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AN ASSESSMENT OF ANTI-SATELLITE CAPABILITIES AND THEIR STRATEGIC IMPLICATIONS

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The success of space-based communications, navigation and reconnaissance programs – in both the commerical and military arenas – presents a significant vulnerability. Intuitively, as the economic importance and military indispensability of space systems grows, so will their attractiveness as targets. Although attacks against satellites would involve significant operational challenges, economic costs and diplomatic risks, it is well within the realm of technological possibility. For example, China's decision to research ASATs is an indication of its long-term strategic goal of weakening America's monopoly on military space capabilities. This essay describes the current capabilities of anti-satellite (ASAT) technology, assesses its military impact and considers its broader policy and security implications. In light of the broad implications of ASAT weapons on the debate about missile defense in particular and space weaponization in general, the author concludes that the best way to protect America's space-related economic and military functions is to avoid ASATs development.

Precision munitions miss their targets, inadvertently destroying mosques and hospitals. Companies of tanks lose their way in the desert, bypassing their objectives and stumbling into ambushes. Special forces teams deployed into enemy territory cannot communicate to coordinate their extraction. Meanwhile, at CENTCOM headquarters, strategic operational and intelligence communications are rendered inoperable and commanders lose battlespace awareness.

This scenario may be far fetched, but it illustrates the reduced effectiveness of American forces if they are denied access to the satellite architectures upon which they heavily rely. The success of space-based communications, navigation and reconnaissance programs – in both the commercial and military arenas – presents a significant vulnerability. Intuitively, as the economic importance and military indispensability of space systems grows, so will their attractiveness as targets. Successful attacks against the ground-based infrastructure, communications capabilities or space-based vehicles of satellite architectures could be extremely effective against selected critical satellites, such as reconnaissance satellites which are small in number, extremely costly and difficult to replace quickly. Although causing such disruption would involve significant operational challenges, economic costs and diplomatic risks, it is well within the realm of technological possibility. This essay shall describe the current capabilities of anti-satellite (ASAT) technology, assess its military impact and consider its broader policy and security implications.

The Military Importance of Space

The American military's dominance in space is unchallenged; however, its dependence on space is also unrivalled.[1] Space operations play an integral role in increasing the effectiveness of American and allied air, land and sea forces. Specifically, the space forces of the Department of Defense (DoD) provide the following capabilities:[2]

- Missile warning satellites of the Defense Support Program provide both ICBM and Theater Ballistic Missile warning to political and military leaders.
- Communication satellites such as MILSTAR provide constant global connectivity with deployed forces.
- Navigation satellites, specifically the Global Positioning System (GPS) constellation, provide precise navigation and timing support to coordinate the positioning and maneuver of military forces and munitions.
- Weather satellites of the Defense Meteorological Satellite Program collect and distribute global weather data.
- Intelligence satellites provide imagery and signals intelligence about global threats to warfighters and policy-makers.

Without these capabilities, the United States would also lack critical information for command and control, battlespace awareness, targeting, mission planning, battle damage assessment, precision strike and force protection.

DoD rhetoric has long acknowledged the importance of its space systems and emphasized the promise of space power.[3] For

40 years, the United States has embraced the approach of researching potential space weapons – including ASAT technologies – but opting not to deploy them, thereby avoiding both difficult funding decisions and a potential arms race in space. However, the January 2001 Commission to Assess United States National Security and Space Management and Organization, chaired by Donald Rumsfeld shortly before his appointment as Secretary of Defense, argued that the United States must pursue an aggressive approach to the military use of space.[4] Building on this argument, DoD's September 2001 Quadrennial Defense Review emphasized the need to improve space systems and stated that a key objective is 'not only to ensure US ability to exploit space for military purposes, but also as required to deny an adversary's ability to do so'.[5] DoD has clearly recognized that protecting the ability to operate satellites – and potentially denying an adversary this ability – is pivotal to the success of future American military operations. The increasing reliance of military forces and commercial applications on space means that the United States must be able to preserve both military and civilian access to space.

Although American space dominance is presently unquestioned, the environment of space is rapidly changing as the number of spacefaring nations increases.[6] Spurred by economic inducements to expand satellite-based services such as television broadcasting and commercial communications, developing nations such a Nigeria now have access to space. Currently, the United States, Russia, China, France, the United Kingdom, India, Japan, Israel and Brazil all have some degree of space-based military capability. Although only the first three states have pursued ASAT capabilities, targeting satellites in low-earth orbit is not beyond the reach of any nation with a nuclear weapon and a relatively primitive launch vehicle.[7]

In light of this possibility, the asymmetric advantages that the United States currently enjoys in space may be unsustainable as potential rivals become compelled to defend their strategic interests by exploiting vulnerabilities in American space-based platforms and architectures. For example, although the GPS constellation is less vulnerable than others because it is relatively large with hardened vehicles that operate in high altitude orbits, it is also a very attractive target. The GPS architecture is comprised of 27 orbiting satellites, including three operational spares, and a constellation of 18–24 satellites is necessary to ensure line of sight with the minimum four satellites needed for three-dimensional accuracy. Therefore, by destroying four satellites, an adversary could potentially render precision weapons useless in some areas of the world. By destroying ten GPS satellites, this essential element of countless military and commercial applications would be totally – albeit temporarily – ineffective.[8] Moreover, as space becomes of ever-increasing importance to air, sea and land-based warfare, it too may become a battleground as rivals recognize that they cannot challenge the American military without developing a space capability of their own. Clearly, as satellites grow in both number and military significance, the issue of ASAT weapons will similarly adopt greater importance.

Types of ASAT Weapons

In assessing the current capabilities of ASAT technologies, it is necessary to discuss the various types of ASAT weapons.[9] As illustrated in Figure 1, there are the three major categories of potential ASAT weapons: isotropic (non-directional) nuclear weapons,

Isotropic nuclear weapons (INW):
Ground-based
– Co-orbital interceptor
– Direct-ascent ('pop-up') interceptor
Space-based
– Co-orbital interceptor ('nuclear space mines')

Kinetic-energy weapons (KEW):
Ground-based
– Co-orbital interceptor
– Direct-ascent ('pop-up') interceptor
Space-based
– Co-orbital interceptor ('space mines')
– Non-co-orbital interceptor which intercepts targets at high velocity from a parking orbit.

Directed-energy weapons (DEW):
Ground-based
– High-power radio-frequency (HPRF) and active electronic countermeasures (ECM)
– High-energy laser (HEL) and active electro-optical countermeasures (E-OCM)
Space-based
– High-power radio-frequency (HPRF) and active electronic countermeasures (ECM)
– High-energy laser (HEL) and active electro-optical countermeasures (E-OCM)
– Neutral-particle beam (NPB)

FIGURE 1 Types of ASAT weapons. *Source*: Office of Technology Assessment, *Anti-Satellite Weapons, Countermeasures, and Arms Control*, p.63.

kinetic-energy weapons (projectiles), and directed-energy weapons (particle beam weapons, radio-frequency weapons and laser weapons).[10] Each has unique characteristics, advantages, and disadvantages that will be explored briefly below.

Nuclear weapons detonated in space will radiate energy and disperse debris in all directions. Such isotropic nuclear weapons (INW) could be carried to within lethal range of a satellite by ICBMs or ballistic missile interceptors and be detonated. Nuclear weapons could also be based in space disguised as a different type of satellite, the presence of which would be-observable but the nature of which might be impossible to ascertain. Such nuclear 'space mines' could maneuver and detonate within lethal range of their targets.[11]

The advantages of isotropic nuclear weapons include their present availability, their relative economy, their potential concealment from surveillance systems, their range against unhardened satellites, the difficulty of hardening satellites against nuclear detonations, and their delivery by launch vehicles with poor guidance capability. On the other hand, nuclear ASAT weapons have significant legal, political and strategic disadvantages. Not only would they cause collateral damage to unhardened friendly and neutral satellites as well as scatter debris across the atmosphere, but the 1967 Outer Space Treaty also prohibits nuclear weapons in orbit.[12] Furthermore, their use would escalate a conflict to a nuclear war, in which INWs add little value because the ground-based satellite infrastructures are significantly vulnerable. Lastly, they would have little effect on those components of DoD's space architecture that are either nuclear hardened, such as MILSTAR satellites, or in higher orbits, such as GPS satellites. Despite the technological feasibility of direct-ascent and co-orbital nuclear ASAT weapons, these disadvantages pose considerable disincentives to their deployment.

Kinetic-energy ASAT weapons pursue satellites and destroy them either by direct impact or by firing at them from close range. These weapons destroy targets through the kinetic energy produced by their mass and velocity. For example, an aircraft or a terrestrial platform may launch a direct-ascent ('pop-up') interceptor to directly impact the targeted satellite. Similarly, a co-orbital satellite or one in a parking orbit could launch a projectile at its target. Pop-up interceptors do not require the investment in payload or the diplomatic risks of space-based weapons, however, a co-orbital satellite can act as a ‘space mine’ that continuously observes and trails its target, prepared to destroy it. Used in this way, two features of space mines pose great threats: first, their ability to attack without warning renders reactive countermeasures such as evasion useless, and second, they could attack at close range and damage even hardened satellites. Furthermore, a co-orbital interceptor could pursue a target indefinitely if it had as much acceleration capability as its target.

Despite the high development costs and diplomatic risks associated with deploying weapons in space, the military argument for space-based kinetic energy ASAT weapons is sound because there is no economical means to protect large satellites against a surprise attack by them. Protection against such weapons would require evading or attacking satellites that orbit in close proximity to defend an agreed or unilaterally declared ‘exclusion zone’ around satellites. Although new generations of small, inexpensive satellites would negate the advantages of kinetic energy weapons, there might be insufficient time to develop such architectures before these weapons are deployed and detected.

Directed-energy weapons can theoretically target satellites and – depending upon the type of energy – jam communications, degrade electronics or destroy sensors.[13] These weapons destroy targets through electromagnetic beams that directly transfer destructive energy. Potential directed-energy weapons could be ground based or space based and employ either high-power radio-frequency generators, high-energy laser weapons, or neutral particle beams. First, radio-frequency weapons, such as high-power microwave weapons, can produce intense, damaging beams of radio-frequency radiation. Such weapons could be used at all levels of conflict because they can overload and damage satellite electronic equipment at high power levels or, at lower power levels, merely jam satellite electronic systems.[14] Second, high-energy laser weapons produce intense, damaging beams of optical radiation that can overload optical communication systems and blind optical sensor systems.[15] For example, a laser ASAT test in 1997 showed that a 30-watt, ground-based chemical laser was able to temporarily blind an Air Force satellite orbiting at 425 km altitude.[16] Lastly, powerful particle accelerators similar to those used for scientific research and isotope production could be used as particle-beam weapons to attack satellites. If deployed, such weapons could endanger low-altitude satellites at relatively low cost as well as damage unhardened electronics on high-altitude satellites.

However, ground-based directed-energy weapons have the significant drawbacks of being subject to the effects of cloud cover and atmospheric turbulence such as absorption and scattering, which could cause energy beams to diverge extensively. Another serious problem for ground-based lasers is the infrequency with which a low-altitude satellite would pass within view of a ground-based laser site. The interval between such passes might be several days and – with enough fuel – a maneuvering satellite could completely avoid coming within range of the laser. In comparison, the beams of space-based laser weapons would not have to pass through the atmosphere and could damage unhardened satellites at great range. A small force of such lasers could pose a threat to a nation's most critical satellites. However, space-based laser weapons, like other satellites, would be subject to attack by adversaries with their own ASAT capabilities.

Countermeasure Options

The military impact of this technology must be examined in light of both its potential effectiveness and the change it forces upon space-based platforms. Technologies applicable to future ASAT weapons are so varied that future ASAT weapons, if developed, could potentially disable all types of satellites. Several options are available for responding to an adversary's ASAT capabilities, such as developing ASAT capabilities able to serve as a deterrent, reducing dependence on military satellites, developing operating procedures to offset the loss of satellite services, and arms control efforts or other diplomatic initiatives intended to constrain ASAT capabilities or reduce incentives to use them. In addition, there are a multitude of passive and active countermeasures for protecting satellites, many of which were articulated in the July 1999 DoD Space Policy: 'DoD space systems are designed, developed and operated to assure the survivability and endurance of their space mission capabilities . . . though such protection measures as ground station protection, satellite proliferation, hardening, communication crosslinks, encryption, communications security protection, and threat warning sensors'.[17] Countermeasures work better in combination than individually, and therefore one must consider the effectiveness of countermeasure packages against various ASAT capabilities.[18] Specific countermeasures and their significant advantages include the following:

- *Hiding* evades detection by surveillance systems; however, this technique must be used in conjunction with other countermeasures because different hiding measures are required against different types of surveillance sensors. For example, painting a satellite black prevents it from reflecting sunlight but causes it to absorb more solar radiation, thereby reducing detection by visible light sensors but increasing detection by thermal sensors.
- *Decoys* induce an enemy to waste firepower on false targets or to withhold fire for fear of doing so. Despite the challenges involved in ensuring that a decoy is sufficiently realistic and significantly less expensive than the satellite it mimics, deception is the passive countermeasure most likely to be effective against all types of ASAT weapons. If used in combination with maneuver, hardening and proliferation, deception is likely to be economical relative to offensive ASAT capabilities.
- *Maneuver* complicates enemy surveillance and evades enemy fire. Satellites are obviously mobile, although in fixed orbits, and may undertake maneuvers to change their orbital path. Pursuit of another satellite and evasion of an interceptor are examples of maneuvers, however, the maneuverability of space platforms is constrained by fuel limitations.
- *Hardening* can reduce the effectiveness of isotropic nuclear weapons by avoiding reliance on light-sensitive components, using shielding to block gamma radiation, and engineering fault-tolerant electronics to reduce vulnerability to electromagnetic pulse. Of course, such practices cannot protect a satellite from a nearby nuclear explosion, but they can force an attacker to expend more nuclear warheads to destroy an adversary's capabilities.
- *Electronic and electro-optical countermeasures* reduce vulnerability to jamming. For example, communication links can use more transmitter power or bandwidth and larger, directional antennas to increase resistance to electronic attack. Moreover, active electronic and electro-optical countermeasures such as jamming, blinding, and spoofing could be used against an adversary's ASAT command, homing, uplink, target acquisition, tracking and pointing systems.

- *Shoot-back* refers to counterattacking space-based ASAT weapons or the ground segments of ASAT weapon systems such as satellite control facilities. Although such active countermeasures could be maintained and publicized in an attempt to deter an ASAT attack, they would be ineffective against surprise attack by advanced, long-range ASATs. However, the capability to actively defend exclusion zones around critical satellites might protect such satellites against short-range space mines.
- *Attack on ground-based ASAT weapons* could be very effective because retaliatory attacks on an adversary's satellites, however thorough and swift, would not deter an ASAT attack by a nation which values the destruction of enemy satellites more than the survival of its own. Furthermore, conventional attacks on ASAT ground infrastructure would be usable at all levels of conflict and cause little collateral damage.

The Air Force Space Command's 'Strategic Master Plan for Fiscal Year 2006 and Beyond', released in January 2004, indicates that research and development must focus on ways to protect American military satellites from enemy ASAT weapons. The plan states that between 2018 and 2030, there will be a need for systems that can neutralize enemy ASAT capabilities. Focusing less on ASAT capabilities to destroy enemy satellites, the plan discusses the importance of defensive measures such as armed spacecraft escorts, satellite maneuver, threat identification systems and destroying ground-based satellite jamming equipment, as was done in Operation Iraqi Freedom.[19]

Increased Resiliency is the Only Effective Safeguard

Perhaps more effective than developing countermeasure packages for specific satellites is reducing the vulnerability of satellite architectures and focusing on increasing the resilience of the services they provide. This approach involves significant changes in military strategy and organization to reduce vulnerability to ASAT weapons through resilient platforms, redundant architectures and distributed groundstations. For example, the proliferation of satellites would ensure that, even if significant numbers of satellites are damaged, enough remain to accomplish critical tasks. Additional satellites could either be pre-positioned in orbit or launched after an ASAT attack to replenish those satellites destroyed by the attack. Because replenishment involves disruptions in functionality, it is better to pre-deploy spare satellites in orbit where – used in concert with inexpensive decoys and hiding measures – they could provide redundant capability or remain dormant.[20] However, in either case, an enemy who can negate an operating satellite might be able, by the same means, to destroy a spare once it became operational.

Therefore, more small satellites could perform the tasks of fewer large ones so that a network is created which is like the American highway system in that, although economically vital, it is not worth attacking because its resilience reduces the criticality of individual components.[21] Modular satellite architectures which partition satellite subsystems into modules can be segregated and deployed on different satellites. For example, current reconnaissance satellites are large vehicles with complicated combinations of multiple sensors and communications systems. Swarms of smaller, less-complex satellites that coordinate to accomplish tasks provide certain 'advantages in scaling, performance, cost, and survivability'.[22] Additional measures such as increased fielding of high-endurance UAVs could reduce dependency upon satellites and thus mitigate the risks associated with ASATs.

Nonetheless, this emphasis on resiliency does not preclude the need for nuclear-hardening of critical satellite architectures that operate in low-earth orbit, given the cumulative effects of nuclear detonations on architectures. Although this would impose higher costs, the risks associated with the loss of the nation's GPS capability, for example, are surely higher. Similarly, until a problem with the Hughes Galaxy IV satellite in 1998 caused 80 per cent of pagers across the United States to fail, there was little argument for commercial satellite architectures to focus on providing uninterrupted access. Redundancy and diversity are now incorporated into operational planning, despite the higher costs involved, because corporations recognize the liabilities involved if – for example – a meteor shower were to damage a satellite and leave millions of Americans unable to use their ATMs.[23]

Furthermore, the increased commercial dependence on satellites of more and more states reduces their strategic interest in having a known ASAT capability. For this reason, ground-based ASAT options become more attractive methods of degrading US military capabilities.[24] Such options can accomplish this objective without the significant investments and diplomatic liability involved in testing and fielding space-based weapons. Nonetheless, if an adversary did seek to disrupt satellite capabilities, two easier and more effective techniques than attacking satellites are disrupting satellite command and control with jamming or computer network attacks and attacking ground control and launch infrastructure with conventional weapons.[25] The logic for doing so is articulated in the July 1999 DoD Space Policy:

> The Department's philosophy is that physical destruction of satellites is not the preferred approach. It could undercut U.S. commercial interests that depend on global cooperation, such as frequency spectrum allocation, as well as potentially damage other U.S. systems from collateral damage and debris. Moreover, commercial space assets are increasingly being utilized for a wide range of defense application. Terrestrial-oriented negation measures thus may be more consistent with long-term American interests. Nonetheless, we must retain the option for irreversible denial.[26]

Moreover, given sufficient resiliency, anti-satellite weapons may prove to be an unnecessary and uneconomical means of either disrupting space-based capabilities or protecting satellites. Although attacking important satellites may disrupt key services, destroy elements of America's critical infrastructure, and damage the economy, the same effects could be achieved more easily by attacking terrestrial targets with conventional, less-sophisticated weapons. Even for an adversary with the technological capability to attack a satellite, it is certainly easier to target pipelines, bridges, computer networks, or dams than to destroy an automobile-sized object hundreds of miles above the earth moving 17,000 miles per hour.[27] Of course, this strategic logic is even more valid for non-state actors because, in short, terrorists do not have space programs. Therefore, because vulnerabilities in America's space architecture do not necessarily translate into its desirability as a target, the overall risk posed by ASAT weapons may be relatively low.

The Mixed Results of Previous ASAT Research

Having explored various ASAT capabilities and countermeasures, it is necessary to discuss previous efforts to implement ASAT research and to explore the future of these technologies. During the Cold War, the superpowers' desire to protect their satellites was superseded by the desire to avoid an arms race in space and its destabilizing effects.[28] Nonetheless, the United States researched, tested and fielded ASATs, most notably during the late 1950s and early 1960s. In 1958, the United States tested a two-megaton nuclear device nearly 50 miles above Johnston Island, disrupting communications as far away as Australia. Another test in 1962 involved a nuclear detonation 250 miles above Johnston Island, which burned out streetlights in Hawaii and damaged a number of weather and communications satellites.[29] Following these tests, the Army fielded a modified Nike Zeus missile with a nuclear warhead that was prepared to attack orbital targets from 1963 until its replacement by the Air Force's Thor system in 1967. However, by 1970 it was clear that attacking Soviet satellites with nuclear warheads would jeopardize American reconnaissance satellites as well, and ASAT development efforts focused on non-nuclear capabilities.

Soviet ASAT programs in the late 1960s had focused on non-nuclear warheads guided by radar and thermal guidance systems. In 1975, Soviets used intense beams of radiation to interfere with three American satellites before declaring a moratorium on ASAT testing in 1982.[30] The United States continued development of a kinetic energy ASAT system that was designed to launch from an F-15 and, guided by infrared sensors, impact a satellite with enough speed to disable it without an explosive warhead. However, the Air Force cancelled this program before it became operational because of concerns about the strategic need for ASATs, their implications for arms control initiatives, and funding levels.[31]

Despite the end of the Cold War, satellites continue to be targeted for disruption. For example, American forces targeted Iraqi satellite ground stations during the 1991 Persian Gulf War to deny access to space capabilities. More recently, Russians disrupted satellite phone communications between Chechen rebels and Iran jammed Western satellite broadcasts.[32] In the United States, the Pentagon has maintained a Kinetic Energy Anti-Satellite (KE-ASAT) program, which has long been the subject of budget debates, and a developmental program for a kinetic-kill vehicle launched from a Minuteman ICBM. Closer to deployment is the Mid Infrared Advanced Chemical Laser (MIRACL), which began as an SDI anti-missile program and is being adapted for use against satellites.[33]

Recently, DoD transformation advocates have called for development of micro-satellites to reduce launch costs and, as a result, Pentagon programs aimed at developing ASAT capabilities increasingly involve micro-satellite technology.[34] Such an approach has a number of advantages: low payload-associated costs, effectiveness against a wide range of targets, low probability of detection, and dormancy until conflict. Of course, there are challenges involved in developing satellites small enough to avoid detection yet still retain the functionality of a satellite able to maneuver, communicate and attack. However, advances in microelectronics and micromechanical engineering do allow for a device weighing only a few hundred grams to contain the requisite solar panels, batteries, computing systems, cameras, propulsion systems, communication suites and combat systems. Miniature satellites potentially allow for lower-cost access to space, enhanced maneuverability and increased ability to launch-on-demand.

Currently, the US Strategic Command (STRATCOM, which recently merged with Space Command) is assigned the mission of space control.[35] Space control involves two requirements related to ASAT technology: ensuring America's uninterrupted access to space and denying adversaries the use of space. By including negation of an enemy's space forces in the concept of space control, STRATCOM overtly suggests offensive space operations:

> Our nation may find it necessary to disrupt, degrade, deny or destroy enemy space capabilities in future conflicts. USSTRATCOM currently does not have an operational anti-satellite weapon; however, conventional weapons also are effective at striking an adversary's space launch or ground relay facilities. Research and development into anti-satellite technology is continuing.[36]

Based on this strategic logic, the development and deployment of ASAT weaponry may become an imperative of the United States and for any nation-state wishing to challenge its conventional forces.

An Examination of ASAT Implications through an Analysis of China's ASAT Program

The strategic implications of ASAT technologies can best be examined in the context of China's ASAT program. Although China officially supports a space weapons ban, it is the only other nation seriously debating the potential value of space weapons such as ASATs.[37] There is insufficient evidence to determine the threat posed by China's ASAT efforts; however, there is strategic logic for China's interest in developing an ASAT capability. With recent conflicts illustrating the reliance of the United States military on space-based assets, Chinese military analysts have highlighted the growing importance of space in future warfare.

China's decision to research ASATs is an indication of its long-term strategic goal of weakening the American monopoly on military space capabilities. Given an inability to compete militarily with the United States, China may focus on asymmetrical methods such as ASAT weapons in an effort to counter US military dominance. That is, China could decrease the ability of the United States to react militarily to a conflict with Taiwan by preemptively attacking American satellites, a measure which would not necessarily invite the immediate fury of, for example, attacking American battleships.

However, this calculus is complicated by American efforts to deploy missile defense systems. Specifically, China's military analysts perceive missile defense as an American attempt to negate China's nuclear deterrence and are increasingly concerned about how missile defense might affect their ability to deter American actions involving Taiwan. Given that missile defense systems must rely heavily upon satellites, Chinese ASAT capabilities could be a useful asymmetrical means to degrade missile defenses. As an article by a Chinese defense analyst stated: 'For countries that can never win a war with the United States by using the method of tanks and planes, attacking the U.S. space system may be an irresistible and most tempting choice'.[38]

In addition to recognizing that ASAT weapons are potential tools of asymmetric warfare, China's civilian and military space programs provide a knowledge base that could be applied to develop ASAT weapons. The space program's ASAT-enabling capabilities include on-orbit maneuvering, mission management, ground control and command, satellite protection, telemetry management, formation flying and precision attitude control. However, China's ASAT research also incorporates unambiguous topics such as kinetic kill vehicles, high-powered lasers, satellite jamming and satellite homing and tracking.

Jane's Defense Weekly reported that China's anti-satellite weapons programs are said 'to have benefited both from research and development. . .and the transfer of Cold War-era space weapon technology from Russia'.[39] China, reflecting work done by the Soviet Union, has reportedly researched co-orbital kinetic satellites and a direct-ascent ASAT system. Moreover, DoD's 2002 annual report to Congress, *The Military Power of the People's Republic of China*, discusses China's emphases on electronic warfare, such as GPS jammers, and the use of space to assure military advantage, specifically laser weapons: 'Beijing may have acquired high-energy laser equipment that could be used in the development of ground-based anti-satellite (ASAT) weapons . . . Given China's current level of interest in laser technology, Beijing probably could develop a weapon that could destroy satellites in the future'.[40] The report also notes that China is said to be acquiring a variety of foreign technologies to incorporate into its own ASAT program.

Although there is skepticism surrounding the issue, China may also be developing micro-satellites for ASAT purposes. In January 2001, Hong Kong newspapers claimed that China's Small Satellite Research Institute's ASAT program reportedly has engineered a 'parasitic' satellite.[41] This micro-satellite would deploy from a launch vehicle and, using radar or heat-seeking sensors, attach itself to the target where it would then either detonate or wait passively for a command from the ground. Although China is actively pursuing micro-satellite technology, ostensibly for communications and other civilian uses, a DoD review states that the claim of a parasitic satellite cannot be confirmed. Moreover, others doubt that China has developed a micro-satellite ASAT because there is little indication of research or on-orbit testing in Chinese scientific journals. Lastly, Jane's stated that not only are ground-based optical sensors 'likely to be able to detect' parasitic satellites in low Earth orbit, but such a weapon would require sophisticated orbital maneuvering that even the United States has yet to demonstrate.

Although evidence suggests that China began preliminary research on ASAT technologies in the 1980s, it has long been an international advocate of a multilateral treaty ban on space weapons. This indicates that although China may be interested in space warfare for strategic reasons, its primary goal is to avoid an expensive space race. Thus, internal pressures may slow progress towards

ASAT development. 'Publicly, China opposes the militarization of space and seeks to prevent or slow the development of U.S. anti-satellite (ASAT) systems and space-based missile defenses', the DoD reports states. 'Privately, however, China's leaders probably view ASAT systems – and offensive counter-space systems, in general – as well as space-based missile defenses as inevitabilities'.[42]

ASAT Technology and the Space Weaponization Debate

Diplomatic measures such the ban on space weapons proposed by China or a multilateral effort to negotiate the 'rules of the road' for space operations could be useful to preclude space operations from threatening global stability. However, this issue is complicated by the broad implications of ASAT weapons on the debate about space weaponization. Although the United State has long conceptualized and researched ASATs, there has not yet been a clear policy decision to weaponize space. This is a politically complex issue, with some advocating the concept of space as a peaceful sanctuary and others foreseeing space as an inevitable future battleground.[43]

The United States' missile defense program has the most bearing on the issues of space weaponization and, therefore, ASAT weaponry. Indeed, the Pentagon's interest in missile defense programs may be the driver of a new space policy, not the other way around.[44] Specifically, systems developed to intercept ballistic missiles have the inherent capability to be used as ASAT weapons, particularly given the comparable ease of attacking a satellite on a predictable orbit vice intercepting a ballistic missile. Indeed, analysts posit that all three ground-based missile defense systems planned by the Bush administration – the Ground-based Midcourse Defense (GMD) being deployed in Alaska, the ship-based Aegis-LEAP system, and the Air-Borne Laser (ABL) program – have at least the capability to attack low-orbiting reconnaissance satellites.[45] Moreover, space-based missile defense systems under development, such as the Space-Based Laser program, would be effective ASAT weapons. Such programs augment DoD's limited investment in ASAT capabilities and obviate the need for dedicated ASAT systems, which have little political and budgetary support.

In response, China and Russia have cited American missile defense plans as an imperative for an international ban on space-based weapons. Expressing concern over the direction of America's military space program, China and Russia have jointly introduced draft treaty language to the United Nations Committee on Peaceful Uses of Outer Space proposing an international ban on all space-based weapons. Given dual-use technology and the possibility of cheating, any treaty involving ASATs is likely to be unable to resolve many issues, as well as unrealistic. A particular challenge regarding ASATs negotiations is that some weapons designed to attack ground-based targets, such as ballistic missiles, also have the residual capability to effectively attack satellites. For example, Scud missiles – although not considered space weapons in the traditional sense – could be incorporated in any arms control effort to limit ASATs.[46] Therefore, categorically banning ASAT weapons is impractical because such a measure would include all technologies – ballistic missiles, missile defenses, even the Space Shuttle – capable of attacking satellites. Limiting the ban to technologies specifically designed to destroy satellites would be similarly impractical because it would not include the dual-use technologies mentioned above and thus pose great challenges to verification.

Currently, the United States refuses to negotiate space policy, instead choosing to maintain maximum flexibility for programs such as missile defense.[47] However, despite the difficulties of formal treaties, this refusal fails to recognize that broader agreements – possibly short-term ones – banning space weapons would serve the national interest and reassure potential adversaries. Although the drawbacks of arms control, as well as the vulnerabilities of satellites, are quite evident, there are also dangers inherent in allowing the development of space-based weapons.

Of note, should the United States pursue space-based weapons, potential adversaries have an increased incentive to develop ASAT systems that can target them. One plausible scenario is that fielding space-based weapons as part of the missile defense program triggers China and Russia – who may perceive a space-based missile defense program as an attempt to negate their own nuclear deterrence or disable their satellites – to deploy ASAT weapons able to disrupt American satellites and negate its missile defenses. Because missile defense systems cannot function without space-based surveillance systems, an adversary's ASAT capability can deny missile defense systems the detection and warning platforms upon which they depend. In light of this requirement, preventing deployment of ASAT systems is a prerequisite for a fully-effective missile defense capability.

Conclusions and Recommendations

In addition to the importance of space for missile defense and other military operations, space also plays a critical role in the global economy. Revenues generated by commercial space ventures exceed government space expenditures, with space-technology industries realizing $125 billion in annual revenues. DoD estimates that, driven by communications and other commercial applications, the number of operational satellites in orbit will rise from approximately 600 today to 2,000 by 2010. In light of their military and commercial importance, satellite architectures are a component of critical infrastructure deserving of policy attention and government protection. However, the most economical and effective way of protecting satellites is not through costly countermeasures, but through verifiable policy agreements and credible deterrence. The United States must avoid damaging national security, global stability, and alliances by exercising restraint in weaponizing space.

Dissuading potential adversaries from developing ASAT technology can only be accomplished if the United States does not deploy space-based weapons. As a Cato Institute brief states

> To be sure, not deploying weapons in space is no guarantee that potentially hostile nations (such as China) will not develop and deploy ASATs. However, it is virtually certain that deploying U.S. weapons in space will lead to the development and deployment of ASATs to counter such weapons.[48]

The United States must choose between dominance and reassurance. Because of the threat of asymmetric attacks on satellite capabilities, dominance would be very hard to achieve and would have many adverse effects. The best way to protect America's space-related economic and military functions, therefore, is to avoid ASATs and space-based weapons altogether. By avoiding space-based weapons, the United States can assure China and Russia that its need for missile defense is predicated on the threat posed by the proliferation of missile technologies by rogue states.

Given the high costs associated with ASAT development and deployment, they pose little short-term threat. Precluding the possibility of a catalytic event, it is unlikely that states will find much utility in putting weapons into space in the short term. Nonetheless, Watts outlines how a series of escalating activities could lead to the fielding of ASAT weaponry in space. Initially, a state could use earth-based lasers to blind imaging satellites or jam communications satellites. An adversary could respond by positioning its satellites near those of its competitor. Soon both states could lead base weapons in space to protect satellites and the military, economic, and political services they provide.[49]

The feasibility of such a scenario is difficult to estimate, but its potential – and the consequences of an ASAT attack – demonstrates that ASATs in particular and space weaponization in general must be considered from a broad policy perspective. Allowing the desire for missile defense to lead to space-based weapons could be remarkably myopic for the United States. Michael Krepon argues that the consequences of pursuing space dominance, both in terms of global stability and economically, would far outweigh the military advantages of such a program:

> The repercussions will include new international competition to put weapons in space, further strains in alliance relations, closer strategic cooperation between Russia and China, deeper partisan division at home, weakened nonproliferation treaties, and, ironically, greater difficulties in developing one of the Bush administration's cherished goals – missile defense.[50]

The need for military protection of American satellites does not yet exist and space-based defenses would be economically, strategically and technologically ineffective. The placement of weapons in space would waste money, create an international space arms race, and increase the risk of armed conflict in or from space.

Notes

1. The United States outspends the rest of the world by vast amounts in the military space arena, accounting for almost 95 per cent of global military space spending in 1999, according to the French space agency CNES (see Theresa Hitchens. 'Developments in Military Space: Movement Toward Space Weapons?' Center for Defense Information. October 2003. <http://www.cdi.org/pdfs/space-weapons.pdf>.

2. US Strategic Command (STRATCOM) coordinates the use of the Department of Defense's space forces. For further information, see <http://www.stratcom.mil>.
3. For a discussion of the military use of space by an outspoken advocate, see Bob Smith, 'The Challenge of Space Power', *Airpower Journal*, Spring 1999, pp.32–40.
4. The full *Report of the Commission to Assess United States National Security Space Management and Organization* can be found at <http://www.space.gov/docs/fullreport.pdf>.
5. Office of the Secretary of Defense. *Quadrennial Defense Review Report*, 30 September 2001, <http://www.defenselink.mil/pubs/qdr2001.pdf>.
6. According to the Stockholm International Peace Research Institute, at the end of 2001 the United States had nearly 110 operational military-related satellites, compared to 40 for Russian and 20 for the rest of the world. See John Pike in Chapter 11 of *SIPRI Yearbook 2002: Armaments, Disarmament and International Security* (Oxford: Oxford University Press 2002), <http://editors.sipri.se/pubs/yb02/ch11.html>.
7. Furthermore, any nation with an intermediate range ballistic missile could instead equip its missiles with payloads of sand or gravel to be released in LEO, causing clouds of damaging debris. See Theresa Hitchens. 'US Space Policy: Time to Stop and Think', *Disarmament Diplomacy*, No.67 (October–November 2002).
8. Barry D. Watts. *The Military Use of Space: A Diagnostic Assessment* (Washington, DC: Center for Strategic and Budgetary Assessments, February 2001), p.35.
9. Anti-satellite weapons are here defined as any device that renders a satellite inoperable or negates its capabilities.
10. Office of Technology Assessment. *Anti-Satellite Weapons, Countermeasures, and Arms Control*. September 1985, <http://www.wws.princeton.edu/~ota/*disk2*/1985/8502.html>.
11. A 'space mine' is an expendable ASAT weapon pre-deployed in space so as to be capable of destroying enemy satellites almost instantly. They could be nuclear, kinetic energy or directed energy; however, the 1967 Outer Space Treaty prohibits nuclear space mines.
12. Watts (note 8) p.28.
13. Ibid., p.86.
14. The boundary between destructive directed-energy weapons and nondestructive directed-energy devices (e.g., radio jammers, lasers used to overload optical sensors, or particle-beam generators used to upset the functioning of electronic systems) is blurred, being one of power or mode of use rather than kind.
15. Theoretically, HELs include nuclear-powered lasers, however, nuclear directed-energy weapons are not developed and, if fielded, would require platforms with accurate targeting capability and invite all the drawbacks associated with space-based nuclear weapons discussed above. Nonetheless, it is theoretically possible to design nuclear directed-energy weapons, such as X-ray lasers, with far greater lethal range and accuracy than nuclear explosive devices. This potential would make them superior to isotropic nuclear weapons for ASAT applications.

16. John Donnelly, 'Laser of 30 Watts Blinded Satellite 300 Miles High', *Defense Week*, 8 December 1997, p.1.
17. DOD Directive 3100.10, 'Space Policy', 9 July 1999.
18. Office of Technology Assessment. *Anti-Satellite Weapons, Countermeasures, and Arms Control*, September 1985 <http://www.wws.princeton.edu/~ota/disk2/1985/8502.html>.
19. For information on the Air Force Space Command's 'Strategic Master Plan for Fiscal Year 2006 and Beyond', see Jeremy Singer. 'USAF Aims to Neutralize Anti-Satellite Weapons', *Defense News*, 2 February 2004, p.19. During Operation Iraqi Freedom, the Iraqi military used high-powered GPS-jamming devices to disorient satellite-guided weapons. These devices cost only $40,000 each and have an effective range over several miles.
20. Dormant satellites would only need to report their status and receive activation commands, thus requiring little exposure of antennas or other sensors while dormant.
21. Karl P. Mueller. 'Totem and Taboo: Depolarizing the Space Weaponization Debate', *Astropolitics*, Vol.1, No.1 (Spring 2003), p.31.
22. Watts (note 8) p.93.
23. Joan Johnson-Freese, *The Viability of U.S. Anti-Satellite (ASAT) Policy: Moving Toward Space Control*, USAF Institute for National Security Studies Occasional Paper 20, Space Policy Series, January 2000, p.25.
24. Watts (note 8) p.22.
25. Mueller (note 21) p.33.
26. DOD Directive 3100.10 (note 17).
27. Mueller (note 21) p.30. He also points out that an exception might be the use of a nuclear detonation in space, which would create widespread economic damage without causing human casualties and inviting certain nuclear retaliation.
28. Joan Johnson-Freese. 'The Viability of U.S. Anti-Satellite (ASAT) Policy: Moving Toward Space Control.' USAF Institute for National Security Studies Occasional Paper 20. Space Policy Series. January 2000. Page viii. This is demonstrated by the fact that throughout the Cold War there were only 20 ASAT tests by the Soviet Union and just 33 by the United States.
29. Watts (note 8), p.19.
30. Ibid., p.10.
31. Ibid., p.18.
32. Ibid., p.10.
33. Johnson-Freese (note 23) pp.19–21. For updated information on KE-ASAT, see <http://www.boeing.com/defense-space/space/propul/keasat.html>. For MIRACL information, see <http://wstc.wsmr.army.mil/technology/direct_energy.html>.
34. Micro-satellites are usually described as those weighing less than 100 kg. The Air Force has long sought to reduce the weight of satellites because launch costs are the greatest expense in any space program, ranging between $5,000 and $10,000 per pound. Further information is available in DoD's 'Transformational Study Report', 27 April 2001, <http://www.defenselink.mil/news/Jun2001/d20010621transrep.pdf>.
35. Watts (note 8) p.2.

36. US Strategic Command website, <http://www.stratcom.mil/>.
37. For comparison, the 2001–2002 *Jane's Space Directory* characterizes the Russian ASAT program as 'inactive'. See Theresa Hitchens. 'Developments in Military Space: Movement Toward Space Weapons?', Center for Defense Information. October 2003, <http://www.cdi.org/pdfs/space-weapons.pdf>.
38. Philip Saunders, Jing-dong Yuan, Stephanie Lieggi and Angela Deters. 'China's Space Capabilities and the Strategic Logic of Anti-Satellite Weapons', Center for Nonproliferation Studies, 22 July 2002, <http://cns.miis.edu/cns/projects/eanp/pubs/pubs.htm>.
39. Quoted in Jon Dougherty. 'China Anti-Satellite Development Continuing', WorldNetDaily.com, 26 April 2001, <http://www.worldnetdaily.com/news/article.asp?ARTICLE_ID=22578>.
40. Office of the Secretary of Defense, *The Military Power of the People's Republic of China*, June 2002.
41. Cheng Ho, 'China Eyes Anti-Satellite System', 8 January 2000, <http://www.spacedaily.com/news/china-01c.html>.
42. Office of the Secretary of Defense (note 40).
43. See Mueller (note 21).
44. Hitchens (note 37).
45. David Wright and Laura Grego, 'Anti-Satellite Capabilities of Planned US Missile Defense Systems', *Disarmament Diplomacy*, No.68 (December 2002–January 2003).
46. Mueller (note 21) p.6.
47. Many warn that unlike discussions with the Soviets, who had conducted observable ASAT testing, negotiations about space weapons with the Chinese pose a challenge to the United States. China has not tested ground-based ASAT systems against satellites and has only unconfirmed claims to have tested a parasitic micro-satellite. Because China recognizes that the United States is more militarily and commercially dependent on satellites, it has more to gain by deploying ASAT weapons. Therefore, China could demand a high price for concessions and force the United States to trade real capabilities for unrealized Chinese ones.
48. Charles V. Peña and Edward L. Hudgins. 'Should the United States 'Weaponize' Space? Military and Commercial Implications.' Cato Institute Policy Analysis. March 18, 2002 Quoted in Avery Sen. 'Space Power Beyond Challenge: The Wrong Direction for the United States.' *International Affairs Review*. Fall 2003.
49. Watts (note 8) p.105.
50. Michael Krepon, 'Lost in Space: The Misguided Drive Toward Antisatellite Weapons', *Foreign Affairs* (May/June 2001).