

Hedging Against Weaponization

The growing importance of satellites for domestic and international commerce, as well as for the conduct of U.S. conventional military operations, requires assurance of quality performance. Consequently, space assurance requires steps to reduce the vulnerability of U.S. satellites and to guard against catastrophic failure. Space assurance requires many steps of a purely defensive, precautionary nature to decrease the vulnerability of U.S. satellites in the event of hostile action. These initiatives could lessen the likelihood that an adversary would seek to damage, disable, or destroy U.S. space assets by means of weapons in space or on the ground. Space assurance initiatives could also lessen the damage done to U.S. satellites if some forms of space warfare were to occur. Moreover, steps to reduce the vulnerability of U.S. satellites are necessary because other elements of a space assurance posture, particularly those relating to cooperative measures, broadly defined, might be difficult to negotiate or to implement effectively.

Vulnerability reduction can be accomplished by offensive, as well as defensive, measures. Offensive measures to reduce satellite vulnerability are defined here as the initiation of actions that disable, defeat, or destroy objects that could do U.S. satellites harm. Offensive measures can be carried out on a broad scale, including the destruction of facilities that support antisatellite (ASAT) operations, such as ground stations and launch facilities. Weapons designed to disable or kill satellites constitute one narrow subset of offensive U.S. military operations to protect U.S. satellites. This narrow subset of offensive activities presents very considerable downside risks for U.S. military, commercial, scientific, environmental, and diplomatic interests. Space warfare is antithetical to space assurance.

A hedging strategy can help minimize risks associated with refraining from the initiation of flight-testing and deployment of dedicated space warfare capabilities, while encouraging similar restraint by potential adversaries. A range of defensive measures that do not entail the use of force in or from space will be described in this chapter. The twin purposes of a hedging strategy would be to minimize any adverse consequences in the event of space warfare initiatives by other states, and to deter other states from first crossing the critical thresholds of flight-testing and deployment. Deterrence would be served by the certain knowledge of potential adversaries that negative initiatives on their part

would be met by prompt and effective rejoinders by the United States. Thus, a hedging strategy requires readiness to respond purposefully in the event of unwelcome or hostile activities in space by another nation.

No aspect of a space assurance posture is more important than the identification of current and future vulnerabilities of U.S. space assets. This, in turn, mandates increased situational awareness of potential threats in space, as well as plans and programs to reduce current and future vulnerabilities. The possibility of “single point failures”—the loss of a single component or a single satellite that would result in significant or long-lasting losses of critically important data—must be dramatically reduced. Compensatory steps must be readied in the event of cyber warfare that could disrupt satellite operations. Quick and agile responses to the jamming, dazzling, or spoofing of U.S. satellites are needed.

In the future, satellites could become vulnerable to a wider variety of threats, including space mines, interceptors derived from long-range ballistic missiles and missile defense programs, or directed energy weapons, such as ground-based lasers. Rudimentary ASAT capabilities, such as those tested by the United States and the Soviet Union during the Cold War, might also reappear. These techniques are replicable, and others are achievable by a growing number of countries. For example, it is not technically challenging for many states to develop crude space mines that could lurk nearby high-value U.S. satellites.

ASAT capabilities were not tested frequently during the Cold War, perhaps owing to the critical roles satellites played as linchpins of strategic nuclear stability between the superpowers, providing hotline links for crisis diplomacy, early-warning systems of nuclear attack, and military communications central to deterrence. Attacks on these satellites would presumably be linked to an attack on deployed nuclear forces—the “bolt out of the blue” that so preoccupied U.S. strategic planners. Consequently, space was widely viewed as an environment exempt from the testing of war-fighting capabilities. Treaty provisions were negotiated seeking to affirm the maintenance of space as a global commons for the peaceful use of all nations.

The uses of space, both military and commercial, have changed dramatically since the end of the Cold War. These changes raise the possibility that the utility of space warfare might be reconsidered anew, not just by powerful states, but also by weaker states that resort to asymmetric warfare against far more powerful adversaries. Satellites are now increasingly important to global commerce and to tactical military operations. For now, these applications primarily benefit the United States and its closest allies. U.S. space assets providing reconnaissance, information processing, and communication

activities are central to what has been called a “revolution in military affairs.”¹ For example, during the 1991 military campaign against Saddam Hussein, none of the U.S. air-delivered munitions were guided to their target by satellites. By the time of U.S. operations in Kosovo, they constituted 3 percent of all such munitions. That figure jumped to 32 percent by the time of operations against the Taliban and al Qaeda in Afghanistan.² As time progresses, other nations, including potential adversaries of the United States, will increasingly be able to enhance military effectiveness on the ground through information gathered or denied from space. States able to reap these benefits will enjoy appreciable growth in military capabilities and war-fighting options. Analysts talk of “information dominance,” “dominant battle space knowledge,” and lifting the fog of war through use of such information networks.

While this particular revolution in military affairs was underway during the 1990s, U.S. military space policy continued along well-worn paths, reflecting a curious duality marked by a political reluctance to pursue avidly space weaponization alongside a more forward-leaning military space doctrine. Doctrine has endorsed offensive capabilities, but practice has been conservative. As the utility of satellites for conventional war-fighting purposes are repeatedly demonstrated and as the implications of this revolution in military affairs become increasingly apparent, U.S. military doctrine could begin to shift practice toward space dominance. One driver for this shift could be demonstrated or presumed efforts by weaker states to neutralize U.S. advantages in space. The second driver could be U.S. ambitions in space, freed from Cold War-era risks and constraints. For these and other reasons, a serious debate over ASAT weapons is likely to resurface for the first time since the 1980s.

Unlike Cold War arguments over ASATs, which were fueled by concerns over satellite vulnerability, a new debate will be shaped by satellite dependency, and how best to derive the benefits of unparalleled U.S. military superiority. U.S. satellites have been vulnerable for many decades against countries possessing nuclear weapons, long-range ballistic missiles, space launch, and jamming capabilities. Satellites in low earth orbit have been particularly

¹ See William S. Cohen, *Report of the Quadrennial Defense Review* (Department of Defense, May 1997), pp. 39–51; Admiral William A. Owens with Ed Offley, *Lifting the Fog of War* (New York: Farrar, Straus, and Giroux, 2000); Stuart E. Johnson and Martin C. Libicki (eds.), *Dominant Battlespace Knowledge* (Washington, DC: National Defense University Press, 1996); Daniel Goure and Christopher M. Szara (eds.), *Air and Space Power in the New Millennium* (Washington, DC: Center for Strategic and International Studies, 1997); John Arquilla and David Ronfeldt (eds.), *In Athena's Camp: Preparing for Conflict in the Information Age* (Santa Monica, Calif.: RAND, 1997); and Admiral Arthur K. Cebrowski and John J. Garstka, “Network-Centric Warfare: Its Origin and Future,” *Proceedings* (January 1998), pp. 29–35.

² Peter Hays, “Current and Future Military Uses of Space,” presentation at Outer Space and Global Security Workshop (Geneva: November 26, 2002); also see “Defense Watch,” *Defense Daily* (August 19, 2002).

vulnerable to a wide range of threats. While satellite vulnerability is not a new phenomenon, it is now discussed in the context of asymmetric warfare. Within this context, non-state actors as well as states could resort to cyber warfare to disrupt information and transmission networks that rely heavily on satellites. Additionally, new states have acquired medium-range ballistic missiles and are seeking to acquire nuclear weapons. These capabilities could be employed in space as well as in terrestrial warfare.

While satellite vulnerability has remained fairly constant (albeit with the variations described above), the growth in U.S. dependency on satellites for the conduct of military operations and for global commerce has been quite dramatic. The Department of Defense regularly utilizes commercial satellite systems for 60 percent of its spaceborne communication. During crisis or conflict, the need for surge capacity can drive this percentage higher, approaching 80 percent during the Kosovo campaign.³ In 1998, the failure of just one satellite—the Galaxy IV—disrupted 80 to 90 percent of 45 million pagers in the United States and blocked credit card authorization at some gas pumps.⁴

The coming debate over space weaponization will necessarily focus on two critical questions: How much would the weaponization of space help or hinder U.S. conventional military operations? And how much would it help or hinder global commerce, of which the United States is the principal beneficiary? In addition, the coming debate over space weaponization will take place in entirely different geopolitical and strategic contexts. Earlier debates were framed by the Cold War struggle between the United States and the Soviet Union, a contest in which both superpowers concluded that they had more to lose than to gain in a competition to weaponize space. The coming debate will take place at a time when the United States has no peer or near-peer competitors. In addition, U.S. military space initiatives will be viewed within the context of the Bush administration's decision to elevate preemptive strikes and preventive war from options to central features of U.S. military doctrine. Future U.S. initiatives to weaponize space will increasingly be viewed through this prism by the rest of the world.

The argument presented here is that terrestrial U.S. military dominance would be impaired, rather than enhanced, by American initiatives to weaponize space. While the United States clearly has the ability to outspend competitors, and to produce more advanced types of space weaponry, weaker adversaries will

³ Linda Haller and Melvin Sakazaki, *Commercial Space and United States National Security* (Washington, DC: Prepared for the Commission to Assess United States National Security Space Management and Organization, 2001), p. 79 and Peter Grier, "The Investment in Space," *Air Force Magazine* (February 2000), p. 50.

⁴ General Accounting Office, *Critical Infrastructure Protection: Commercial Satellite Security Should Be More Fully Addressed* GAO-02-781 (Washington, DC: August 2002), p. 1.

have affordable, asymmetric means to counter U.S. initiatives in space, as well as on earth. The net result of an uneven competition to weaponize space would be that prudent U.S. defense planners could not count on protecting space assets, and that weaker adversaries could not count on the negation of U.S. advantages. Neither could be certain of the outcome of space warfare, but both adversaries would have to fear the worst. Because of the vulnerability of space assets to ASATs, both would need to assume a dangerous “hair-trigger” posture in space—unless the United States employed preemptive military means to prevent the launch or deployment of presumably hostile space assets belonging to other states.

The likely consequences of a dynamic, but uneven, space warfare competition are not hard to envision. Potential adversaries are likely to perceive American initiatives to weaponize space as adjuncts to a U.S. military doctrine of preemption and preventive war. Depending on the scope and nature of U.S. space warfare preparations, they could also add to Chinese and Russian concerns over the viability of their nuclear deterrents. U.S. initiatives to extend military dominance into space are therefore likely to raise tensions and impact negatively on U.S.-China and U.S.-Russia relations at a time when bilateral relations have some promising, but tenuous, elements. Cooperative relations with both countries will be needed to successfully combat proliferation, but Moscow and Beijing are unlikely to tender such cooperation if they perceive that U.S. strategic objectives include the negation of their deterrents. Under these circumstances, proliferation of weapons in space would be accompanied by terrestrial proliferation.

What compelling need is there to weaponize space when American military superiority is so extensive, and terrestrial developments to extend U.S. power projection capabilities are so promising? One argument is that portions of the earth’s surface are not quickly reached by conventional U.S. power projection capabilities, and that space-based weapons could remedy this apparent shortcoming. Perceived gains by somewhat longer and quicker reach into the interior of, say, Russia, China, or Iran must be weighed against the resulting impairment of U.S. diplomacy, non-proliferation efforts, and alliance ties. Moreover, space warfare initiatives would threaten commercial networks on which advanced industrial societies have become increasingly dependent. They could also impair the continuation of an extraordinary phase of scientific exploration that fosters new insights about the origins and future of our planet, our solar system, and the mysteries that lie beyond.

Conversely, those who support U.S. initiatives to dominate space are obliged to explain how the benefits of their preferred course of action exceed downside risks. Those who are adamantly opposed to U.S. initiatives to

dominate space are obliged to advance an alternative posture. The alternative to space dominance proposed here is space assurance. A space assurance posture requires the adoption of defensive measures to lessen or compensate for satellite vulnerability as well as a hedging strategy against troubling initiatives undertaken by others. Steps to reduce or compensate for satellite vulnerability will be discussed next.

REDUCING SATELLITE VULNERABILITY

How vulnerable are U.S. satellites today, how vulnerable are they becoming, and what realistically could be done to reduce vulnerability? Different types of satellite orbits have common vulnerabilities, although the closer satellites are to the earth's surface, the more vulnerable they are to varied means of attack. Constellations of satellites are less vulnerable to mission failure than singular satellites that perform vital missions. For example, a remote-sensing satellite might have a twin in orbit, but the loss of one to ASAT attack is not compensated by the survival of the other.

Although it is not quite so simple in practice, most satellites can be categorized as falling within one of three main altitude zones: low earth orbit (LEO), medium earth orbit (MEO), and geosynchronous orbit (GEO). The reason to begin with such a categorization scheme is that the vulnerabilities of satellites depend fairly strongly on their altitudes.⁵

Geosynchronous orbit is located at 22,300 miles or 35,888 kilometers above the surface of the earth (although in practice satellites may be located at slightly different altitudes, and follow figure-eights in their orbits rather than tracking the earth's rotational movement exactly). Low earth orbit is not so precisely defined.⁶ A generous definition would include all satellites up to at least 2,000 kilometers altitude (partially on the grounds that existing intercontinental ballistic missiles could easily reach such altitudes if used as antisatellite weapons or in an "ASAT mode"). Medium earth orbits can be defined as those falling between LEO and GEO. As a practical matter, they are concentrated between 10,000 and 20,000 kilometers above the surface of the earth. Molniya

⁵ Primers on these technical matters include Ashton B. Carter, "Satellites and Antisatellites: The Limits of the Possible," *International Security* 10, no. 4 (Spring 1986), pp. 46–98; Paul B. Stares, *Space and National Security* (Washington, DC: Brookings Institution, 1987); Peter L. Hays, *United States Military Space Into the Twenty-First Century* (Maxwell AFB, AL: Air University Press, 2002); Bob Preston, Dana J. Johnson, Sean J.A. Edwards, Michael Miller, and Calvin Shipbaugh, *Space Weapons, Earth Wars* (Santa Monica, CA: RAND, 2002).

⁶ Barry Watts, *The Military Uses of Space: A Diagnostic Assessment* (Washington, DC: Center for Strategic and Budgetary Assessments, 2001), p. 9.

orbits are highly elliptical, with low points at 800 kilometers in altitude and high points at 40,000 kilometers up.⁷

Most satellites today are in LEO or GEO orbits. Each of those zones accounts for about 45 percent of all non-Russian satellites, approximately 600 of which are in active use.⁸ Another 5 percent are in MEO; most of the remainder are in elliptical orbits, and most of these are Russian-owned and operated. Of the 600 total satellites now in operation, nearly 350 are for non-military or general communications, 140 for military communications and imaging, 60 for navigation, and 50 for scientific or other commercial purposes.

U.S. military satellites are primarily situated in LEO or GEO orbits. The United States reportedly operates two weather satellites in polar LEO orbits, and perhaps half a dozen high-resolution imaging satellites in that zone as well. The United States also reportedly operates ocean reconnaissance satellites and geodesic or gravity-measurement satellites in low orbit. In GEO or near-GEO orbits, the Pentagon operates roughly five defense satellite communications system satellites, a similar number of defense support program satellites for early warning of ballistic-missile launch, three MILSTAR communication satellites, perhaps nine ultra-high frequency communication satellites, one polar military satellite, and a classified number of signals intelligence satellites. In MEO are found NAVSTAR/GPS satellites.⁹

A major space power or a nation possessing ocean-spanning missiles would have the means to disable or destroy large numbers of satellites. A larger grouping of states that possess medium- or intermediate-range ballistic missiles and states possessing small nuclear arsenals could also damage or destroy satellites in LEO. An even wider array of states could employ jammers to disrupt satellite operations in all orbits. And non-state actors as well as states could resort to cyber warfare to disrupt some satellite operations.

Satellites in GEO orbit could be attacked by another satellite placed in their vicinity, although this is not a simple matter. A satellite-killing mission to GEO orbit would first require propelling the ASAT vehicle beyond the earth's atmosphere and then powering the payload on a five-hour journey to reach GEO altitudes. Such ASATs could be "parked" in GEO orbits and readied for attack

⁷ For more on this topic, see Department of Defense, Joint Chiefs of Staff, "Orbital Characteristics," in *Joint Doctrine for Space Operations*, Joint Publication 3-14, Appendix F and James Oberg, *Space Power Theory* (Washington, DC: GPO, 1999), pp. 23-41.

⁸ Watts, *The Military Use of Space*, p. 50.

⁹ *Ibid.*; "2001 Space Almanac," *Air Force Magazine* (August 2001), available online at <http://www.afa.org/magazine/space/0801alm.pdf>; Aviation Week and Space Technology, *2003 Aerospace Source Book* (January 13, 2003).

as needed. ASATs could come in varying sizes and weights, with some predicting small packages that are difficult to detect when placed into orbit. Work on maneuvering "microsatellites" has been reported. Analysts also suspect that work is underway on hard-to-detect space mines. Larger maneuvering "space mines" are quite likely within the technical reach of a number of countries.¹⁰

If attacked by a space mine or by another form of kinetic energy ASAT, be it large or small, the satellite in question would likely be damaged severely, if not destroyed. It is extremely difficult and expensive to harden satellites against explosive charges or physical contact designed to negate satellite operations. Competition in this realm heavily favors the attacker, and any state capable of sending 1,000-kg payloads over intercontinental distances, requiring 7 km/second speeds during midcourse flight, or capable of putting relatively large satellite payloads into LEO or MEO, should be quite able to mass produce and launch ASATs.

Low- to medium-power lasers fired from the ground or from an aircraft at high altitude might be able to damage sensors on imaging or missile launch detection satellites. The amount of energy needed to destroy a light sensor, or infra-red sensor, at the wavelength to which it is most sensitive is much smaller than that needed to do structural damage to a satellites. If the U.S. airborne laser program proves to be militarily as well as cost-effective, it could have capabilities against some satellites in LEO but not beyond. One could envision a very large laser on earth or in space that might reach GEO, but none exist today.

While laser attacks on satellites in LEO could be envisioned, they are not simple to execute. To begin with, the target satellite would be over the horizon of a laser for only a few minutes, and the laser might not have sufficient power to heat the target to destruction in that limited time. In addition, fire control is complicated by the fact that the laser beam cannot be seen from the ground. The usual way to acquire a target is to "paint" a raster pattern in space around the presumed location of the target, just as a television picture tube sweeps an electron beam across the face to create an image. When the laser strikes the target, a reflection would be observed, permitting the raster size to be reduced. Eventually, the laser could zero-in on the satellite and destroy it. However, all this takes some time, laser fuel, and great precision.

A vulnerability assessment for MEO orbits would reach very similar conclusions. Given their orbital tracks, satellites in MEO orbits are in some

¹⁰ See Tom Wilson, *Threats to United States Space Capabilities* (Washington, DC: Prepared for the Commission to Assess United States National Security Space Management and Organization, 2001), pp. 28–31.

ways harder to track than those in GEO. In addition, most satellites in MEO orbit operate in constellations, meaning that the loss of a single satellite or two might not result in mission failure. Thus, in some ways, satellites operating in MEO orbits are less vulnerable or susceptible to catastrophic loss than are GEO assets. However, their lesser distance from Earth than GEO satellites could also make them vulnerable to a greater panoply of missiles used to propel ASATs. Because satellites in MEO, including those in Molniya orbits, are closer to Earth than are satellites in geostationary orbits, they can be attacked with smaller interceptor rockets or with lasers of significantly lower power than those required to engage satellites in a 24-hour orbit.

Satellites in LEO orbits are vulnerable to attacks by booster rockets used for medium-, intermediate-, as well as intercontinental ballistic missiles.¹¹ Cruise-missile-sized ASAT vehicles launched from aircraft, along the lines of the U.S. Pegasus program of two decades ago, could also be capable of ASAT operations in LEO.¹² Rockets in the SCUD-C class (with ranges of 500 to 600 km) can reach altitudes of 200 to 300 km with their full high-explosive payload.¹³ With minor modifications, their payload could be reduced, allowing them to reach somewhat higher altitudes. Such missiles could be used to place a debris cloud in the path of a low earth orbit satellite. Medium- and intermediate- range missiles might have the ability to maneuver in order to intercept a satellite with a hit-to-kill warhead. Finally, ICBMs can be fitted with an ASAT and adapted for orbital matching against target satellites.

The combination of a SCUD-C or a missile in the No Dong class (1,300 km) with even a crude nuclear weapon in the 20-50 kiloton yield range permits a completely different and highly effective method of attacking virtually all LEO satellites with a single shot. The nuclear warhead would create an electron belt at the desired altitude, and within a matter of weeks or less virtually all satellites passing through this belt would be degraded or negated by the electron exposure. It would be much more difficult to produce such an intense electron belt at higher altitudes than a few thousand kilometers.

Orbit-matching attacks on LEO satellites are not simple to execute, as was evidenced by the failure rate of the Soviet Union's co-orbital ASAT interceptor flight tests. In the rare case of the target passing directly over the ASAT launch

¹¹ David Wright and Laura Grego, "Antisatellite Capabilities of Planned US Missile Defence Systems," *Disarmament Diplomacy* no. 68 (January 2003), available online at <http://www.acronym.org.uk/dd/dd68/68op02.htm>.

¹² The Pegasus booster was not a cruise missile, but rather a fairly simple combination of solid fuel rockets with a homing vehicle attached. However, this contraption was similar in size and shape to a cruise missile.

¹³ See David Tanks, Principal Study Investigator, *Future Challenges to U.S. Space Systems* (Cambridge, MA: Institute for Foreign Policy Analysis, 1998), pp. 6, 8.

point, then the interceptor can simply be launched at a time just preceding the passage of the target. More likely, an orbit-matching ASAT weapon will need to maneuver to become aligned with the orbital plane of the target, during which time the intent of the maneuver and its initiator may become apparent. Effectiveness requires either highly mobile ASAT launchers that can move to the orbital track or an interceptor with the ability to change orbital planes in flight. The most fuel-expensive maneuver any satellite can make, however, is a significant change in orbit plane. For that reason, orbit-matching ASATs have historically used quite powerful space launch vehicles rather than ballistic missiles.

Midcourse ballistic missile defense interceptors able to reach altitudes of 1,000 to 2,000 km could also be used as ASATs against satellites in LEO.¹⁴ Ballistic missiles carrying nuclear weapons could do considerable damage to satellites in LEO, as was demonstrated by the STARFISH nuclear test in 1962. This test of a 1.4-megaton warhead effectively killed or disabled every satellite in LEO over a seven-month timeframe.¹⁵

Much lower yield nuclear detonations in space would suffice to severely damage satellites in low earth orbit. A Defense Threat Reduction Agency study concluded that a single low-yield nuclear weapon detonated at high altitude (above 100 km) can negate a majority of LEO space assets in a few months. This study estimated that tens of billions of dollars in space assets would be destroyed in such a scenario. Recovery of services provided would require several years. Reconstitution might have to wait months until the radiation levels dropped to the point where satellite electronics could survive. The total cost to replace all lost civilian satellites could be as high as \$100 billion.¹⁶

Very small nuclear weapons, perhaps with yields as low as 1-2 kilotons, such as were detonated in Project ARGUS in the late 1950s, could produce more discriminate effects, destroying a satellite at a distance of a few hundred meters while not producing enough radiation to reduce significantly the lifetimes of other LEO assets. Nor would a low-yield nuclear weapon create an electromagnetic pulse that could damage installations on the earth.

¹⁴ Wright and Grego, "Antisatellite Capabilities of Planned US Missile Defence Systems."

¹⁵ See Stares, *Space and National Security*, pp. 74-75.

¹⁶ Advanced Systems and Concepts Office, Defense Threat Reduction Agency, Department of Defense, *High Altitude Nuclear Detonations (HAND) Against Low Earth Orbit Satellites ("HALEOS")* (Defense Threat Reduction Agency, April 2001); Dennis Papadopolous, "Satellite Threat Due to High Altitude Nuclear Detonations," presentation for the Center for Nonproliferation Studies, Monterey Institute of International Studies (July 24, 2002); "High-Altitude Nuclear Explosions: Blind, Deaf And Dumb," *Jane's Defense Weekly* (October 23, 2002).

States as well as non-state actors that do not possess nuclear weapons and ballistic missiles could still disrupt satellite operations on the ground without resorting to space weaponry. Communications with ground stations could be vulnerable to disruptive techniques. These vulnerabilities are greatest for unprotected commercial systems, on which the U.S. military depends heavily for high-data-rate exchanges of information in modern war (approaching 1 billion bits per second in the Afghanistan conflict).¹⁷ Military satellites could also be disrupted by hostile terrestrial acts. Satellite launch sites are few in number and could be subject to attack.

Threats and Countermeasures

Satellite protection can be developed against a number of electronic and directed energy threats, but protection against explosive devices or ramming is difficult to ensure. Because protection cannot be guaranteed, satellite hardening, agility, and redundancy could provide partial, but useful, insurance against these threats. A prompt ability to reconstitute or compensate for systems that have been attacked could also foil attacking plans. A cursory survey follows of the threats facing satellites and their possible remedies.

Jamming

Space systems face jamming threats both to the communications link from the ground to the satellite and from the satellite back to the ground, or to the uplink and the downlink, respectively.¹⁸ In general, uplink jamming is more difficult because the jammer must be roughly as powerful as the ground-based emitter in order to overwhelm the signal received at the satellite's antenna. Jamming can be complicated by techniques such as spread-spectrum transmission. Downlink jammers, on the other hand, can frequently be much less powerful and still be effective because they are much closer to the receiver than the source of the signal (the satellite). Many U.S. receivers, such as GPS systems on precision munitions, use special directional receiving antennas that mitigate all but the most intense jamming.¹⁹ The U.S. military will shy away from solely jam-resistant communication satellites because of the high costs involved. However, it is possible to envision an improved communication

¹⁷ Haller and Sakazaki, *Commercial Space and United States National Security*, p. 79; Grier, "The Investment in Space," p. 50; and GAO, *Critical Infrastructure Protection*, p. 1.

¹⁸ Satellite-to-satellite communication can also be exposed to a "crosslink" jammer. However, it is the most complex and difficult approach and viewed as a low-probability threat. GAO, *Critical Infrastructure Protection*, p. 13–14.

¹⁹ Wilson, *Threats to United States Space Capabilities*, pp. 37–39.

architecture that mixes jam-resistant systems with fiber optic capacity and more vulnerable commercial and military satellite transmissions bandwidth.²⁰ Beyond communications, the U.S. military has already included antijamming features in its upgrades to the GPS satellite constellation.²¹ The Defense Advanced Research Projects Agency continues to work with pseudo-satellites (“pseudolites”) on the land and in the air to boost the GPS signal and “burn” through the jamming.²² “Filters” can be added to non-space components to allow them to better sort through the jamming noise and pick up the true signal.²³

Hardening against electromagnetic pulse

Satellites can be hardened by factors of about ten against externally generated electronic pulses created by nuclear detonations. Satellite construction costs may grow by up to perhaps 10 percent as a result, but for military satellites in particular, the added costs are hardly onerous.²⁴ It is more difficult to harden equipment against system-generated electromagnetic pulse phenomena, which is likely to be a dubious financial proposition for commercial satellites. Hardening against electromagnetic pulse for satellites in MEO and GEO might be less of an imperative, since distances between satellites are greater at those altitudes. On-orbit spares or replacements on the ground can substitute for those satellites rendered inoperable.

Hardening against radiation

Satellites can be hardened somewhat against electrons and other radiation generated by nuclear explosions. This is an imperative for satellites in LEO, since radiation generated from nuclear bursts can be trapped in these orbits, destroying *all* non-hardened satellites over a period of weeks or months. The resulting radiation would slowly dissipate, requiring perhaps 18 months of waiting before non-hardened replacements would experience near-normal

²⁰ Daniel Gonzales, *The Changing Role of the U.S. Military in Space* (Santa Barbara, CA: RAND, 1999), p. 20.

²¹ Michael Dornheim, “GPS Improvements Set to Help Civil Users,” *Aviation Week and Space Technology* (September 23, 2002), p. 56.

²² Special Projects Office, Defense Advanced Research Projects Agency, “Global Positioning Experiment (GPX),” Internet: http://www.darpa.mil/spo/SPO_handouts/GPX.pdf.

²³ “Raytheon gets GPS anti-jam contract for DAE program,” *Aerospace Daily* (October 11, 2002), p. 6.

²⁴ Advanced Systems and Concepts Office, Defense Threat Reduction Agency, Department of Defense, *High Altitude Nuclear Detonations (HAND) Against Low Earth Orbit Satellites (“HALEOS”)* (Defense Threat Reduction Agency, April 2001), slides 29–30.

lifespans.²⁵ Hardening against radiation would add perhaps 2-5 percent to total system cost.²⁶ It seems unlikely that the space industry would harden its satellites without significant prompting and subsidization from government entities.²⁷

An additional effect from radiation in space is “transient radiation effects on electronics,” or TREE. Ionizing radiation, particularly high-energy electrons, passing through electronic equipment can cause currents to flow where they should not, short-circuiting or burning out microcircuitry. TREE can also cause highly integrated chips to fail because the charge state of the microscopic transistors in those chips is changed by the passage of a charged particle. The smaller the chip, the more transistors packed into it, the greater is the probability of such an “upset” failure. While the upset might heal, it is possible that the equipment will be out of commission for some period. If the upset is so great as to require a reboot of the software, the time lost could become extremely significant.

Hardening against explosives

It is impossible to harden satellites against direct assaults by kinetic energy ASATs. The closing velocities and masses involved are simply too great for metals to withstand. Normal closing velocities in space are likely to be between 10 and 20 km/second. Hardening against explosives or ramming is therefore likely to be expensive as well as futile. Additionally, hardening would seriously reduce the life span of the satellite and significantly raise production and launch costs without providing suitable protection.

The more refined satellite sensors are, the more likely they are to be susceptible to crude forms of attack. Adding satellite maneuverability might well be more useful than hardening or armoring. While a 10-ton imaging satellite would have a hard time escaping from a highly maneuverable homing ASAT, some potential adversaries fielding much cruder ASATs might have difficulty dealing with maneuverable targets. The costs of adding thrusters and strengthening the satellite for higher structural loads are estimated to be between 10 and 20 percent of total system costs.²⁸ For certain high-value satellites and

²⁵ *Ibid.*, particularly slides 12–16. Also Dennis Papadopolous, “Satellite Threat Due to High Altitude Nuclear Detonations,” presentation for the Center for Nonproliferation Studies, Monterey Institute of International Studies (July 24, 2002).

²⁶ DTRA, “HALEOS”, slide 31 and Wilson, *Threats to United States Space Capabilities*, p. 43.

²⁷ DTRA, “HALEOS”, slide 32. Satellites in higher orbits are necessarily hardened against the greater levels of radiation they experience without the protection of the Van Allen belts.

²⁸ Wilson, *Threats to United States Space Capabilities*, p. 44.

particularly those in higher orbits that have more time for evasive maneuvers, this additional cost might be deemed worthwhile.

Self-protection

An alternative to maneuverability would be to provide important satellites with their own means of self-defense, such as explosive charges or small homing missiles to destroy ASATs before they can carry out attacks. To be effective, this self-protection measure would require shooting first, rather than waiting to find out whether an approaching object were an ASAT—unless, of course, warfare has already begun. The flight-testing and deployment of weapons in space designed to defend satellites from attack would be indistinguishable, for all practical as well as for space policy purposes, from the flight-testing and deployment in space of offensive weapons. Put another way, preemptive defense of satellites could also be employed as a preemptive offense. Moreover, the military utility of defending satellites by offensive means in space might be limited against sophisticated, maneuverable ASATs. The creation of space debris resulting from an active defense in space could also impair satellite operations.

Deception

Satellites, much like advanced combat aircraft, could be designed to be “stealthier.” Reducing visibility to either radar or optical systems would complicate the tracking, and hence the targeting, of satellites.²⁹ Further, on-board decoys could be used to divert an attack. These decoys, which would mimic the radar and optical signatures of the satellite, are estimated to increase system cost by between 1 and 10 percent.³⁰

Ground station protection

Destroying ground-based control facilities associated with satellite operations may be a more feasible option for future U.S. adversaries than initiating space warfare, particularly when large constellations of target satellites are supported by a small number of terrestrial facilities, as is the case with the GPS system. In such circumstances, the loss of a few ground stations could “result in a significant decrease in GPS performance worldwide.”³¹ The same

²⁹ The United States reportedly developed a satellite with stealth features that was apparently successful in alluding Soviet and U.S. civilian observers. See Jeffrey Richelson, *The Wizards of Langley: Inside the CIA's Directorate of Science and Technology* (Cambridge, MA: Westview Press, 2001), pp. 247–249.

³⁰ Wilson, *Threats to United States Space Capabilities*, p. 45

³¹ *Ibid.*, p. 20.

argument applies to attacks on the ground segment of observation satellites, early warning satellites, and weather satellites. Clearly, there is benefit in diversifying and multiplying ground segment nodes, as is the case for some communication satellites in GEO. Cyber attacks against critical infrastructure, including satellite operations, must receive priority attention, as this threat appears more likely than the direct threat of physical destruction or sabotage. The Homeland Security Act's inclusion of satellites within the classification of critical infrastructure should accelerate risk reduction measures in this regard.³²

Insurance Policies

One generic approach to reducing the vulnerabilities noted above would be to present an adversary with fewer high-value targets in space. A second generic approach would be to have back-ups, spares, or alternative means ready to replace or compensate for satellite losses. If potential adversaries know or presume that multiple attacks against satellites would be required to impair American military capabilities on the ground, and that U.S. space assets could be quickly reconstituted, they might well conclude that the initiation of space warfare would be both inadvisable and unsuccessful. However, as noted above, these measures would not be successful if an adversary detonates a nuclear weapon of sufficient yield anywhere above 100 km altitude.

Another form of satellite insurance is improved situational awareness of developments in space, particularly those of a potentially threatening nature. Improved situational awareness could provide early and repeated warnings of unwelcome developments warranting a U.S. response. Increased U.S. awareness could clarify to potentially hostile states that unwelcome steps will be detected promptly, thereby increasing the prospect of deterrence, at least in some cases. In addition, increased transparency of space activities and an improved U.S. ability to characterize developments in space could help convince some potential adversaries that they cannot carry out stealthy attacks on U.S. satellites with the expectation of plausible deniability. Better tracking of space debris can be used for collision avoidance. Improved monitoring techniques could also lay the groundwork for cooperative measures in space. Lastly, steps to improve situational awareness in space could increase the possibility that future U.S. decisions regarding space warfare initiatives could be made more on the basis of informed judgment than on surmise.

Situational awareness can be improved through unilateral measures and through cooperative arrangements with other nations or consortiums that have space launch capabilities. Cooperative threat reduction measures relating to

³² Homeland Security Act, Sec. 201(d)(5); also see GAO, *Critical Infrastructure Protection*.

space are discussed in Chapter 4. Unilateral steps to increase U.S. awareness of the space operations of others, including nations that might at some future date wish to engage in space warfare, are discussed below.

There are a number of ways in which the United States could improve situational awareness in space. Improved capabilities in X-band radars currently being developed for missile tracking as part of a national missile defense system could also be tasked for space and debris monitoring. Additional X-band systems could be brought online to supplement the current, less accurate, C-band systems. The optical cameras that track objects in space, known as the Ground-Based Electro-Optical Deep Space Surveillance System, have undergone upgrades in recent years that, when complete, will allow the system to do an adequate job at monitoring those orbits. Information collected by these sensors has to be processed, filtered, organized, and stored. These data points are then used to build models of orbits using complicated algorithms. The algorithms being used, created when computer processors were significantly slower than today, could be updated to create a more accurate picture of the environment. Automation and filtering software needs to be used to “mine” the data and minimize the time required of human operators, a significant potential bottleneck in the cataloguing process. The United States currently has no space surveillance sensors in the southern hemisphere. Agreements with friendly countries to exchange information, or simply leasing land for space surveillance facilities, could help close some of these coverage gaps. Space-based sensors would also provide expanded understanding of the threat environment. There has been some discussion of using the Space-Based Infrared Sensors–High for space threat detection.

Additionally, few, if any, current satellites appear to carry the kind of long- and short-range detection systems needed to tell if the satellite is under attack, or even being closely approached by another object. Adding an on-board system for attack reporting would likely increase total system cost by between one and five percent and would probably require some kind of low-power 360-degree radar or proximity fuse system to detect the approach of another object.³³

Vulnerability assessments need to become more of a factor in the design of future satellites and systems. One type of insurance policy against space warfare would be to opt for more systems with less, but adequate, capability instead of far fewer satellites with significantly greater capability. In some instances, advanced technology might permit the distribution of a single

³³ United States Air Force Scientific Advisory Board, *Space Surveillance, Asteroids and Comets, and Space Debris*, vol. 1 of *Space Surveillance* (United States Air Force Scientific Advisory Board, June 1997); “Changing Space Surveillance Needs,” in Gonzales, *The Changing Role of the U.S. Military in Space*, pp. 45–54; and Wilson, *Threats to United States Space Capabilities*, p. 44.

satellite's function so that no single kill would be disabling. In other instances, back-up systems should be available in the event of the loss of satellites crucial for U.S. military operations. The U.S. military could move towards larger constellations of satellites, with greater overlap in coverage, that could withstand or compensate for gaps in coverage caused by the loss of a satellite. On-orbit spares or replacements on the ground could be used for rapid reconstitution. Replacements on the ground, however, would require U.S. investment in a rapid launch capability.³⁴

Even if back-ups prove less capable or efficient than the satellites lost, they would address the risks attendant to single-point failures resulting in significant degradation of U.S. military capabilities. Of particular note in this regard are advances in unmanned aerial vehicles.³⁵ Looking toward the future, airborne assets, particularly for imaging and signals intelligence, but also for targeting, guidance, and communications, could be available to supplement, or, if need be, help compensate for satellites that are destroyed. Significant advances in remotely piloted vehicles could reinforce the conclusion by potential adversaries that the initiation of space warfare would produce ephemeral gains and punishing retaliation. Additional backup capabilities such as fiber optic land lines and undersea lines could prove helpful in some regions of the world to permit high-volume communications even if satellites are lost. Fiber optic capability could be leased at pre-set prices for use during crisis, analogous to the way that the Civil Reserve Air Fleet functions today.³⁶ U.S. naval combatants can be expected to retain the ability to communicate through line-of-sight and airborne techniques, so that battle groups have the ability to function as integrated entities even if their access to satellites is disrupted. Netted tactical data link systems provide relative navigation among net members. While not as accurate as GPS, netted systems, such as the Joint Tactical Information and Distribution System, mitigate the harm caused by jamming or more pernicious damage to the GPS system.³⁷

Not all of these insurance policies will be realizable. Even after adopting as many of these measures as can prudently be afforded, satellites will remain vulnerable objects that usually follow predictable paths with limited maneuvering capability. The expense of sophisticated satellites reflects, in part,

³⁴ Currently, assuming all components are already at the launching facility, a launch requires between 40 to 150 days of preparation. Joint Chiefs of Staff, *Joint Doctrine for Space Operations*, p. 1-4.

³⁵ In addition to long-endurance unmanned aerial vehicles, recent work has been done on using high-altitude blimps for certain intelligence, surveillance, and reconnaissance functions.

³⁶ Gonzales, *The Changing Role of the U.S. Military in Space*, p. 22.

³⁷ See Federation of American Scientists, "Joint Tactical Information and Distribution Systems," Internet: <http://www.fas.org/man/dod-101/sys/land/jtids.htm>.

their complex internal workings, and their unavoidably fragile external antennas and solar panels. There are no widely effective or comprehensive remedies to these threats, just as there is no assured escape from the dangers posed by weapons of mass destruction in this uncertain world. The best possible satellite defense mechanisms, like missile defenses, cannot possibly work perfectly. Defensive measures can make attacks on satellites more difficult, more expensive, more obvious, and less consequential, but they cannot ensure survivability under attack. Threats to satellites will continue to exist much as vulnerability to weapons of mass destruction and terrorism remains a fact of modern life, despite our best efforts to protect ourselves and to deter these threats.

This is not an invitation to despair or helplessness. While the dangers of proliferation are great, we still pursue a wide array of initiatives to reduce risk and to safeguard deadly materials. Similarly, insurance policies can be pursued to reduce the risks associated with satellite vulnerability. No single satellite must become so essential that its loss would result in catastrophe. Situational awareness, redundancy, and satellite reconstitution capabilities remain sound investments in national security.

In addition, the United States will continue to rely upon deterrence to protect its space assets. The United States maintains many military capabilities designed for other purposes that could be employed against an adversary's satellites in an emergency. These latent or residual capabilities reinforce deterrence and constitute yet another form of insurance against space warfare. In this context, deterrence does not require dedicated ASATs or flight tests and deployments of space weapons, since it is well understood that weapon systems designed for other purposes have the inherent capability to disrupt or destroy satellites. Indeed, these residual capabilities are growing, as the United States pursues advanced missile defenses and the airborne laser program that are designed for other missions but that could, if needed, be utilized against the satellites of a state that initiates space warfare. There are, in sum, numerous and growing ways for the United States to convey messages abroad that those who engage in space warfare against U.S. assets can expect to fail in their intended purpose and to reap significant penalties. The United States does not need to flight-test and deploy space weapons, whether offensive or "defensive" in nature, to underscore these messages.

DOWNSIDE RISKS OF WEAPONIZATION

The United States far outstrips potential competitors in military might, defense spending, military-related space activity, and the application of technology for national security. The United States will not give away these

advantages, nor react with equanimity if a geopolitical challenger seeks to close these gaps. Indeed, President George W. Bush's first national security strategy posture statement asserted that, "Our forces will be strong enough to dissuade potential adversaries from pursuing a military build-up in hopes of surpassing, or equaling, the power of the United States."³⁸ The question at hand is whether the United States should also apply and extend dominant military capabilities to the weaponization of space.

Two divergent policy options are available to Washington. The United States can be the first to initiate the flight-testing and deployment of instruments of space warfare. Alternatively, the United States can seek to avoid these key thresholds, while hedging bets in the event that others do not follow the U.S. lead. The first option is consistent with a space dominance or space control posture. The second option is consistent with a space assurance posture.

The choice between space assurance and space dominance is fundamentally important since it will shape the contours of international security, global commerce, alliance ties, and relations between major powers. The United States cannot have it both ways: The pursuit of space dominance will come at the expense of space assurance. And space assurance is undermined by the pursuit of space dominance.

The choice to initiate weaponization would be based on the twin presumptions that other states will surely develop and proceed to deploy such capabilities, and that the United States has more to gain than to lose by competing to win in this domain. Under this course of action, deterrence of space warfare would be based on demonstrated capabilities and deployments. In contrast, a space assurance posture would rely upon a hedging strategy. The choice of a hedging strategy rather than weaponization presumes that other states will covertly develop, but not necessarily flight test and deploy, space warfare capabilities. This choice further presumes that the acknowledged ability of the United States to compete effectively in the weaponization of space, as well as a readiness to do so, would discourage other states from crossing key thresholds first. Deterrence, in other words, would continue to be served by inherent, rather than by demonstrated, capabilities. Another presumption behind a hedging strategy is that, if other nations flight-test and deploy space weaponry before the United States, Washington will not be placed at a dangerous or long-lasting disadvantage. Still another presumption behind the adoption of a hedging strategy is that, while the United States can compete quite successfully

³⁸ *The National Security Strategy of the United States* (September 2002), p. 30, available online at <http://www.whitehouse.gov/nsc/nss.pdf>.

in the weaponization of space, on balance this posture would produce more complications than advantages, even for the strongest competitor.

Advocacy of a hedging strategy rests on the conclusion that the risks associated with the weaponization of space far exceed the benefits to the United States. Weaker adversaries may not wish to compete with Washington in the flight-testing and deployment of space weaponry, but neither are they likely to concede this high ground entirely. The technical challenges associated with developing space mines and other crude forms of space weaponry are not severe. Weaker states would therefore have the means to counter U.S. initiatives to weaponize space at low cost.

In space, as with terrestrial missile defenses, it is far more challenging to mount a successful defense than to penetrate a soft target. Because of their threatening nature and their vulnerability, weapons designed for space warfare, whether on the ground or in orbit, would become extremely high-value targets. To prevent a precarious and dangerous mix of satellites interspersed with ASATs, the United States would seek to prevent space mines and other attacking devices either from being launched or from being parked in orbit. Alternatively, if the United States does not prevent the deployment of foreign ASATs in space, it must be prepared to wage war by shooting first and asking questions later. Military operations in space would thus be placed on continual hair-trigger alert because successful dominance in space would not be possible without the capacity for preemptive strikes or preventive measures. Having first crossed key thresholds relating to the flight-testing and deployment of space weaponry, would the United States arrogate to itself the right during peace time to carry out preemptive strikes to prevent others from following suit? And having rejected arms control arrangements prohibiting the flight-testing and deployment of space weaponry, would the United States seek to impose or dictate these constraints solely on others, and by force of arms?

It is inconceivable that a quest by the United States to enforce dominion or appropriation of space in this manner could be politically sustainable or successful against varied means of retaliation. And even if a future government of the United States attempted to destroy threats to unimpeded U.S. satellite operations, how would U.S. satellites and the space shuttle cope with the debris resulting from space warfare? The technical challenges of launching successful preemptive or preventive attacks against deployed space mines would be daunting. Attacks against some space mines would doubtless trigger hostile responses, so preemptive or preventive attacks would need to be launched against as many targets as can be identified. Would warfare of this kind be confined to space? Would the United States also attack the space launch facilities and key communication nodes of the state or states that have orbited

space mines? If not, would the United States shoot down space launch vehicles or aircraft that might be carrying space mines?

These questions, and others that flow logically from them, clarify the adverse military and diplomatic ramifications that would accompany U.S. initiatives to weaponize space. Considerable skepticism is warranted that preemption or preventive war strategies can be confined to space, since satellite warfare is so intimately related to military operations on Earth.

Attacks on satellites could severely damage prospects for escalation control and, in the worst case, could trigger the use of weapons of mass destruction against U.S. expeditionary forces, allies, or the U.S. homeland. Since space warfare would not be perceived as a trivial pursuit, those nations that could be gravely disadvantaged by the flight-testing and deployment of space weaponry are likely to consider equally grave countermeasures.

At a minimum, an attempt by the United States to seek space dominance through deployed war-fighting capabilities is likely to generate the launch of relatively cheap, low-tech, but lethal ASATs by weaker adversaries. An unequal competition to weaponize space could still place at risk satellites that are essential for U.S. military communications and early warning in deep crisis. The weaponization of space could thus result in increased U.S. casualties on the conventional battlefield.

U.S. initiatives to “seize” the high ground of space are likely to be countered by asymmetric and unconventional warfare strategies carried out by far weaker states—in space and to a greater extent on Earth. In addition, U.S. initiatives associated with space dominance would likely alienate longstanding allies, as well as China and Russia, whose assistance is required to effectively counter terrorism and proliferation, the two most pressing national security concerns of this decade. No U.S. ally has expressed support for space warfare initiatives. To the contrary, U.S. initiatives to weaponize space would likely corrode bilateral relations and coalition-building efforts. Instead, the initiation of preemptive or preventive warfare in space by the United States based on assertions of an imminent threat—or a threat that cannot be ameliorated in other ways—is likely to be met with deep and widespread skepticism abroad.

The international community has long been aware of latent threats to satellites residing in military capabilities designed for other purposes. Common knowledge of such military capabilities designed for other means has not generated additional instability in crisis or escalation in wartime. The flight-testing and deployment of dedicated space weaponry would add new instability in crisis and new impulses toward escalation. It would be folly to invite these consequences unless it is absolutely necessary to do so.

Space warfare, far more than terrestrial combat, does not lend itself to the formation of “coalitions of the willing.” U.S. initiatives to weaponize space could therefore result in a lonely journey that leads to war without end and to war without friends. The burdens and risks placed upon the shoulders of U.S. expeditionary forces would be exceedingly great. In addition, the quest for space dominance would undoubtedly accentuate domestic political divisions on national security issues, which results in diminished U.S. security.

Given the strong likelihood of these severe penalties, what political imperatives or military requirements could possibly justify the initiation of flight-testing and deployment of space weaponry by the United States? The military rationales posed to justify space weaponry—such as the development of global, prompt, deep-strike capabilities against high-value targets that cannot be reached quickly enough by other conventional means—appear paltry when juxtaposed against these downside risks.

The only justifiable rationale for initiating the flight-testing and deployment of space weaponry by the United States is if another state crosses these thresholds first. Then, the United States would have ample grounds to respond in kind, or to take alternative steps to negate any presumed advantages accruing from such action. To be effective in deterring the flight-testing and deployment of space weaponry by others, the United States must be prepared to respond in kind. Otherwise, the threat of a rejoinder would be hollow, and deterrence of ill-advised initiatives by others would be weakened. A hedging strategy holds out the hope that the “prisoners’ dilemma” that characterized U.S.-Soviet interactions on strategic offensive forces—in which competitors took steps that weakened their security because they felt even more insecure by not reacting—can be avoided in space.

The vastly uneven power equation now in place provides a potential escape from a reprise of the prisoner’s dilemma. Since weaker states would not gain meaningful advantages by initiating weaponization of space, they would be well advised not to initiate space warfare. By doing so, they will not alter the fundamentals of U.S. military superiority, nor change the outcome of warfare with the United States. Besides, weaker states need not engage in asymmetric warfare in space when it is easier to do so on the ground. Conversely, the United States does not need to dominate space in order to dominate terrestrial warfare. Consequently, the prisoners’ dilemma in space can be avoided during a period of profound asymmetries in national power, just as it was avoided during the Cold War.

Given the significant costs and risks associated with the weaponization of space, and the negligible military benefits this course of action would add to U.S. military superiority, there are no compelling reasons to bear these costs

other than the initiation of flight-testing and deployment of space weaponry by other states. For as long as U.S. military primacy is unchallenged and growing, and as long as potential adversaries appear to be exercising restraint in flight-testing and deploying space warfare capabilities, U.S. respect for these thresholds constitutes the prudent course—particularly when the weaponization of space causes more complications than benefits for U.S. military operations.

The thresholds of flight-testing and deployment are considered central not because a single crossing of these thresholds will irretrievably lead to the weaponization of space, but because they lend themselves best to unilateral and cooperative monitoring arrangements. Flight-testing and deployment of ASAT capabilities occurred during the Cold War, but these were of a limited nature and did not signal irrevocable interest by the two nuclear superpowers in weaponizing space. The monitoring of flight-tests and deployments of space weaponry are not without challenges, as will be discussed below. Nonetheless, these monitoring challenges pale in comparison to those associated with the risks of weaponizing space.

Additional steps clearly need to be taken, both unilateral and cooperative in nature, to provide greater assurance that other states are not crossing key thresholds in space while the United States is exercising restraint. Unilateral steps to increase situational awareness in space are essential to monitor such activities and other potential threats to U.S. satellites. Cooperative measures to provide greater assurance that other states are also exercising restraint will be discussed in Chapter 4.

ELEMENTS OF A HEDGING STRATEGY

What are the essential elements of a hedging strategy? One central goal of a hedging strategy is to provide assurance that the United States is not surprised, and technologically outdistanced, by advances in ASAT capabilities that another country is able to achieve. Another central goal is to provide assurance to potential adversaries that, should they initiate the flight-testing and deployment of space warfare capabilities, they will prompt a most unwelcome reaction by the United States.

A hedging strategy therefore requires laboratory research and development on basic ASAT technologies. Military or civilian capabilities designed for other purposes but with inherent space warfare capabilities would remain operational and would occasionally be flight-tested. Such activities must be pursuant to the primary missions that these military or civilian programs were designed to execute and they must not be carried out against target satellites. One of the most difficult challenges would be to provide assurance, through unilateral monitoring capabilities and through cooperative measures, that flight tests of

military or civilian systems designed for other purposes are not covertly being tested in an “ASAT mode.”

What constitutes testing in an ASAT mode? By analogy with the Anti-Ballistic Missile Treaty’s definition of “testing in an ABM mode,” one could define “testing in an ASAT mode” to include all attempts to intercept or damage a satellite in space, or to target any object (ballistic target vehicle) in space with a velocity comparable to that of a satellite in a circular orbit at its altitude. The particulars of such a definition—and their application to different kinds of weapons—require detailed technical analysis. Since many different types of weapon systems could carry out such tests, the answer will vary from case to case.

Ballistic missile defense tests will require special attention. Realistic testing to improve intercept capabilities against theater ballistic missiles—missiles that have now proliferated to troubled regions where the United States has allies, friends, and forward-deployed forces—is essential. Midcourse intercepts are also being carried out to provide a ground-based, limited missile defense against ocean-spanning missiles. Some of these tests provide capabilities that, in the future, might be applied to satellite intercepts. Missile defense interceptors will add to the latent or residual ASAT capabilities that the United States and other states possess.

Some blurring of the line between missile defense and ASAT tests is inherent in on-going and projected flight-testing. One way to prevent such blurring is to cease all missile defense flight tests at altitudes that are suggestive of ASAT intercepts. This is neither a feasible nor a wise course of action, given the realities of missile proliferation and the imperative to field effective missile defenses. Rather than view missile defense flight-testing as removing the barriers to space weaponry, such activities can be considered another form of insurance against ASAT tests being initiated by others. Thus, on-going missile defense flight tests can constitute another component of a hedging strategy as long as tests are not undertaken against satellites or conducted in an ASAT mode. The use of satellite targets or “points of light” that substitute for satellite targets, needs to be foreclosed in missile defense testing either by executive branch policy or by congressional action.

A hedging strategy requires that the United States strictly abstain from flight-testing and deploying space weaponry. In Chapter 2, weaponization was defined as activities that involve the direct application of force either from space, within space, or, directed against objects in space from the earth’s surface or atmosphere. Additionally, “space control” activities resulting in the denial of access to space or negation of an adversary’s spacecraft constitute weaponization. Included in this definition of weaponization are dedicated

ASAT weapons, “defensive” weapons carried on satellites or other space objects that could be used for offensive purposes, and attacks against terrestrial-based targets carried out by military weapons systems operating in or from space. Excluded from this definition of space weaponization are military and civilian capabilities that could be used as ASATs but which have clearly been designed to carry out other missions, such as long-range ballistic missiles, advanced missile defenses, space launch vehicles, and the space shuttle. In a hedging strategy, these capabilities must not be tested in an ASAT mode. In addition, a hedging strategy would prohibit kill mechanisms for missile defenses that are flight-tested or deployed in space. Other basing modes for missile defenses would not be constrained as long as they are not flight-tested in an ASAT mode.

More specifically, essential elements of a hedging strategy might include the following:

Pursue indoor laboratory research and development

Basic technologies and concepts that could be applied to space warfare should be explored, as they are presumably being explored by other states and because the United States needs to be able to respond to unwelcome developments in space, should they occur. There will always be unanswered questions about the status of space warfare research and development by other states, since U.S. access to these facilities will be insufficient or denied outright. Nor would the United States necessarily be willing to provide complete indoor access. Because the United States will not be in a position to know for sure how close other states are to flight-testing ASAT capabilities, at least some U.S. ASAT concepts and development programs should be sufficiently advanced to be in a position to proceed quickly with flight-testing, should this need arise.

Seek transparency and cooperative measures for flight tests

Flight-testing, unlike laboratory research and development, lends itself to unilateral and cooperative monitoring arrangements. These measures could be applied to reinforce restraints on the flight-testing of space weaponry. The status of secret laboratory research and development programs will raise many unanswered questions. The initiator of space warfare laboratory programs will also have questions over the performance and effectiveness of techniques under development. Satisfactory answers to these questions usually require moving this work to the stage of flight-testing. Flight tests normally take place at test ranges that have the specialized accoutrements needed for launch, telemetry, and tracking. Tests that are of maximum use to design teams produce reams of data.

Cooperative measures might be pursued in conjunction with flight-testing to increase transparency about mission objectives in space. These principles and

procedures, which are discussed further in Chapter 4, could provide states with the means to assure others that space weapons are not being flight-tested and that prudent hedges are not being deployed. States that wish to provide such reassurance could do so in many ways. They could agree only to launch space assets from declared or agreed test ranges. They could provide advance notification of all flight tests and space launches, along with their purpose, while making sufficient data available associated with space launches to confirm their stated purpose.

States could also adapt transparency measures painfully and meticulously negotiated in the strategic arms reduction talks (START) to provide reassurance that covert flight-testing and deployment of space weapons are not taking place under other guises. The first START accord explicitly permits close proximity to shrouded payloads on nuclear-tipped missiles, as well as the mandatory provision of telemetry to facilitate monitoring of the number of “stops” a multi-warhead-carrying missile in releasing its payload. A serious effort to investigate how these provisions might be adapted for space assurance is needed. The challenge for proponents of a space assurance posture would be to adapt these and other transparency measures in ways that do not compromise essential secrets associated with the operation of U.S. national technical means.

Avoid flight-testing in an “ASAT mode”

The residual capabilities of weapon systems designed for other purposes to serve as satellite killers could both strengthen and weaken a hedging strategy. Residual capabilities could reduce the imperative to test and deploy dedicated space warfare systems, thereby strengthening a restraint regime. But residual capabilities could also be flight-tested as satellite killers without advance warning, thereby weakening a restraint regime. One way to deal with residual space warfare capabilities while reducing downside risks would be to avoid the flight-testing of these “dual use” capabilities in an ASAT mode.

For example, the midcourse missile defense intercept programs now underway in the United States could easily have capabilities against low-altitude satellites, which move at roughly the same altitudes and speeds characteristic of ballistic missile warheads. Another missile defense concept, the airborne laser, is designed primarily for intercepting relatively short-range missiles in their boost phase. In principle, it, too, could be reoriented to attack satellites passing overhead, although the power and tracking requirements may be quite different. Even though satellites would not be located in the upper atmosphere, where the

airborne laser is intended to operate, they are probably no more difficult to reach with its beam than a burning rocket within the upper atmosphere.³⁹

These programs would add to the residual capabilities the United States and other countries already possess—capabilities that could be applied to space warfare. These programs, which include land- and sea-based ballistic missiles and space launch vehicles, will remain operational. Additional capabilities with latent potential for space warfare will be coming on-line, such as theater missile defenses. These programs should not be cancelled or curtailed simply because they have latent ASAT potential.

The advent of new missile defense programs with latent ASAT capabilities ought to provide further grounds for the United States to seek an ASAT restraint regime, since they reinforce the hedging posture advocated here. New U.S. missile defense programs that could be applied to space warfare are also likely to reinforce hedging strategies by other states. A space assurance posture therefore requires, at a minimum, common understandings of what constitutes flight-testing in an ASAT mode for different weapon systems now under development, field-testing, or deployment.

A more challenging, but potentially far more useful, approach would be to move beyond common understandings to arrive at detailed, common definitions of what constitutes testing in an ASAT mode for different types of weapon systems. Common definitions could be advanced in “Track II” forums, meetings between governmental experts, bilateral accords, and in formal, multilateral negotiations. Drawing distinctions between “normal” flight-testing and flight-testing in an ASAT mode will be easier for some weapon systems than for others. The airborne laser, for example, would clearly be engaged in missile defense if it is directed against rising missile bodies, and will clearly be directed against satellites if tests are conducted against such targets. Arriving at common understandings or definitions will be far more challenging in the case of midcourse missile defense intercepts.

Drawing distinctions in ambiguous cases—and having sufficient assurance to maintain a hedging strategy—would depend in part upon data collected by cooperative and unilateral means. It would be advisable for states that wish to affirm that tests have not been carried out in an ASAT mode to provide sufficient data during flight tests to affirm this, and to conduct tests in such a fashion as to clarify the alternative mission a state is striving to accomplish. Cooperative measures, combined with unilateral monitoring capabilities, could alleviate concerns and reaffirm a restraint regime.

³⁹ David Fulghum, “Laser Offers Defense Against Satellites,” *Aviation Week and Space Technology* (October 7, 1996), p. 27.

Perhaps the hardest and most ambiguous cases relate to the testing of ground-based lasers against objects in space. The distinction between defensive tests to measure the weaknesses of one's own satellites so that better protective measures can be instituted, and offensive-oriented tests that provide data useful for disabling another country's satellites, is very difficult to draw. A flat prohibition on testing lasers against a satellite belonging to someone else would be an essential element of space assurance. But what about testing to improve satellite protection? Testing to determine satellite vulnerability and to help devise defensive measures should not be prohibited. It should, however, be carried out in an indoor laboratory setting, rather than at outdoor test ranges.

For the foreseeable future, such problems weigh far more heavily on other nations than on the United States. With the demise of the Soviet Union, the United States far outstrips and out-funds other nations in space-related activity, including directed energy programs. New outdoor laser test ranges are difficult to conceal. The construction of such facilities takes a great deal of time and expense. Thus, the United States does not need to conduct open-air laser tests in an ASAT mode out of concern that a potential adversary might resort to similar tactics. As with other space warfare technologies in which the United States holds a clear lead, a workable restraint regime that involves lasers must therefore begin at home.

Emphasize research and development on non-destructive ASAT concepts

ASAT research and development programs will not serve as useful hedges if they entail explosive means to kill threatening objects in space, since the explosive effects could produce debris that hinders U.S. satellite operations. Thus, hedging efforts by the United States ought to focus on techniques that would have minimal destructive effects. However, even if the United States were to adopt this practice, other states might not. The question of debris mitigation and steps that might be taken to address this issue are discussed in Chapter 4.

Prohibit ASAT flight tests and deployments

A hedging strategy that seeks to reinforce restraint and provide assurance is not possible unless states fail to refrain from flight-testing and deploying space weapons. If states wish to uphold a restraint regime, they will agree to employ cooperative measures sufficient to allow confidence in mutual compliance. The difficulties involved in arriving at cooperative measures that balance the needs of transparency required for assurance against the needs of maintaining secrecy cannot be underestimated. However, harder monitoring challenges have been tackled in bilateral and multilateral negotiations. The challenges identified here

could be satisfactorily addressed if key states are willing to accept the requirements of space assurance instead of the consequences of demonstrated space warfare capabilities. The requirements of space assurance include a higher level of transparency and cooperation than many states—including ardent opponents of space warfare—have previously been willing to accept.

Space warfare as a last resort

A final essential element of a space assurance and a hedging strategy is the clear recognition that space ought not to become a realm where preemptive strikes and preventive war become instruments of national policy. Space warfare should be an instrument of last resort. The means to execute first strikes from space ought to be avoided because, as discussed earlier, this quest could have severe political, diplomatic, economic, and military consequences for the United States. The flight-testing and deployment of space weaponry should be pursued with great reluctance, and only in the event that a hedging strategy fails.

Even in the event that the United States flight-tests and deploys space weaponry because of the ill-advised actions of other states, the explosive destruction of satellites must be viewed as an instrument of last resort. Debris in space represents a common enemy to all space-faring nations. Other means that are well within U.S. military capabilities to disrupt the military utility of an adversary's satellites are clearly preferable to the explosive destruction of objects in space, including the jamming of satellite communications and the destruction of ground stations. Superior U.S. war-fighting capabilities on the ground permit the United States the luxury of not having to turn space into a theater of actual warfare.