost*. Its ballistic missile defense (BMD) programs thus provide the US with what is probably the most extensive and most widely distributed ASAT potential among the great powers. However, the reach of this arsenal is currently limited to low Earth orbits. Moreover, while the BMD and anti-satellite missions are fundamentally very similar, and satellites are much less operationally demanding targets, substantial technical modifications are nonetheless required to realize the latent ASAT potential of these systems. It is therefore fair to say that the US does not routinely field space weapons as part of its global defense strategy.

The Russian Federation is also reportedly engaging in a variety of space warfare activities, driven in large part by US insistence on a continental missile defense system, which Moscow perceives as a potential threat to its nuclear deterrent, as well as by Chinese and US ASAT testing. The most recent example of such activities is what may amount to a reactivation of the co-orbital attack programs that constituted the backbone of Soviet space warfare during the Cold War. According to media reports, a satellite launched in May 2014 and known as Cosmos-2499 has been engaging in unusual approach maneuvers that may constitute a series of ASAT-related tests. Russia has also maintained and recently updated the ground-based sensors that used to support its co-orbital attack programs. In addition to its traditional focus on co-orbital attack, Russia may be reviving its air-launched Kontakt system as well as an airborne laser that could be employed to temporarily dazzle, and perhaps even permanently disable, satellites in low Earth orbit. Russia is also a leading manufacturer of GPS jammers, which it has exported to various countries.

Another significant military power that is known to possess at least a latent direct-ascent ASAT program is India. The Indian armed forces are currently working towards a layered missile defense system and have so far conducted at least seven tests, which may have provided sufficient know-how to conduct an ASAT mission



Source: European Space Agency

with relative ease. India is not currently known to be developing or fielding a dedicated capability, but is sure to keep a close watch on China's activities in this area, given its own growing stakes in outer space, its unresolved territorial disputes with that country, and a potential for serious geostrategic competition in the Indian Ocean.

Other nations that currently possess the technical prerequisites for direct-ascent or co-orbital attack systems and could field such systems within years of a political decision to do so include Japan, Israel, and France. In fact, Japan's deep involvement in the Aegis BMD program means that it is already in possession of a latent capability similar to that of the US. France and Israel are both nuclear powers with considerable military stakes in space, although it would appear that neither is critically dependent on space-based C2 or early warning for the integrity of its deterrent. However, even in the absence of such dependence, these states may come to decide that an ASAT capability of some kind is desirable for symmetrical deterrence of threats to their spacecraft. In addition to these established space powers, the proliferation of satellite, launch system, and precision-guidance technologies means that a growing number of states will possess latent space warfare capabilities in the future. They will most likely include Pakistan,

Iran, Turkey, South Korea, and North Korea, and possibly additional actors like Brazil, South Africa, and Ukraine.

ASAT and counter-ASAT in great-power military planning

While a number of actors possess mobilized or latent ASAT potentials, only the US, China, and the Russian Federation are known to be integrating these potentials, or military options of dealing with enemy potentials, into their war planning. While Russian doctrinal statements have generally focused on the threat posed by opponents' space warfare capabilities to its own strategic warning and C2 assets as well as on the possibility of deploying ASAT weaponry against the space-based elements of a US ballistic missile defense system, many more details are known about the emerging Sino-American interactions in this area.

From a Chinese perspective, space warfare is perceived as a critical element of a 'counter-intervention' or peripheral defense strategy designed to deny US military forces access to China's immediate maritime environment in event of a conflict over Taiwan or other vital Chinese interests. Given the PLA's sustained investment in this strategy, the creation of such an exclusion zone is now no longer an idle threat, even though serious deficits are thought to persist in areas including joint operations and operational command and control. Chinese planners view US space assets as important enablers of US military superiority, and being both vital and vulnerable, they are seen as highly attractive and, indeed, natural targets for any serious anti-access strategy.

As a result, the PLA is preparing to target US satellites at the outset of a conflict to partially equalize what is still a seriously skewed balance of military power in the Asia-Pacific region. One must assume that PLA planners are aware of the escalatory implications of any such move, but it appears that this has not led them to rule out such a course of action, which could provide substantial advantages once war initiation is perceived as inevitable. It is, however, likely that the PLA would seek to keep the use of kinetic weaponry to an unavoidable minimum, to forestall unnecessary escalation as well as excessive international opprobrium, and perhaps to retain this most extreme option as part of a strategy of intra-war deterrence. This is particularly likely as non-kinetic alternatives including electronic attacks, cyber-attacks, and reversible laser or microwave attacks may be available in many cases. One can also expect that Chinese reluctance to escalate immediately to a kinetic exchange would increase further as the

PLA itself becomes more dependent on space-based services as well.

It is much less clear, however, that artificial 'firebreaks' instituted and tacitly or explicitly communicated at the outset of a conflict would hold as US and Chinese forces engage in high-intensity, conventional exchanges, suffering grievous losses and progressive disruption of essential services and capabilities. It is also unclear whether space systems employed in support of conventional forces can be distinguished from systems that are entangled in the strategic nuclear deterrent with sufficient clarity to avoid, at a minimum, the impression of a coordinated and sustained attack on the opponent's nuclear forces. In some cases, including infrared sensors deployed for early warning, which would likely also be employed to locate conventional missile batteries, this would be next to impossible. Overall, even a Chinese strategy of highly selective space warfare could trigger escalation to the nuclear level.

Such a dynamic could be compounded by current US military planning, which also exhibits some highly offensive traits and which must contend with the inherent vulnerability of vital assets. Given the tense fiscal environment and the timelines for fielding new and more survivable platforms or advanced payloads, this state of affairs may well persist into the 2030s. To offset the current vulnerability of the nation's military posture, planners may opt to counter or even preempt Chinese initiatives with early attacks of their own that would have to be directed against some of the most threatening capabilities and installations, which would generally be situated on the Chinese mainland.

One of the more worrisome aspects of the US doctrinal debate is the suggestion, which has gained some traction in recent years, of using conventional prompt strike weaponry to disable the PLA's most threatening ASAT systems before they can be brought to bear against vulnerable US satellites. While such attack options are not currently available, the reliance on missile-based prompt strike during the early hours of a conflict would further compress decision-making timelines and create 'use-or-lose' dilemmas on both sides of the equation. The implications of such developments for crisis management and conventional first-strike stability could be grave, and cross-domain linkages including to cyberspace and the nuclear sphere are sure to complicate political and military decision-making even further.

On the other hand, the development of viable alternatives to space-based

services and of doctrinal constructs for operations in space-denied environments could serve to reduce the incentives for early attacks on space or counter-space systems on both sides of the confrontation. Hence, the current vulnerability of space-based services might provide sufficient impetus for change to avoid some of the more destabilizing implications of the renewed interest in the means and methods of space warfare, and may eventually lead to closer consultation between the great powers.

Robust deterrence or fragile state of non-aggression?

Ultimately, however, the avoidance of the more destructive forms of space warfare would seem to require not just the successful management of successive crises as they emerge, but ultimately the institution of stable deterrence relationships between the main parties to this burgeoning competition. This will depend in part on the effective communication of deterrent threats, based both on denial (the ability to negate the opponent's initiatives, for example by creating sufficient redundancies and being able to operate effectively even in the absence of space support) as well as punishment (the ability to impose unacceptable cost by inflicting symmetrical or asymmetrical damage).

Even more than on these well-known elements of a credible deterrent strategy, the prevention of space conflict may depend on the recognition of mutual vulnerability in space, and the internalization of a sense of shared interest in avoiding worst-case outcomes. While there are obvious similarities to the nuclear sphere, the situation with regard to the space environment is complicated by several factors.

First, the consequences of a kinetic exchange in space are not very well understood, and the proposition that catastrophic damage to orbital infrastructures would be the most likely outcome of such an exchange is not universally accepted. Consequently, the exact degree of vulnerability and the likely ramifications of a military clash remain a matter of debate. While few analysts would deny that unrestrained space warfare would entail serious collateral damage, the 'crystal ball effect' that is associated with nuclear weapons is not nearly as clear-cut with regard to space warfare. This raises the possibility that some decision-makers may calculate that the political aftershocks and economic costs of waging war in space will be commensurate with the advantages gained by crossing this threshold. The total absence or very low number of human casualties constitutes another fundamental difference between nuclear and space warfare, and may serve to underline such considerations.

Secondly, the availability of non-kinetic options and the possibility, at least in some scenarios and with some proposed technologies, of achieving kinetic effects while keeping environmental damage to a minimum would lower the initial threshold for attacks against space systems even further. While a space conflict, once joined, may still spiral out of control, resulting in massive damage to civil and well as military infrastructures, initial military steps may not suggest that such an outcome is likely. This would also tend to undermine any shared perceptions of vulnerability.

Finally, future technological developments may increase the actors' ability to reconstitute the space environment by removing some (though certainly not all) debris, increasing the robustness of space systems, or rendering them more easily replaceable. Such developments would also tend to make kinetic attacks a more palatable option. In addition, some types of debris removal capabilities may also have an inherent dual-use ASAT potential. The introduction of space-based strike weapons for use against terrestrial targets, which also remains a possibility, would add a further layer of complications.

While the case for mutual vulnerability in space can be overstated, none of the factors cited above change the fundamental fact that the human presence in space is comparatively fragile and will continue to be vulnerable to disruption as a result of military conflict. All of them, however, might make it more difficult to avoid such conflict in the long run. Overall, then, despite some striking similarities, deterrence relationships based on mutual vulnerability are bound to be significantly less robust in space than is the case in the nuclear field.

Managing vulnerability in the new era of rivalry

Fortunately, a number of options are nonetheless available for hedging against the ramifications of conflict, and many of these would also serve to render space warfare a less attractive course of action. A first line of effort would involve the supplementation or partial replacement of space-based systems with terrestrially based, airborne, or near-space systems for communication, positioning, and other critical applications. While this would not solve the basic problem of vulnerability in space, it would create redundancies, reduce the effectiveness of space denial programs, and serve to partially deflect the military competition from the space arena. States could also seek to reduce the reliance of their civilian and military activities on space-based assets wherever possible,

which would diminish – though certainly not eliminate – the impact of any future disruptions.

A second line of effort would rely on more technical approaches designed to mitigate particularly destabilizing aspects of militarized competition through targeted confidence- and security-building measures, and perhaps eventually more robust arms control agreements. A moratorium or ban on counter-space weapon testing would be extremely useful during the earlier stages of a competition, but may be difficult to achieve in practice. As is often the case in arms control processes, a slow, deliberate, and incremental approach may offer the greatest chances of success. While they would severely hamper vertical as well as horizontal proliferation, these measures would leave in place existing capabilities and would entail significant verification challenges. Non-proliferation measures, including more stringent export controls on dual-use goods and technologies, may (or may not) prevent additional actors from entering into competition. Finally, increased space situational awareness would increase the risk of cheating on any existing or future agreements, especially if it were to be provided by a multilateral agency.

Despite the considerable potential of such targeted mitigation measures, the possibility that space may yet become the scene of military conflict will undoubtedly remain, and the essential fact of civil as well as military vulnerability is likely to persist well into the future. Given that a stable sense of mutual vulnerability is unlikely to emerge in the short run, and may not hold in the long run, the re-emergence of serious space rivalries is a cause for concern, both for established space powers and for small states that depend on space-based services provided by others. For better or worse, the coming decade may be decisive in shaping the future of our tenuous presence along this vulnerable frontier.