THE STATE OF SPACE:
From Strategic Reconnaissance to Tactical Warfighting to Possible Weaponization

Testimony of Michael O'Hanlon, Brookings Institution (mohanlon@brookings.edu) before the Subcommittee on Strategic Forces of the House Armed Services Committee, June 21, 2006

The way in which the United States uses space for national strategic purposes is in far more flux than casual observers may realize. Nearly 25 years after Ronald Reagan's Strategic Defense Initiative was undertaken, and more than $100 billion later in money spent on missile defenses, the United States still does not base any weapons in space or deploy any weapons designed explicitly to counter satellites. This fact is misleading, however. Over that quarter century, the United States has moved from using space primarily for strategic reconnaissance, weather forecasting, and low-data-rate communications to tactical warfighting. While the former missions have clearly had military importance as well, they did not include "kinetic" operations of putting steel on targets. Today, space greatly facilitates the latter types of warfighting operations in real time. That is, it does so for the United States, but not yet for other countries.

We are at an unusually good moment for America. Of course, it conducts more types of military operations from outside the atmosphere than ever before. But it also monopolizes more than ever before. Russia has lost much of its capacity; China has ambitions yet has not reached great power status in this way to date; private firms provide a great deal of imagery and communications via satellite but do not own or operate the types of real-time networks needed to turn their space assets into real warfighting machines. Only the United States does these things. And with each successive wartime experience—Desert Storm, the Balkans, Afghanistan, Operation Iraqi Freedom—it does them much better than the time before. Practice makes perfect. And improving computers and communications systems make for great increases in speed and data throughput rates. Limits on the effectiveness of missile defense systems to date are not particularly worrisome since land-based systems do exist with some level of capability.

This moment of American predominance in space is highly desirable. Yet it cannot, and will not, last. As such, U.S. policymakers need to contemplate next steps. Logically speaking, they could include tools ranging from arms control to unilateral restraints, on one side of things, to space-based missile defenses and anti-satellite systems on the other extreme. They almost certainly should include prudent military measures to enhance the survivability, redundancy, and replaceability of existing space assets as well.

Two overall general guidelines should, in my view, guide future U.S. policy on space. They are not contradictory, yet they are in some tension with each other. First, given the advantageous position of the United States at present, policies that would tend to hasten military competition in space and specifically the weaponization of space should generally be avoided. But second, there is no inherent reason to enact a permanent ban on greater military uses of the heavens. Space is heavily militarized, even if not weaponized, already. It is not clear what political or military principle should provide permanent sanctuary to satellites that are actively used to find, track, and thus help destroy targets on the battlefield. Such assets do not deserve special protection, given the nature of their functions. Moreover, technology trends will make it increasingly hard to prohibit space weapons even if we wanted to. The verification challenges would be formidable, if not insurmountable. In addition, there is a real possibility that, at some future point, the United States may have powerful reasons to develop antisatellite weapons itself. These realities call for a balanced, patient, hedging strategy—often the least appealing type of approach politically and rhetorically, yet precisely what America's strategic position counsels.

Given the purview of today's hearing, my testimony has two main focal points: to review the state of play in space, primarily from a strategic and military perspective, and to explore what types of basic measures can improve the survivability of America's space assets—leaving a fuller discussion of the issue of weaponization for a different day.[1]

[1] For my fuller arguments on space, see Michael E. O'Hanlon, *Neither Star Wars Nor Sanctuary: Constraining the Military Uses of Space* (Washington, D.C.: Brookings, 2004).

WHERE WE ARE IN SPACE AND HOW WE GOT HERE

What future role will space play in warfare? And what should the United States do about it now? These questions have not been the focus of intensive and sustained political debate since the cold war days of the 1980s. In the meantime, technology has changed a great deal; geopolitics has changed even more.

Space is already militarized. Indeed, it has been militarized for more than four decades. But satellites played a rather benign role during much of the cold war, when they were most important for preserving strategic stability. Particularly since the cold war ended, however, space assets have been reestablished as competitive military instruments, especially by the United States. This trend has not extended to placing weapons in space or developing weapons for the purpose of threatening objects in space, but that clearly could change in the coming years. And weapons now being developed for other purposes, most notably missile defense, will make low-altitude satellites increasingly vulnerable even if no explicit steps are taken to achieve that end.

The Soviet Union and the United States employed satellites during most of the cold war. They did so largely for purposes of watching each other's nuclear tests, missile launches, and military force deployments. They also used space for communicating with their own global force deployments and operations, weather forecasting, mapping, measuring Earth's gravitational field (largely to improve the accuracy of ballistic missiles), and maintaining exact and uniform time standards for their deployed military forces. Many of these activities ultimately served the nonconfrontational and desirable purposes of maintaining strategic nuclear stability and promoting arms control. But their purposes were still basically quite military—contributing, for example, to the development of nuclear war plans—and hence were competitive as well. Indeed, from the launching of *Sputnik* in October 1957 until 1963, when a series of UN resolutions, implicitly at least, acknowledged and allowed the use of reconnaissance satellites, the Soviet Union struggled with the question of whether to tolerate U.S. satellites over its own territory. Both superpowers ultimately concluded that mutual toleration served their interests. The United States wanted means to tie together its global force deployments and to monitor capabilities in closed societies like the Soviet Union and the People's Republic of China (PRC). The Soviet

Union saw its space program as a sign of national prestige and may have found reconnaissance satellites quite useful for watching events in places such as Cuba, China, and Europe.

As time went on, both sides explicitly agreed not to interfere with the operations of each other's satellites in a number of arms control accords, including the 1972 ABM Treaty, the 1974 Threshold Test Ban Treaty, the 1976 Peaceful Nuclear Explosions Treaty, the 1979 SALT II Treaty, the 1990 multilateral CFE Treaty, and the 1991 START accords. (They also signed the 1992 Open Skies Treaty, along with a couple dozen European countries, providing mechanisms for aerial monitoring under specific circumstances.)[2]

Since the cold war, the United States has increasingly used satellite assets for tactical warfighting purposes in wars against Iraq, Serbia, and the Taliban in Afghanistan. Space systems, notably the global positioning system (GPS) satellite constellation, were used to help American soldiers navigate in the featureless desert starting most notably in the 1991 war against Iraq. GPS satellites are employed to synchronize operations in time as well, with remarkable accuracy. They are also increasingly used to pinpoint the locations of enemy targets and help guide precision-strike munitions, such as cruise missiles and the GPS-guided joint direct attack munition (JDAM), to those targets. Hundreds of JDAMs were used in the Kosovo war of 1999. More than 5,000 were employed in the Afghanistan war of 2001–02, striking as close as five meters from their aimpoints, and a comparable number were used in Operation Iraqi Freedom in 2003. GPS devices are also integral to the "blue force" tracking systems that keep tabs on friendly units in a given region to reduce fratricide. Such systems still have only limited capabilities and use, and present challenges for filtering data so that users are not swamped by information they do not need, but they are quite useful nonetheless.

Communications satellites are used for an increasing range of activities as well. While they still carry traditional voice messages, they also transmit real-time imagery taken by cameras and radar on platforms such as unmanned aerial vehicles (UAVs) and reconnaissance aircraft to

[2] Much of this comes from Michael E. O'Hanlon, *Neither Star Wars Nor Sanctuary: Constraining the Military Uses of Space* (Washington, D.C.: Brookings, 2004); references for the factual information and data in this testimony can be found there (see www.brookings.edu/scholars/mohanlon.htm for electronic access to the first chapter of the book).

individuals far removed from the scene of battle, whether for purposes of data processing or for command and control. They transmit detailed air war targeting plans to commanders and pilots. As a result, the use of such satellites in war has skyrocketed. In Desert Storm, a total of sixteen military satellites and five commercial satellites provided coalition forces with a maximum possible transmission rate of 200 million bits per second (the equivalent of nearly 40,000 simultaneous telephone calls). Nearly twice as much capacity was available during the Kosovo war eight years later—much of it commercial, however, and hence unhardened against possible enemy action, such as electronic jamming, and unsecured. It was used for purposes that included teleconferencing among commanders. Available capacity doubled again, to close to a billion bits per second, during the Afghan campaign of 2001–02. Again, much of the data flowed through commercial systems. What that means is that, remarkably, a U.S. military operation of some 50,000 troops in 2001–02 used five times as much communications bandwidth as did a war with 500,000 troops a decade earlier—fifty times as much bandwidth per person, on average. In Operation Iraqi Freedom, the military used 2.4 gigabits per second.

But the 2003 Iraq war was less notable for further increases in bandwidth, perhaps, than for several other aspects. More than fifty satellites were used in the war effort; commercial firms, including France's leading satellite services company, provided the majority of communications capacity and a fair amount of imagery as well. Satellite channels in the so-called EHF frequency band gave ships fifty times more bandwidth for secure data transmissions than in the past (128 kilobits per second). And the GPS permitted the United States to drop more than 6,000 satellite-guided JDAMs.

Recognizing what satellites now offer the warfighter, the U.S. military is improving its means for utilizing their services. A space team was established and put on full-time duty in the Persian Gulf in late 2002 to plan operations against Iraq, for example. Among other things, its purpose was to help air planners understand when the greatest number of GPS satellites would be available to help guide bombs to target as accurately as possible.

Space systems may soon be used to maintain a track on ballistic missiles, so that ground-based interceptors can be launched to shoot them down. Further in the future, space-based weapons may be used to destroy the ballistic missiles directly, though this is not necessarily a desirable goal for American policymakers anytime soon.

The increasing militarization of space is not exclusively a superpower story, however. The United States certainly dominates military space spending—accounting for more than 90 percent of the total, by some measures. The country's military space budget totals exceed $15 billion a year. But other countries besides the United States and Russia have also increasingly sought military satellites, largely for reconnaissance and communications purposes so far, and will surely continue to pursue space capabilities of many types in the future. They may make use of civilian and commercial assets for military purposes as well. They are surely studying American capabilities to find, track, and quickly attack targets using space assets. Some are trying to emulate the United States; some are trying to find vulnerabilities in U.S. space systems so they can challenge them in any future wars. China may be the most notable example of a country that is doing both. Its progress to date is limited, as far as we can tell, and its progress in the coming years is likely to be modest as well—but these prognostications may prove wrong, and in any case will not be applicable forever.

Although space is becoming increasingly militarized, it is not yet weaponized—at least as far as we know. That is, no country deploys destructive weapons in space, for use against space or Earth targets, and no country possesses ground-based weapons designed explicitly to damage objects in space. The challenges of weaponizing space should not be overlooked; in the words of one top Air Force specialist, space is a very challenging environment in which to work. It is also a very different medium than the air, as then-Air Force Chief of Staff General John Jumper emphasized when he discarded the popular term "aerospace" and instead insisted that the Air Force must specialize in both air *and* space operations. On the other hand, trends in technology and the gradual spread of space capabilities to many countries will surely threaten the status quo. Not only the United States but other major western powers, China, and smaller states as well, will have weaponization opportunities within reach.

But space is not a true sanctuary from weapons today. Virtually any country capable of putting a nuclear weapon into low-Earth orbit (LEO) already has a latent, if crude, antisatellite (ASAT) capability (though in many cases such weapons would have to be modified so that the warheads could be detonated by a timer or by remote control). Not only would such a weapon be likely to physically destroy any satellite within tens of kilometers of the point of detonation and to damage or destroy unhardened satellites within line of sight many hundreds of kilometers away (if not even further); it would also populate the Van Allen radiation belts with many more charged particles, which would destroy most low-Earth orbit satellites within about a month.

Nor has space been treated as an inviolable sanctuary in the past. The nuclear superpowers made some progress toward developing antisatellite weapons in fits and starts from the 1950s through the 1980s. For example, the United States had something of an ASAT capability with its Nike Zeus and Thor nuclear-armed interceptor missiles in the 1960s and early 1970s, and with the Spartan program of the 1970s. The Soviets later developed and tested a nonnuclear "co-orbital" ASAT that needed to conduct a couple orbits to gradually approach its target. Into the 1980s, the United States developed a nonnuclear "direct ascent" ASAT, launched by an F-15, that would reach its target much more promptly and then collide with it. Soviet antiballistic missile (ABM) systems deployed around Moscow probably had ASAT capability as well; given the size of their warheads, they may have been able to damage satellites as distant as hundreds of kilometers from their detonation points. Some of these capabilities may remain warehoused in some form. Still, the ASAT competition was held in check. Likewise, technological constraints made any deployment of space-based ballistic missile defenses impractical, even though the idea of such missile defenses was hotly debated.

Decisions not to deploy ASATs or space-based missile defenses during the cold war did not, however, reflect any permanent commitment to keep space forever free from weaponry. Nor do existing arms control treaties ban such activities. Instead, they ban the deployment or use of nuclear weapons in outer space, prevent colonization of heavenly bodies for military purposes, and protect the rights of countries to use space to verify arms control accords and conduct peaceful activities. In addition, in 2000 the United States and Russia agreed to notify each other in advance of most space launches and ballistic missile tests. Most other matters are still up for grabs. And the concept of space as a sanctuary will be increasingly difficult to defend or justify as space systems are used more and more to assist in the delivery of lethal ordnance on target.

Some scholars, such as Ambassador Jonathan Dean, do argue that the START I, Intermediate-Range Nuclear Forces (INF), and multilateral CFE treaties effectively ban the use of ASATs by one signatory against any and all others, given the protection they provide to satellite verification missions. But these treaties were signed before imaging satellites entered their own as targeting assets for tactical warfighting purposes, raising the legal and political question of whether protection originally provided to a satellite for one, generally nonprovocative and stabilizing mission can be extended to its use in a more adversarial fashion. Moreover, no one argues that these treaties ban the development, testing, production, or deployment of ASATs.

In the late 1980s and 1990s, debates over military space policy became less visible than they had been during the Reagan era and a number of periods during the cold war. Détente, and then the end of the cold war, defused the immediate argument for such systems. Bill Clinton's election in 1992 reinforced these strategic developments, among other things leading to a shift in missile defense efforts from strategic to theater systems, for which weapons based in space did not figure prominently (though some theater missile defense [TMD] systems could have capabilities against low-Earth orbit satellites). Even when Clinton reemphasized national missile defense in mid-decade, his plan called for land-based interceptors. Sensor technology was to be based in space, but other capabilities were not. Clinton also curtailed the development of a kinetic energy, or "hit-to-kill," antisatellite system that he inherited from George H. W. Bush, as well as a microsatellite program known as Clementine II, despite the efforts of then Senator Robert Smith of New Hampshire and other conservatives.

But Clinton did not stop technology in its tracks. Two of the missile defense systems he promoted steadily, the midcourse national missile defense program and the airborne laser theater missile defense program, continue to this day and have latent capability as ASATs. Moreover, he allowed the use of the mid-infrared advanced chemical laser (MIRACL) in a test against a target in space, confirming that the United States may have at least a rudimentary capability of using that ground-based high-energy laser in an ASAT mode. (Meanwhile, some work continued more quietly and is ongoing under President Bush. For example, the Army has reportedly been working on laser dazzlers to blind surveillance satellites and jammers to disrupt communications and surveillance satellites.)

The election of George W. Bush as president, and, even more important, his decision to select Donald Rumsfeld as secretary of defense, made it likely that such efforts would accelerate. Just before he became secretary, Rumsfeld chaired a commission on the military uses of space that warned of a possible future “space Pearl Harbor” for the United States unless it took a wide range of defensive and offensive steps to better protect its security interests in the heavens. The worry was that countries such as China and Iran, among others, would gradually get their hands on technologies, such as high-energy lasers or homing microsatellites, that could threaten U.S. space assets. But the secretary’s thinking is not strictly defensive. Rumsfeld’s major strategic plan as secretary of defense states, “The mission of space control is to ensure the freedom of action in space for the United States and its allies and, when directed, to deny such freedom of action to adversaries.”

It is possible to exaggerate the change that occurred in U.S. policy when the Bush administration came into power. During the Clinton era, Air Force leaders increasingly discussed space as a military theater like any other. They envisioned the day when the Air Force would become an air and space force, or even a space and air force. And Rumsfeld’s language quoted above resembles official statements on Clinton administration space policy. Consider this excerpt from Space Command’s 1998 Long-Range Plan in regard to one option it would eventually wish to develop more fully:

> *Negation* means applying military force to affect an adversary’s space capability by targeting ground-support sites, ground-to-space links, or spacecraft. Negation will be executed when prevention fails. High-priority targets include an enemy’s ability to hold US and allied space systems at risk. Negation will evolve from current concepts, which emphasize terrestrial attacks on an adversary’s ground nodes, to a full range of flexible and discriminate techniques against the most appropriate node. Acting under clear lines of

> authority and rules of engagement, USCINCSPACE will take actions necessary to meet the National Command Authorities' objectives and defend our nation's vital space interests. Actions will range from temporarily disrupting or denying hostile space systems to degrading or destroying them. Our objectives must consider third-party use, plausible deniability and how actions will add to debris or otherwise affect the environment.

But in broader context, Rumsfeld's approach indeed seems more assertive than policies under Clinton. To quote Peter B. Teets, during his service as undersecretary of the Air Force for acquisition and head of the National Reconnaissance Organization, the nation must develop "ways to get a vehicle rapidly off the pad to any orbit on short notice. . . . It is easy to see how such a responsive capability could be useful for rapid constellation replenishment and sustainment, but I leave it to your imagination . . . to find other ways to employ such a capability to achieve desired warfighting effects." Little imagination is needed if one reads official doctrine, given its emphasis on disrupting, degrading, and, if necessary, destroying enemy space assets in future combat. This approach also seems to have emboldened a number of Air Force officers to make more public statements about the inevitability of weaponizing space. As one example, Air Force general Pete Worden argues that small launchers could be useful to the U.S. military for, among other reasons, their ability to launch weapons on short notice against targets in space. Certain specific actions have already affected the policy landscape quite directly as well. For example, the Bush administration's decision to withdraw from the ABM Treaty, an action that was publicly announced in December 2001 and officially put into effect in June 2002, opened up the legal possibility of space-based ballistic missile defenses. Eliminating Space Command as one of the country's ten unified commands and placing space functions under Strategic Command may also reflect an inclination to think about space as another theater of combat, rather than as a special, and possibly safeguarded, domain.

Not all policymakers agree with Rumsfeld. Opponents of weaponization make a practical national interest argument: as the world's principal space power today, the United States stands to lose the most from the widespread weaponization of space, since that outcome could jeopardize the communications and reconnaissance systems on which it so disproportionately depends.

Opponents of weaponizing space also point to the world's growing economic dependence on satellites, and the risk of damaging those capabilities should weaponry be based or used above the atmosphere. Worldwide, commercial revenues from space ventures exceeded government spending on space activities in the late 1990s, reaching and then exceeding $50 billion a year. The spread of fiber-optic cable has actually reduced the relative importance of satellites in global telephone services, and global economic conditions caused a downward revision in forecasts for space services. But nonetheless the global satellite business now involves more than 1,000 companies in more than fifty countries.

Non-American opponents of weaponizing space make many of the same arguments. They also worry about a unilateralist America pursuing its own military advantage at the expense of other countries, most of which do not favor putting weapons in space. This dispute has much of its origins and motivation in the history of the ballistic missile defense debate, as well as the ASAT debate of the 1980s. But it has taken on a new tone in what many view as an era of American unipolarity or hegemony. In recent years, China and Russia have been consistently vocal in their opposition to the weaponization of space and their desire for a treaty banning the testing, deployment, and use of such capabilities. So have a number of U.S. allies, including Canada, which in 1998 proposed that the United Nations convene a committee on outer space in its Conference on Disarmament in Geneva. The UN General Assembly has continued to pass resolutions, for more than twenty straight years, opposing the weaponization of space. In December 2001 it called for negotiations on a treaty to prevent an arms race in outer space at the Geneva Conference. (The vote passed by 156 to 0; the United States, Micronesia, Israel, and Georgia abstained.) In 2001 China presented an incomplete draft treaty banning the weaponization of space, and in 2002 China and Russia jointly presented another draft that included bans on weapons based in space and on any use of weapons against objects in space.

For most defense planners today, by contrast, developing more military applications for outer space is an important imperative. Much thinking about the so-called revolution in military affairs and defense transformation emphasizes space capabilities. Ensuring American military dominance in the coming years—which proponents tend to see as critical for global stability as well—will require that the United States remain well ahead of its potential adversaries technologically. For some defense futurists, the key requirement will be to control space, denying its effective use to U.S. adversaries while preserving the unfettered operation of American satellites that help make up a “reconnaissance-strike complex.” Others favor an even more ambitious approach. Given that fixed bases on land and large assets such as ships are increasingly vulnerable to precision-strike weaponry and other enemy capabilities—or to the political opposition of allies such as Turkey, Saudi Arabia, and France, who have sometimes opposed use of their territories or airspaces for military operations—they favor a greater U.S. reliance on long-range strike systems. These include platforms in space.

Advocates of space weaponry also argue that, in effect, space is already weaponized, at least in subtle ways. As noted, most medium-range and long-range rockets capable of carrying nuclear weapons constitute latent ASATs. Likewise, rockets and space-launch vehicles could probably be used to launch small homing satellites equipped with explosives and capable of approaching and then destroying another satellite. Such capabilities may not even require testing, or at least testing easily detectable from Earth. Advocates of weaponization further note that the United States is willing to use weapons to deny other countries wartime use of the atmosphere, oceans, and land, raising the question of why space should be a sanctuary when these other media are not. As Barry Watts put it, “Satellites may have owners and operators, but, in contrast to sailors, they do not have mothers.”

Specific military scenarios can bring these more abstract arguments into clearer focus. Consider just one possibility. If in a future Taiwan Strait crisis China could locate and target American aircraft carriers using satellite technology, the case for somehow countering those satellites through direct offensive action would be powerful. If jamming or other means of temporary disruption could not be shown to provide reliable interruption of China’s satellite activities, outright destruction would probably be seriously proposed—and would not immediately be unreasonable as an option. Despite rhetorical and diplomatic opposition to the weaponization of space, China's military planners have also reportedly given thought to how they might attack U.S. military space systems. That is quite a natural reaction for any defense planner who thinks his country may have to take on the United States someday. But it also underscores the strong pressures toward the weaponization of space, given current trends.

Although technological progress, the absence of arms control regimes banning most military uses of space, and the growing use of space for tactical warfighting purposes suggest that space may ultimately be weaponized, the issue is not a simple yes or no proposition. The nature of the weapons that might ultimately reach space, or affect space assets, is important. So does the timing of weaponization, and the state of great power relations when it occurs. Even if weaponization is indeed inevitable, in other words, when and how it happens may matter a great deal. Accordingly, even if most weapons activities are not banned categorically by treaty, reciprocal restraint by the major powers, together with some limited and formal prohibitions on activities in space, may make sense.

There are various competing positions in current American military space policy. The military's publicly stated views are quite assertive, even if its actual programs for moving ahead with the weaponization of space are generally restrained for the moment. Moreover, most possible moves toward weaponization are unconstrained by any arms control accords. The Outer Space Treaty of 1967 only bans a small set of activities—notably, nuclear weapons in space, as well as hostile colonization of the moon and the planets. The outcome of the debate is unclear, and fundamentally up for grabs.

HARDENING AND DEFENDING (OR DOING WITHOUT) U.S. SATELLITES

What are the basic ways in which military satellites can be protected? And to the extent protections are insufficient, how can satellite backups be developed for possible emergency use in war? The basic fact of the matter is that protection can be developed against a number of electronic threats, but that explosives are difficult to counter. As such, satellite vulnerability is here to stay as a physical fact of life. Moreover, the U.S. military's increasing dependence on commercial satellites for communications means that it is now vulnerable to relatively simple jamming as well. Arguments that hardening satellites, building spares, building decoys, and taking similar measures may suffice as antidotes against ASATs are often advanced.[1] But they are not completely reassuring, even if such steps are still justified to reduce U.S. vulnerabilities and delay the date by which they become more serious.

Several types of defensive responses can be imagined to counter a growing vulnerability of American satellites. At the simplest level, greater monitoring of space activities may be desirable so that the United States will know more confidently if and when its satellites are being threatened. Greater hardening and other passive defenses—against nuclear effects, against lasers and artificial heating, against homing microsatellites—is next on the list of increasingly assertive and active measures. Then some simple satellite defenses, such as greater fuel for maneuvering and possible means of attacking homing microsatellites, could be envisioned. Finally, if and when it is determined that all of the above cannot reliably defend U.S. space assets, alternatives may be needed—ranging from the capacity for rapid launching of replacement satellites to ground-based substitutes for satellites.

The specific recommendations that emerge from this analysis are straightforward. First, military satellites should continue to be hardened against nuclear effects, and to the extent possible should also employ radio transmission frequencies and signal strengths capable of penetrating a nuclear-disturbed atmosphere. These recommendations should be straightforward to implement; indeed, they already have been for some systems such as MILSTAR. Second, low-Earth orbit (LEO) satellites should have sensors capable of detecting laser illumination and possibly other attack mechanisms as well, together with the means to protect themselves temporarily against such harassment or attacks via shutter controls for protection of their optics. (Someday, they may also need means of cooling themselves against prolonged exposure from high-energy lasers.) Third, despite such measures, it should be assumed that most types of military satellites may not be available in future war, and alternatives thus maintained. This is particularly true for lower-altitude assets. Fourth, plans should be made in the event that commercial communications satellites, which probably cannot be hardened in any practical way, prove unavailable for purposes of warfighting. That assumption should lead the U.S. military to devise means for making do with much-reduced bandwidth in combat; it should also buttress efforts to develop more dependable means of communications such as laser satellite constellations.

Improved Space Monitoring

The United States needs to know if its satellites are under attack or likely to soon be under attack, to the extent possible.[2] Otherwise, evidence of attack may only occur as multiple simultaneous satellite failures allow for no other real possibility. Such sensors can trigger shields or other protective measures to be deployed against certain types of threats, such as jammers or lasers. They may allow for satellite maneuvers or other means of evading kinetic or explosive attack, as discussed more below. For example, if the enemy ASAT were in reasonably close proximity, it might be defeated with high-energy but short-range microwaves by a device that would not necessarily constitute a more general ASAT capability. But leaving aside the possible responses, which are not urgently needed at present, space awareness is important on multiple grounds and should be improved now.

Some U.S. satellites, including Defense Support Program early-warning assets and National Reconnaissance Office imaging satellites, already have some attack warning capability. But most U.S. satellites apparently do not.[3] The U.S. space surveillance network can track the movements of larger objects or boosters, and that may suffice for now against homing space mines. But at some future date, satellites may need their own warning of approaching microsats. And low-altitude satellites should soon have sensors that would alert them to artificial illumination by laser.

Greater Resilience to Jamming

Jamming is generally fairly easy against the communications links of satellites that have not been made resilient to such attacks. As one example, at the Air Force Research Laboratory, engineers “homebuilt” an effective jammer using about $7,500 worth of goods bought at electronics and hardware stores.[4]

A good deal of protection can be provided in this area. But it is unlikely to be practical for commercial satellites, on which the U.S. military does depend for many high-data-rate transmissions such as those needed in tactical targeting (even if not for most high-level strategic command and control operations). Among its other implications, that fact heightens the importance of moving along with the laser satellite communication system now under development by the Department of Defense, which will provide enormous bandwidth through the military's own system.

But the military also needs to prepare for the possibility that it will not have as much available communications bandwidth as it would like in future conflicts. The United States needs to ensure some level of robust, survivable satellite communications. New DSCS satellite systems with bandwidths in the vicinity of 60 Mbps are a step in the right direction (well above the MILSTAR capacities of 1 to 2 Mbps).[5] Data transmission rates needs to be minimized as much as possible. That can be done through data compression techniques that can transmit high-fidelity data with one-tenth the bandwidth or slightly degraded data at one-hundredth the bandwidth of standard means.[6] It can also be done by maximizing the amount of analysis done by the platform obtaining the data.[7] Finally, the military needs to develop procedures for prioritizing its use of satellites so that it can make do with less capacity if necessary.

New GPS satellites with greater power will also be helpful as counters to jamming, and should not be again postponed (the GPS 3 constellation is to begin deployment in 2011 according to current plans).[8] If possible, indeed, deployment should be hastened. For now, inertial guidance or other terminal guidance may still be needed as a supplement to GPS for munitions used against a capable foe.

Improved Electronic Hardening

Satellites can be hardened against the electronic interferences created by nuclear detonations. The concept of a Faraday cage is well known and practical. Costs may grow by a few percent, up to perhaps 10 percent, as a result, but for military satellites in particular, the costs are hardly onerous. If there has been any letup in such hardening since the Cold War ended, it s should be rectified; it is hardly beyond the realm of the conceivable that an enemy would attack U.S. satellites with nuclear weapons.

It is dubious that such hardening will ever occur for most commercial satellites, however, again underscoring the importance of not depending on such capabilities for wartime purposes indefinitely. Even if the government were prepared to subsidize such hardening, the satellites would remain vulnerable to jamming and to direct attack, calling into question the value of the effort.

For military systems, however, hardening should be de rigeur. It is important for low-Earth orbit systems.[9] It is also desirable at higher altitudes. Satellites in MEO are often already hardened, since normal Van Allen radiation is greater at such altitudes, necessitating protective measures. But standards may not be not sufficiently demanding for all altitudes, from what can be deduced through unclassified sources. If true, that situation should be remedied.

There is yet another reason for radiation hardening, apart from nuclear threats. Within perhaps 15 years, countries such as China could have the capacity to attack a variety of satellites using high-powered microwaves. The basic physics of radio-frequency weapons and high-powered microwave weapons is not particularly complicated. The engineering challenges associated with building devices that can emit very short pulses of radio energy, lasting perhaps just billionths of a second but reaching billions of watts in power, are considerable, but far from insurmountable.[10] So as satellites are designed and produced in the coming years, such possible enemy capabilities should form part of the assumed future threat environment.[11]

<u>Increased Defenses Against Explosives</u>

Alas, physically shielding satellites from the effects of nearby explosives is difficult to do, given the ability of a hunter-killer satellite or space mine to approach arbitrarily close to a target satellite before being detonated. It probably should be viewed as simply not worth the effort even to attempt.

Could satellites maneuver, or be given self-defense weapons, to evade hunter killer satellites? Maneuvering is a difficult proposition given the size of certain satellites; a ten-ton imaging satellite will have a hard time escaping from a 10-kg explosive charge with small boosters attached. As a general proposition, maneuvering may work against simple ASATs with poor terminal guidance, but is likely to fail against small, sophisticated ASATs.[12] Perhaps the larger satellite could be given small explosive charges of its own to fire at such a device. But this gets into a more assertive kind of space weapon capability. Increased maneuvering capability may not be a permanent solution, but it could buy the United States time down the road and should be retained as an option, albeit a costly one given the corresponding fuel requirements.

Backup Satellite Capabilities and Alternatives to Satellites

If the United States could take the expensive but prudent step of having some additional satellite capability in its inventory at all times, together with the ability to launch and make operational such satellites quickly, it would mitigate its vulnerability to antisatellite weapons. In particular, it would be better prepared against ASAT threats that were only capable of incapacitating a small number of its space assets.

Largely for this reason, Space Command would like to gain the capacity to replenish satellites in orbit within days. It hopes to have such an ability towards the end of the decade.[13] However, since that goal was articulated in 1998, the United States has not made rapid progress towards lowering launch costs or satellite costs.

Regardless of progress on the rapid relaunch front, the United States is probably entering an era when it should no longer count on its satellites remaining safe and secure. No foe is likely close to an ability to "clean up the heavens," systematically eliminating the dozens of GPS and communications satellites on hand for U.S. military use when needed. But satellites deployed now only in small numbers, such as imaging and signals intelligence satellites, may be more plausibly attacked. Over time, minisatellites or directed-energy weapons may even put the large constellations at risk. Although such a period of time is probably quite distant, the United States should avoid blind optimism in the availability of all satellite capabilities.

The United States needs backups to satellites. Even if they prove less capable or efficient than the satellites they would replace, they are important, because the United States cannot afford to develop "single-point failures" that would bring down whole warfighting systems after the loss of a single type of asset. Catastrophic degradation of U.S. military capabilities from a single type of action or attack must be prevented.

As a practical matter, this conclusion means several things are necessary. First, numerous airborne assets, particularly for imaging and signals intelligence, but also for targeting and guidance and communications, should be retained in the force posture despite their non-trivial cost. In addition, refurbishment or modernization programs for assets such as P-3 aircraft and EC-135 electronic reconnaissance aircraft need to be kept on track. Second, additional backup capabilities such as fiber optic land lines and undersea lines should be retained in numerous regions of the world to permit high-volume intercontinental communications even if satellites are lost. Third, naval fleets, ground-force units, and aircraft should retain the ability to communicate internally through line-of-sight and airborne techniques so that battle groups always have the ability to function as single entities even if their access to satellites is disrupted.

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[1] See James Clay Moltz, "Reining in the Space Cowboys," *Bulletin of the Atomic Scientists* (January/February 2003), p. 66.
[2] U.S. Space Command, *U.S. Space Command Long-Range Plan* (1998), p. 21; Robert Wall and David A. Fulghum, "Satellite Self-Protection Gains Added Protection," *Aviation Week and Space Technology*, October 28, 2002, p. 68.
[3] Robert Wall and David A. Fulghum, "Satellite Self-Protection Gains Added Attention," *Aviation Week and Space Technology*, October 28, 2002, p. 68.
[4] William B. Scott, "Innovation Is Currency of USAF Space Battlelab," *Aviation Week and Space Technology*, April 3, 2000, p. 53.
[5] Communication to author at Vandenberg Air Force Base, November 8, 2002.
[6] Michael Sirak, "US Air Force targets UAV bandwidth problem," *Jane's Defence Weekly*, July 31, 2002, p. 28.
[7] David A. Fulghum, "It Takes a Network To Beat a Network," *Aviation Week and Space Technology*, November 11, 2002, p. 31.
[8] Jeremy Singer, "U.S. Air Force Scales Back GPS Upgrade Plans," *Space News*, January 27, 2003, p. 8.
[9] It may be possible to clean up electrons pumped into Van Allen belts after a nuclear explosion. In other words, it may be possible to reverse the so-called Christofilos Effect, specifically through the use of low-freqency kilohertz waves emitted from ground stations to make electrons "rain out" of orbit. This may help make low-altitude space usable within months instead of years, provided of course that subsequent nuclear explosions can be prevented, and that new satellites can be orbited reasonably quickly to replace those that had been lost.
Ian Steer and Melanie Bright, "Blind, Deaf, and Dumb," *Jane's Defence Weekly*, October 23, 2002, pp. 21-23.

[10] Ira W. Merritt, U.S. Army Space and Missile Defense Command, “Radio Frequency Weapons and Proliferation: Potential Impact on the Economy,” statement before the Joint Economic Committee, 105 Cong. 2 sess. (February 25, 1998); David A. Fulghum, “Microwave Weapons Await a Future War,” *Aviation Week and Space Technology*, June 7, 1999, pp. 30-31; Carlo Kopp, “The E-Bomb—A Weapon of Electrical Mass Destruction,” Monash University (Australia), 1998; and Barbara Starr, “Russian Bomb-Disarming Device Triggers Concerns,” *Jane’s Defence Weekly*, March 18, 1998, p. 4.

[11] Robert Wall, “Chinese Advance In Electronic Attack,” *Aviation Week and Space Technology*, October 28, 2002, p. 70.

[12] See Tom Wilson, “Threats to United States Space Capabilities,” Paper prepared for the Commission to Assess United States National Security Space Management and Organization, 2001, pp. 41-46.

[13] U.S. Space Command, *U.S. Space Command Long-Range Plan* (1998), p. 24.