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SPACE-BASED WEAPONS

Long-Term Strategic Implications and Alternatives

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The *U.S. Air Force Transformation Flight Plan* released in November 2003 reinvigorated the debate on the issue of space weaponization. Taking a "snapshot in time" of that service's ongoing and future transformation efforts, the *Transformation Flight Plan* lays out current programs, advanced concept technology demonstrations, and "future system concepts."[1] Many of the systems described can be interpreted as a significant move by the United States toward weaponization of space. As Rep. Silvestre Reyes (D-Tex.) pointed out during a recent hearing of the Strategic Forces Subcommittee of the House Armed Services Committee, "putting weapons either offensive or defensive into space is a major policy decision."[2] This decision will require thorough discussion and analysis to ensure that American system deployments not only provide the short-term benefits promised by service advocates but contribute to increased security in the long term.

This article addresses one component of the debate on whether or not to weaponize space. Specifically, it looks at whether a decision to base weapons in space would produce a net, long-term increase in *relative* military capability for the United States or serve to reduce its current military dominance. It defines "space-based weapon" as a system placed in orbit or deep space that is designed "for destroying, damaging, rendering inoperable, or changing the flight trajectory of space objects, or for damaging objects in the atmosphere or on the ground."[3]

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U.S. Air Force Transformation Flight Plan has several program concepts that include space-basing of weapons. The Evolutionary Air and Space Global Laser Engagement (EAGLE) concept will use "airborne, terrestrial, or space-based lasers in conjunction with space-based relay mirrors to project different laser powers and frequencies to achieve a broad range of effects from illumination to destruction."[4] Another, the Space-Based Radio Frequency Energy Weapon, will "be a constellation of satellites containing high-power radio-frequency transmitters that possess the capability to disrupt/destroy/disable a wide variety of electronics and national-level command and control systems . . . typically . . . used as a non-kinetic anti-satellite weapon."[5] A third, "hypervelocity rod bundles," would "provide the capability to strike ground targets anywhere in the world from space."[6] While other system concepts and programs *Flight Plan* describes are less specific on the point, there seems little doubt that space-basing of weapons is an accepted aspect of the Air Force transformation planning. Now, therefore, is the time to analyze the advantages and disadvantages of basing weapons in space—in the end, either endorsing or recommending revision to this space-basing assumption.

In the event, this analysis indicates that space-based weapons, though in the short term increasing military capabilities, are in the long term very likely to have a negative effect on the national security of the United States. Specifically, I will argue, the vulnerabilities of space-based systems would largely negate their projected advantages. Further, potential enemies would react to U.S. deployments, either avoiding their effects or, more ominously, space-basing weapons of their own. These deployments would fundamentally reduce the current relative advantages the United States enjoys in conventional forces and strategic depth—reducing the time and distance in which effective defenses must be created. Arguments for the necessity of space-basing weapons are politically untenable, based on false assumptions, or narrowly focused on space-centric concepts that fail to integrate and take full advantage of capabilities of terrestrially based forces. Finally, I will propose a balanced policy and strategy that should optimize maintenance of relative advantages while hedging against uncooperative adversaries.

HIGH GROUND OR SITTING DUCK?

Space is frequently referred to as the "ultimate high ground." While few would dispute that space provides an excellent vantage point, "high ground" implies a great deal more, and in fact space is far from being the "ultimate high ground."

> On earth, high ground has physical resources near at hand for shielding and hiding behind. In space, the "high ground" has nothing: it's a vacuum and there is nothing there that you don't bring with you. On earth, high ground is often a peak with a

> castle on it like the Krak des Chevaliers, a choke point, a symbol of power. In the "high ground" of space, you're a thin-skinned sitting duck with a bull's-eye painted on your side. Anybody has a chance to shoot at you whenever they feel like it. High ground on earth provides you with a view of everything below you, while the people down below can't see you, because you're up over the edge of the fortification. In space, everybody can see you and people on the ground can hide from you, so all those advantages are gone. On earth, from high ground you can strike anywhere around you while those below are limited in reaching you. In space, the attacks that you might make, the trajectories that your vehicles might follow, follow paths that are predictable in advance, predictable in both space and time. Ground attacks, meanwhile, on a point in space can be almost random; they are highly variable in time and space and are unpredictable. On earth, on the high ground, you have weapons that are more effective when you aim downward, but the "high ground" in space is the easier target, being unprotected. Attacking uphill involves difficulty and delay on the ground but in space, uphill and downhill attacks take about the same amount of time and your "high ground" is very much harder to resupply and rearm. Lastly, on earth, high ground allows a permanent control over some strategic road or territory, a choke point that interdicts all hostile traffic around it. In space, the so-called high ground is a shifting Maginot line that is easily avoided, outwaited and circumvented.[7]

Aircraft have long performed elevated observation as well as air control and ground strike missions. It is thus tempting to equate their demonstrated ability to overcome ground defenses with that of spacecraft to do the same. However, for missions in high-threat environments, various types of aircraft are grouped in "packages" combining offensive and defensive capabilities as specifically required. Route selection, timing, and deception are keys to success, as are deliberate unpredictability and maintenance of the initiative. Spacecraft, on the other hand, are inherently predictable, and combinations of satellites are "new" to the enemy only on the first orbit, after which they can be planned against and lose the initiative. Again, few similarities seem to exist between air and space vulnerabilities.

The multiplicity of potential threats posed to U.S. space-based systems is highlighted in the *Transformation Flight Plan* itself. In addition to the space-based weapons already described that have space control missions, several terrestrial systems are also pertinent—such as the Ground Based Laser, which would "propagate laser beams through the atmosphere to Low-Earth Orbit satellites to provide robust defensive and offensive space control capability."[8] Opponents with mobile or hardened lasers could conduct speed-of-light attacks on space-based systems at times of their choosing. The Air-Launched Anti-Satellite Missile would "be a small air-launched missile capable of intercepting satellites in low earth orbit."[9] Launching antisatellite weapons from aircraft could increase the unpredictability of attack and provide additional kill mechanisms against our space-based systems. Opponents desiring to attack our space-based capabilities in the future would seem to have plenty of options.

THE SPACE CONTEXT

Objects in space are governed by astrodynamics: "The speed and direction of a satellite cannot be changed as easily as an aircraft's, and enormous amounts of energy are required to accomplish seemingly trivial changes in a satellite's altitude or orbital inclination" (Howard). The movement of objects in orbit is highly predictable—the overwhelming majority of satellites carry fuel only for minor maneuvers at slow accelerations. Orbits, once chosen as best suited to the satellite's missions, are rarely changed.

Low earth orbit (LEO) (150–800 km, or 90–500 miles) gives the best imagery resolution but limits time above the horizon with respect to any given point on earth and renders satellites vulnerable to attack or interference. *Geosynchronous orbits* (GEO) (approximately 35,000 km/20,000 miles) have periods equal to the earth's rotation; a satellite observed from the earth appears to stay at or near the same longitude. GEO is excellent for weather observation, communications relay, and other tasks requiring continuous hemispheric coverage from a single satellite. Beyond GEO lie *high earth orbits* (HEO). Between GEO and LEO is the *medium earth orbit* (MEO) range. Highly *elliptical* orbits can extend the time over a particular latitude.

The "clean," clutter-free background makes objects in space easier to detect. Attempts to hide from passive or active sensors operating at one frequency can make detection by other sensors easier; as an example, painting a satellite black to reduce reflections detectable to visible-light sensors would cause it to become hotter and therefore emit long-wave infrared radiation detectable by infrared sensors at even greater range. However, the transparency of space is somewhat offset by its vastness; above the lowest earth orbits, tremendous volumes must be searched to find satellites, let alone stealthy vehicles deployed from satellites. "Space situational awareness," as a result, may be, in practical terms, a relative concept.

All elements of space systems—in space, on the earth, and in the link between them—have vulnerabilities. Ground sites are vulnerable to threats ranging from mortar attack to software viruses; communications links are susceptible in varying degrees to jamming. The space segment suffers not only from predictable movement but from fragility imposed by launch weight restrictions; "armor is heavy," and a simple device "exploded in close [would send] shrapnel through solar arrays, battery systems, onboard computers, guidance systems, and sensors alike" [Kennedy et al.]. If timed correctly, direct-ascent antisatellite weapons (ASATs) fired from earth "could disperse something as simple as sand in LEO, leaving anything passing through it . . . severely damaged or destroyed." Space, ground, or air-based directed-energy weapons could conduct attacks on fragile satellite components without warning. Electromagnetic pulse (EMP) and radiation generated by the high-altitude detonation of nuclear weapons is perhaps the most devastating threat, since "lingering effects of radiation could make satellite operations futile for many months" [Space Commission].

Sources: William E. Howard III, "Satellites and Naval Warfare," *U.S. Naval Institute Proceedings* (April 1988); Colin S. Gray, *Modern Strategy* (Oxford, U.K.: Oxford Univ. Press, 1999); U.S. Congress, *Anti-Satellite Weapons, Countermeasures, and Arms Control;* Fred Kennedy, Rory Welch, and Bryon Fessler, "A Failure of Vision," *Airpower Journal* 12, no. 2 (Summer 1998); U.S. Air Force, *Space Operations Doctrine;* DeBlois, "Space Sanctuary"; and *Report of the Commission to Assess United States National Security Space Management and Organization*.

Space-based weapons, like all space systems, are predictable and fragile, but they represent significant combat power if used before they are destroyed—leading to a strong incentive to use these weapons preemptively, to "use them or lose them." The problem is further complicated by the difficulty in knowing what is occurring in space. As the Commission to Assess United States National Security Space Management and Organization pointed out:

> Hostile actions against space systems can reasonably be confused with natural phenomena. Space debris or solar activity can "explain" the loss of a space system and mask unfriendly actions or the potential thereof. Such ambiguity and uncertainty could be fatal to the successful management of a crisis or resolution of a conflict. They could lead to forbearance when action is needed or to hasty action when more or better information would have given rise to a broader and more effective set of responsive options.[10]

This lag in situational awareness can increase the effectiveness of attacks. That is, striking first is likely to mean inflicting disproportionate losses on the enemy; waiting increases the chances of suffering disproportionate losses oneself.

SPACE-BASED WEAPON CONCEPTS: ADVANTAGES, ISSUES, AND REACTION

If technical and fiscal challenges are overcome, there is little doubt that an integrated combination of airborne, terrestrial, and space-based lasers with orbiting relay mirrors would be a flexible weapons constellation. Striking at 186,000 miles a second, laser weapons and mirrors help overcome the problems posed by the large distances and high speeds for targeting in and from space.[11] Perhaps they would be most effective at space control, but they would also be useful for boost-phase intercept of ballistic missiles. This is a critical missile-defense function, particularly when dealing with nuclear, chemical, or biological warheads. If not destroyed in boost, nuclear-tipped missiles may deploy decoys, and chemical or biological warfare payloads might be broken into small, separate submunitions or canister reentry vehicles, each of which is a lethal weapon that must be destroyed.[12] In such cases there is a high likelihood that defenses would be overwhelmed.

Evolutionary Air and Space Global Laser Engagement (EAGLE)

Space-based systems would be logical for this important mission. By virtue of the speed of the laser and its "ability to accurately place energy on targets that are thousands of kilometers away," a constellation would provide worldwide coverage against ballistic missile launch.[13] EAGLE—which uses orbiting mirrors that are effectively space-based weapons—might prospectively be just such a system.

Its effectiveness, however, can only be gauged in terms of the probable reaction of enemies.

A deployed EAGLE missile defense system by the United States would hold at risk the ballistic missile assets of every other state. Even states with enough missiles to overwhelm EAGLE if launched simultaneously would feel increased risk, since a first strike might reduce their inventory below the size required to saturate defenses. In that light, opponents might:

- Develop faster-burning missiles to reduce their period of vulnerability, or harden the missiles to reduce the laser's capacity
- Proliferate the missiles and their launchers to saturate the lasers
- Develop antisatellite capabilities against the lasers
- Shift force structure toward cruise missiles.[14]

The space-based segment of EAGLE would be highly predictable in its movements. An attacker would know how large a salvo of ballistic missiles would have to be to overwhelm the defenses and when coverage would be at a minimum. Furthermore, the one or two EAGLE laser-defense platforms that would have engagement opportunities during the boost phase of the missile salvo could be attacked just before it was launched. Defensive sensors could be degraded using relatively low-powered lasers or decoys, while space-based weapons platforms were attacked by ground-based lasers, orbiting space mines, or fast-burning, hardened, direct-ascent antisatellite (ASAT) weapons. In this way, with relatively modest resources an enemy might overwhelm the extremely expensive EAGLE boost-phase capability. A more sophisticated foe might deploy clusters of space-based mirrors to use in conjunction with mobile or hardened ground-based lasers. The mirror clusters could attack large segments of the U.S. defensive system whenever they came over their targets' horizon.

Given these vulnerabilities and initiative possessed by the attacker in a missile attack, it seems unlikely that EAGLE could provide anything like assured boost-phase intercept.

Space-Based Radio-Frequency Energy Weapon

A constellation of satellites containing high-power radio-frequency (RF) transmitters would be a flexible system that meets critical space-control needs. During recent congressional testimony, Peter Teets, Under Secretary of the U.S. Air Force, highlighted the need to prevent foreign powers from targeting U.S. forces and the "need to have capability to deny them the use of their space assets."[15] Power and modulation variations designed "to disrupt/destroy/disable a wide variety of electronics and national-level command and control systems" would likely provide a great deal of operational flexibility.[16] In the prelude to combat it might jam or disrupt systems involved in targeting U.S. forces; during conflict, operating at high power, it could destroy confirmed enemy systems.

Here again, the question of enemy reaction is critical. It seems likely that given the U.S. reliance on space assets, once the United States deploys RF space-control weapons, other nations will find it to their advantage to do the same. However, their lack of detailed intelligence on target vulnerabilities may drive them to different space-control solutions. An opponent might fall back on an offensive concept, using large numbers of destructive weapons—again, with a premium on first use.

Placing space mines in the immediate vicinity of high-value American satellites would likely be a major component of an opponent's strategy. These weapons could be fairly lightweight and possess considerable range. "For example, a directional fragmentation warhead similar to that of a Claymore mine could project 100,000 one-gram pellets in a pattern that would cover a 100 x 100 meter area with 10 pellets per square meter at a range of 1 kilometer."[17] One approach to the space mine is to "design a very small stealth weapon that is moved into position over a long period of time" and in secrecy.[18] However, while a stealthy space mine has definite advantages, it is not clear that an unobserved approach is required. In a fully weaponized space environment, U.S. space-based lasers and mirrors, each capable of attacking satellites thousands of kilometers away, threaten distant satellites as much as would a space mine in close proximity. In any case, until space mines actually damaged or interfered with their victims, it would be difficult to challenge their legitimacy. To attack or disable them as a potential threat would set a precedent for preemptive strikes against U.S. space-based weapons, if not all its satellites.

Thus, it is likely that other countries will respond to deployment of space-based weapons by the United States with space-control programs of their own. Lower-technology kinetic weapons may even be seen as attractive deterrents to the sophisticated, reversible effects preferred by the United States. Would we jam a surveillance satellite, however important, if it meant having one of ours destroyed by a space mine? Would we not be deterred by the prospect of seeing the critical low-earth and geosynchronous orbital zones littered with the debris of kinetic weapons? In this area, simplicity may offer advantages to the opposition.

Hypervelocity Rod Bundles

As far as can be known from unclassified sources, Hypervelocity Rod Bundles are similar to other proposed kinetic-energy weapons designed for use against terrestrial targets. These weapons, frequently referred to as "eroding rods," seek "to destroy targets by converting the KE [kinetic energy] associated with the weapon's high velocity (5 to 11 km/s [kilometers/second]) into work and heat. . . . For example, a two-meter rod weighing 50 pounds and penetrating a depth of six to eight meters is similar to detonating 50 pounds of explosive in a hole slightly larger in diameter than the rod."[19] The destructive force of these weapons is directed almost entirely in the path of the weapon's travel; for this reason, suitable targets include "tall buildings, missile silos, ships, and hardened aircraft shelters."[20] Due to their extremely high speed and lack of vulnerable points, defense against the rods "would be very difficult inside the atmosphere"; the best approach might be finding and attacking them in space before the penetrator reentry burn is complete.[21] For a constellation of eroding-rod space-based weapons, trade-offs between total "delta" velocity (energy needed to deorbit), impact velocity (destructive power), area coverage, and reentry angle suitable for accuracy seem to yield an optimum orbit altitude of around eight thousand kilometers and a response time of 1.5 to two hours.[22] Such a deployment would add to U.S. global strike capabilities, with responsiveness better than that of current manned aircraft, and some unique munitions effects.

Once again, however, enemy reaction must be considered. Space-based global strike weapons would confer on hostile nations much greater increases in combat power, in proportional terms, than they would for the United States. A RAND study concluded that

> because of their extremely high velocity, these [kinetic-energy] weapons are very difficult to defend against during their brief transit through the atmosphere and might therefore be particularly interesting against heavily defended targets. These weapons may be of only limited interest to the United States, which has other means of global power projection. However, they may be a very good fit for another country, such as one seeking global power projection without duplicating the American terrestrial investment or one seeking to deny access to U.S. power projection forces. For example, instead of playing catch-up against highly evolved air and submarine defenses, a country might prefer these space weapons to bypass the defense entirely.[23]

However, conventional ordnance from space could be significantly more responsive than even kinetic weapons. Because they do not require high terminal velocities or steep reentry angles, they could be placed in lower orbits; as a result, "the responsiveness of orbital basing can reasonably be about 20 to 30 minutes."[24] Space-basing precision weapons that are already available does not require high technology. In fact, a "shape capable of carrying a large number of smart munitions might resemble a larger version of the original Discoverer/Corona film return capsules."[25] The combination of global access, rapid response, and moderate technological development could eventually make space-based strike weapons the preferred choice of a number of countries.

Potentially hostile nations, however, are likely to concentrate instead on first strike. Rather than distributing their space-based weapons evenly and at altitudes optimal for consistent, worldwide response, they might cluster weapons-delivery platforms in lower orbits so as to reduce response time available to defenses and increase the probability of saturating them. Even a small number of weapons so deployed would have periodic opportunities for attacks on large numbers of targets. Potential enemies might also emphasize the survival of individual weapons en route to targets—for instance, by firing, nearly simultaneously, numerous submunitions that disperse even before reentry into the atmosphere.

In general, space-basing weapons would offer an enemy a number of interesting targeting options. Even a small number of kinetic weapons could have a devastating effect on space-launch or satellite-control facilities, large warships in port, and sensors involved in space and missile defense. Large numbers of conventional submunitions could attack military and economic targets across the continental United States. If the attack were preemptive, the chances of defeating it or preventing extensive damage would be very low.

Even more disturbing are the targeting options if an enemy chooses nonconventional means. The 1967 Outer Space Treaty prohibits weapons of mass destruction (WMD) in orbit. However, "it is difficult to distinguish space-based WMD from space-based non-WMD."[26] Once space-based weapons become commonplace and munitions dispensers are placed in orbit, inspection of their contents is next to impossible. Submunitions with biological payloads, such as anthrax, would be very deadly even if intercepted by air defenses inside the atmosphere. "A few kilograms of the spores delivered in an inhalable form can cause extremely large numbers of fatalities in areas of high population density. Against that kind of a target area with that kind of lethality, precision delivery is not required, just widespread dispersal and rough timing relative to the time of day and weather."[27] Kinetic-energy weapons could add to the destruction by targeting such sites as nuclear containment buildings and missile silos. Given current efforts to develop a missile defense system that removes the WMD threat to the U.S. populace, a future with space-based weapons could be very unappealing indeed.

THE ARGUMENTS FOR SPACE-BASING WEAPONS

Basing weapons in orbit, then, will not be in the long-term interests of the United States. Still, there are those who disagree. The two most commonly heard arguments that full weaponization of space would be beneficial for the United States are that it is inevitable, and that space is a "center of gravity" that the nation must weaponize in order to protect. A third argument less frequently heard is that moving first to weaponize space would achieve complete dominance in that domain and thus permanently secure U.S. national interests through a benevolent hegemony.

U.S. Space Hegemony

Everett Dolman argues that the downsides of space-basing weapons can be avoided by using current and near-term capabilities "to . . . seize military control of low-Earth orbit. From that high ground vantage . . . space-based laser or kinetic energy weapons could prevent any other state from deploying assets there, and could most effectively engage and destroy terrestrial enemy ASAT facilities."[28] Other states would be allowed to compete commercially in space with the United States, but only after notification and approval of each launch.

Underlying this view and the arguments adduced in its support is the idea that by seizing space the United States will have seized a vantage point from which the earth itself can be dominated. This is the "ultimate high ground" argument, which, as we have seen, has serious weaknesses; it is not at all clear that even in strictly military terms dominance in space means dominance on earth. In fact, its benefits are likely to be both marginal and temporary if an enemy shifts the terms of the engagement.

The more important questions would be the political and legal. The preemptive destruction of another nation's space-based weapon would be a direct violation of the 1967 Outer Space Treaty, which states that outer space "shall be free for exploration and use by all States without discrimination of any kind."[29] If U.S. deployment of space-based weapons is a peaceful use of space under the treaty, deployment by another state is protected as well. This is not in itself a problem for space hegemonists, who advocate "withdrawing from the current space regime" and announcing "a principle of free-market sovereignty in space."[30] However, potential foes are not in the least likely to accept unilateral American assertion of space dominance, negating as it would many countries' deterrence strategies and implying permanent and irreversible asymmetric U.S. advantage in space. In the absence of a direct threat to their existence, such as existed during the Cold War, it is unlikely that allies would accept it either. Both would probably, as the United States does now, view "purposeful interference with space systems" as "an infringement on sovereign rights."[31] Heavy political and economic costs would likely be imposed on the United States, which is unlikely to find the political will to uphold such a dramatic change in policy against both friends and enemies.

A more limited approach, denying "rogue states" access to space, could also be proposed. This could be construed as in accordance with the current National Security Strategy objective to "prevent our enemies from threatening us, our allies, and our friends with weapons of mass destruction," since it is difficult to verify that there are no weapons of mass destruction on orbital space weapons platforms, and even conventional space-based ordnance could attack such facilities as nuclear power sites and so produce WMD-like effects.[32] This concept might be accepted internationally, or imposed unilaterally with acceptable political cost, against a state like North Korea, with a history of attacking its neighbors, clear links to terrorist acts, a record of violating treaties, and an authoritarian regime. Even this example poses problems, however. Debris from a boost-phase EAGLE engagement of a missile launched from North Korea would presumably not hit the United States, but other nations in the region might be struck. It is not hard to envision the outcry should debris rain on Japan, China, or Russia from a booster that North Korea claimed had been merely placing a communications satellite into orbit.

Other rogue state space "lockout" issues are even more problematic. Iran is frequently quoted as a potential future threat to the United States, but it seems almost certain that a space "lockout" against a country that has not attacked its neighbors in recent history and has functioning democratic institutions would cause a severe international backlash. Additionally, any deployment of space-based weapons against a "rogue state" is likely to elicit space-based weapons deployments by third parties. China is likely to be one of the first countries to follow suit. The destabilizing aspects of space-based weapons would be particularly unhelpful in any future crisis over Taiwan. Thus, a decision to space-base weapons should not be made under the illusion that it will result in unilateral U.S. advantage. Some limited "lockout" from space of a rogue state may be possible under certain circumstances, but the space-basing of weapons in response by other states that could become enemies must be considered.

Space Weaponization Is Inevitable

The Commission to Assess United States National Security Space Management and Organization reported five major findings. One of these concerned the inevitability of weaponizing space:

> Every medium of transport—air, land, sea—has seen conflict. Space will be no different. . . . As with national capabilities in the air, on land, and at sea, the United States must have the capabilities to defend its space assets against hostile acts and to negate the hostile use of space against American interests.
>
> Explicit national security guidance and defense policy [are] needed to direct development of doctrine and concepts of operations for space capabilities, including weapons systems that operate in space and that can defend assets in orbit and augment current air, land, and sea forces. This requires a deterrence strategy for space, which in turn must be supported by a greater range of space capabilities.[33]

The report cites no background analysis supporting this rather dramatic chain of logic. The argument seems to be, first, one of historical determinism—that other mediums having seen conflict, space will as well. That inevitability requires not only defense of assets in space but negation in advance of the hostile use of space. The final leap is to the idea that these offensive and defensive requirements can be met only by "weapons systems that operate in space." No potential disadvantages or possible alternatives are noted.

As for the inevitability argument, Dr. Karl P. Mueller concludes that arguments based on human nature or historical analogies to the air and sea are "thought-provoking but ultimately weak."[34] They do not account for the fact that though some nations continue to possess banned chemical and biological weapons, there is no clamor in the United States to deploy such weapons in such large numbers on the ground that their further spread is inevitable. "Perhaps most strikingly of all, even among space weapons advocates one does not find voices arguing that the placement of nuclear weapons in orbit is inevitable based on the rule that weapons always spread."[35] The analogy to the medium of air also has significant holes. Less than fifteen years after the first powered flight, military aircraft were carrying out reconnaissance, offensive and defensive counterair, and strategic and tactical bombing missions. In contrast, over forty-five years after Sputnik, space-based counterspace and terrestrial bombardment is not being conducted, long after the technical capability emerged. "In fact, both superpowers did develop anti-satellite interceptors, but then abandoned their ASAT programs, something utterly without precedent in the history of air power that casts further doubt on the soundness of the analogy."[36]

If a decision to space-base weapons should not rest solely on arguments of historical inevitability, it is possible to argue that weaponization of space will occur at some time in the future. When humans ultimately explore deep space, they may indeed carry weapons for protection. A powerful weapons system may ultimately be deployed to protect the earth from asteroids. "Ultimately" is a long time. However, it is not long-term predictive accuracy that is important but the almost complete irrelevance of "inevitability" to current efforts. Things that are inevitable can be either good or bad. If something is good and inevitable, it is logical to pursue acquisition now in order to obtain the benefits as early as possible; if something is inevitable and bad, it is logical to delay it as long as possible. Thus, our current decisions with regard to space-basing weapons must be dictated not by its inevitability but by whether it is good or bad—by whether weaponization and its consequences will improve or degrade the national security environment. If analysis points to overall degradation, U.S. policy should be to delay the introduction of space-based weapons: "Even if weaponization of space is ultimately inevitable, like our own deaths, why should we rush to embrace it?"[37]

There is, nonetheless, an inevitability-based argument that is more strongly supported by history—that once a nation deploys weapons that provide an advantage, other nations will build similar weapons or find asymmetric ways to avoid their effect. Britain's introduction of the dreadnought battleship at the beginning of the last century, with its combination of heavy guns, armor, and speed, caused in Germany "something close to panic."[38] However, this revolution in warship effectiveness did not forever solidify Britain's hold on the seas. Only four years later, in 1909, it was the British who were in a panic, over the rapid buildup of dreadnoughts by Germany;[39] the new concept, by making previous ships almost irrelevant, was allowing Germany to overtake British naval power much more quickly than would otherwise have been possible. History is filled with other examples: chemical weapons, atomic bombs, multiple independently targetable reentry vehicles, etc.; it is difficult to think of a single counterexample, even when the original innovator had the clear capability to maintain a numerical lead.

Worse, space-based weapons differ in important ways from the dreadnoughts of the early 1900s. First, as we have seen, space-based weapons are not individually robust under attack, nor can they be hidden in port; instead, they are fragile and always exposed to attack. Additionally, in the 1900s a nation needed almost as many expensive dreadnoughts as the enemy fleet had to have a chance of wresting from it control of the sea. In the twenty-first century, high-technology space-based lasers and mirrors may be able to destroy many satellites before the attack is even detected. Even low-technology space mines and global-strike weapons can destroy high-technology satellites and ground facilities if employed first. Finally, because of these less expensive alternatives, American technical and industrial capacity advantages will not ensure the security in space that it would have at sea a century ago. Even if the United States deploys space-based weapons first, its supremacy in space would not be "inevitable."

The Space "Center of Gravity" Must Be Protected

A former director for Space Policy within the Office of the Secretary of Defense outlines the essential "center of gravity" argument:

> The contributions of space forces to the success of U.S. military operations and the importance of space activities to the economy may make the medium a military and economic "center of gravity" for the nation. A center of gravity . . . is a point of vulnerability where an attack may be decisive for the course and outcome of war. . . . Space has emerged as an area of vital interest to the United States because of its importance to national and economic security.[40]

This argument emphasizes the criticality of space to the military and economic interests of the United States: in view of the "hundreds of billions of dollars of national treasure invested in space activities that are woven into the fabric of the nation's society and economy, the U.S. armed forces will be expected to be vigilant and ready to protect space as an area of vital national interest."[41]

But is space truly an economic "center of gravity"? A thousand satellites in ten years at an investment of a half-trillion dollars may sound large, but against an eight-trillion-dollar annual gross domestic product, a half trillion dollars in a decade is less impressive, on the order of 3 percent of the gross domestic product of the private service sector.[42]

Additionally, the explosive growth of fiber-optic cable has brought a relative decrease in commercial importance of satellite communications. Total satellite communications capacity in 2000 was approximately 130 gigabits per second (Gbps). In contrast, 1999 cable capacity was approximately 329 Gbps, and it expanded to approximately 11,942 Gbps by 2000.[43] By 2003 the worldwide commercial satellite broadband capacity had reached approximately 160 Gbps, with a projected increase of 60 percent over the next ten years; however, in the same year a throughput of 160 Gbps was demonstrated over a single frequency of a single fiber-optic cable.[44] While satellites will continue to be important to commercial communications, it seems difficult to argue that they are a "center of gravity" requiring substantial portions of the defense budget to protect.

In any case, space-based weapons would dramatically increase the vulnerability of the commercial assets they would be meant to defend. The most economically significant satellites are communications platforms in geosynchronous earth orbits (GEO). The projected demand for commercial satellites in GEO over the next ten years is 211, compared to only forty-eight in nongeosynchronous orbits.[45] Global Positioning System satellites, on which commercial communications and transportation systems are increasingly dependent for timing and navigation signals, are also in high, semisynchronous orbits.

Ironically, space-based weapons would place satellites in these higher orbits at greater risk than they are now. Currently, sheer distance provides protection from direct-ascent ASATs and the effects of nuclear detonations in low earth orbit (LEO). Even earth-based directed-energy weapons powerful enough to attack LEO satellites would need hundreds of times more power to threaten geosynchronous orbits.[46] Fairly modest hardening could even further reduce the physical vulnerability of these satellites and, more importantly, their links. However, no amount of hardening could protect them from space mines following in similar orbits or from kinetic ASATs in retrograde orbits—which, by attacking any geosynchronous satellite, would place others in the geosynchronous belt at grave risk of collateral damage. Deploying space-based weapons to protect even a true commercial "center of gravity" would be self-defeating.

The second element of the "center of gravity" argument is that space must be protected as vital to the U.S. military. However, "sound military judgment has often led military strategists to eliminate a COG's [center of gravity's] vulnerability rather than require them to protect it."[47] It is not "space" that must be protected but the vital functions of intelligence, surveillance, reconnaissance, communications, and navigation. The medium in which they are performed is not the key. It is the ability to support military forces while simultaneously denying those functions to the enemy that "will enable combatant commanders and operational forces to think and react faster than an adversary and thereby dictate the timing and tempo of operations."[48]

ALTERNATIVES

Given the notable and inherent vulnerabilities of space assets, huge investments in pursuit of total space dominance in an attempt to shield these vulnerabilities may not be the most intelligent approach. Better to seek alternative, terrestrial ways to augment and enhance the key services provided from space. Space assets would continue to perform their critical functions, but alternate systems would provide redundancy even under attack. This approach offers even greater advantages if the alternatives operate in usefully different and, in important respects, superior ways. When both systems are available, synergy would produce markedly better support than either could offer alone. To deny service entirely, an enemy would have to conduct successful, simultaneous attacks in two distinct mediums; the difficulty and uncertainty involved might prevent opponents from even making the attempt. In such a "system of systems," terrestrial assets might do much more to protect space assets than could any space-based weapon.

C4ISR Mission Alternatives

Numerous options for "C4ISR"—command, control, communications, computers, intelligence, surveillance, and reconnaissance—as well as for navigation are available to augment space-based assets (see sidebar). The most logical ISR architecture would fully integrate the relevant capabilities of satellite, unmanned aerial vehicle (UAV), and manned systems—capitalizing on their individual strengths and increasing overall performance through networked integration at the machine-to-machine level. Satellites, for instance, possess an inherent advantage in peacetime access; further, and though full coverage is episodic and predictable, satellites can provide ISR across the breadth of foreign nations. If hostilities are initiated, satellites become vulnerable to attack, but it is at precisely this time that U.S. conventional superiority enables penetration of enemy airspace by manned and unmanned aircraft. UAVs can approach closest to

C4ISR ALTERNATIVE TECHNOLOGIES

Architectures that fully integrate the capabilities of satellites, manned and unmanned airborne platforms, and ground-based facilities could provide both superior performance and vital redundancy in the major missions typically envisioned for satellites—intelligence, surveillance, and reconnaissance (ISR); communications; and navigation.

Intelligence, Surveillance, and Reconnaissance *Unmanned aerial vehicles* (UAVs) are likely to assume an increasing share of ISR responsibilities. "Specially designed UAVs have long loiter time, can be positioned flexibly near potential targets, and are small and relatively difficult to detect." Global Hawk offers a sixty-five-thousand-foot operating altitude, thirty-six-hour endurance, and an integrated suite of electro-optic/infrared (EO/IR) and synthetic aperture radar/moving target indicator (SAR/MTI) sensors. In 2002, the Department of Defense foresaw three major trends for UAV sensors: "(1) migration of video to high-definition television standards, accompanied by automated precision geolocation; (2) increasing use of synthetic-aperture radar (SAR) and moving-target indication (MTI) modes to provide all-weather, high-resolution, wide-area situational awareness/cueing; and (3) a combination of foliage-penetration (FOPEN) radars with hyperspectral imagery (HSI) to detect and identify targets in deep hide" (quoted in Hewish). A tiered, networked constellation of UAVs could be fielded that included high-altitude, wide-area-surveillance UAVs working with medium and low-altitude tactical UAVs employing EO/IR and range-gated laser radars. It could support U.S. forces even if most space-based ISR assets were lost. UAVs, however, are not without limitations—primarily cost, large-bandwidth communications, and low combat survivability.

Communications and Navigation The U.S. military is already highly dependent on space for communications and navigation. Growing information requirements and the introduction of bandwidth-intensive systems like UAVs are increasing this reliance. The Department of Defense is developing Transformational Communications System (TCS), a new laser-based architecture that will provide extremely high bandwidth between satellites and high-altitude airborne platforms. This truly transformational capability will increase reliance on space-based communications; the vast majority of communications satellites, being in GEO orbits, are relatively invulnerable to direct attack from earth, but they could be attacked, as could Global Positioning System (GPS) navigation satellites in MEO orbits, by space-based weapons.

Complements and alternatives to space-based communications and navigation capabilities include fiber-optic cable, which could provide cheap, extremely large-bandwidth access to fixed forward military assets.

Communications with mobile military ground and air assets will likely be conducted via radio frequency (RF) transmission. Alternatives to satellite RF relay include manned aircraft and UAVs, which offer increased flexibility, reduced relay time, and lower power requirements. One option being explored is to install relay capability on current large manned aircraft with other primary duties. A family of Scalable, Modular, Airborne, Relay Terminals (SMART) has been tested on tanker aircraft. The Defense Advanced Research Projects Agency (DARPA) is examining the use of scalable, modular nodes that support both communications relay and signals intelligence from a variety of airborne platforms. The Army is considering mounting radios in its current tactical UAVs to provide a "tactical internet node."

Even the unique advantage of geosynchronous satellites will soon be challenged, by a High Altitude Airship (HAA) program. The HAA is to fly at seventy thousand feet, carry a payload in excess of four thousand pounds, and, using onboard propulsion and GPS navigation, maintain a geostationary position for over a year. Various missions and payloads are envisioned, including communications broadcast and relay, in addition to the original focus on wide-area air and maritime surveillance of continental U.S. coasts and the southern border. An HAA, no more than three hundred miles from its ground users, would not suffer the "time-late" problem inherent in the 22,000-mile round trip to geosynchronous orbit. A system linking HAA and satellite via laser communications would be highly flexible and robust indeed.

Military forces and weapons, as well as civilian infrastructure, are becoming increasingly reliant on GPS navigation and timing. While the GPS constellation has the vulnerabilities of any MEO-based satellite, terrestrial jammers are the greater threat, as they can be small, cheap, and relatively easy to deploy. Again, complementary systems are available. The Global Positioning Experiment (GPX), conducted by DARPA, and the U.S. Air Force's UAV Battlelab have demonstrated the ability of airborne "pseudo-satellites" *(pseudolites)* to generate high-power signals—forty-five decibels above those from the satellites themselves—that burn through anti-GPS jamming.

There would be military options even were GPS to be completely denied. The Army's Enhanced Position Location Reporting System (EPLRS) provides a network of up to a hundred kilobytes per second with a navigation accuracy of fifteen meters circular error probable. Similarly, the Link-16 tactical data link has a "relative navigation" (RELNAV) that improves navigation resolution in a GPS-denied environment, potentially at accuracies that equal or exceed that of the current GPS system. Reliance on GPS for precision bomb delivery could be greatly reduced with such low-cost seeker technology as the Direct Attack Munitions Affordable Seeker (DAMASK), which has already demonstrated accuracies to within one meter without GPS. Finally, navigation receivers compatible with non-GPS satellite navigation signals (like Galileo and GLONASS) would provide redundancy and multiply the number of navigation systems an enemy would have to attack.

Suborbital and Space Vehicles The Suborbital Operations Vehicle (SOV) and Space Maneuver Vehicle (SMV) are under study. The SOV is a hypersonic vehicle that, launching and recovering in the continental United States, would "pop up" to exoatmospheric altitudes. There it would release an SMV, which would boost itself to orbit, where it would either release low-cost ISR satellites or collect data itself—it could pass over any given point on earth within an hour.

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targets, under cloud cover, thereby providing optimal sensor performance when target obscuration or angular resolution is an issue. UAVs and manned platforms are unpredictable threats, complicating the enemy's cover and concealment efforts. Sensor integration from all ISR systems would enhance situational awareness and allow rapid localization and suppression of threats to either medium. Perhaps most importantly, such networked systems would eliminate space-based ISR as a critical vulnerability, successful attack on which could prevent U.S. victory.

As with ISR, space-based communications and navigation systems, while providing key functions, also have terrestrially based alternatives and complements. Further, the vast majority of communications satellites are in geosynchronous orbits and, as we have seen, would be much more vulnerable if space-based weapons were deployed nearby; GPS navigation satellites in medium earth orbits would suffer similarly. Thus, the argument that defense of military space assets requires space-based weapons is particularly weak for communications and navigation satellites.

Alternatives to Space-Based Weapons

The USAF *Transformation Flight Plan* itself lists numerous alternative systems to perform the missions also proposed for space-based weapons. The Hypersonic Standoff Weapon and Hypervelocity Missile concepts would allow conventional aircraft to attack on time-critical targets at ranges out to a thousand nautical miles in less than thirty minutes.[49] The Common Aero Vehicle (CAV) program will "be an unpowered, maneuverable, hypersonic glide vehicle . . . able to strike a spectrum of targets, including mobile targets, mobile time sensitive targets, strategic relocatable targets, or fixed hard and deeply buried targets."[50] CAVs could be employed from a number of expendable or reusable platforms, including ballistic missiles, with responsiveness that matches that of space-based kinetic weapons.

The unique weapons effects of space-based eroding rods can also be achieved from ground-based systems. Intercontinental ballistic missiles (ICBMs) can produce impact velocities of seven to eight kilometers per second, about the same as in kinetic attacks from low earth orbit.[51] Eroding-rod penetration capability is a function of rod length: "As long as the rod impacts at a velocity in excess of 3 km/s, the depth it penetrates depends exclusively on the composition of the target and the rod, with only slight differences among specific hard target materials."[52]

Similarly, non-space-based space-control weapons are available. Electronic jamming and blinding can largely negate enemy satellite communications, surveillance, and reconnaissance. These efforts can be ground or air based.[53] The

Air-Launched Anti-Satellite Missile and terrestrially based components of EAGLE would contribute significantly, and computer attack could prevent information dissemination. In any case, current American conventional capabilities and forward basing *already* provide a tremendous relative advantage against hostile space systems—specifically, against ground-based telemetry, tracking, and commanding support sites, downlink reception sites, product-delivery communications systems, and launch infrastructure. If space-based weapons remain prohibited during peacetime, competition initiated during hostilities to place weapons in space would highly favor the nation with superior conventional strike capabilities and strategic depth—that is, the United States.

Satellite vulnerability and the negation options described above make satellite protection a particularly challenging aspect of space control, even if space-based weapons are prohibited. A "near-peer competitor" with ASAT capabilities is highly likely to disable at least some U.S. space assets in low earth orbit. An important portion of the *protect* function identified in the U.S. Space Command's *Long Range Plan* comprises, therefore, reconstitution and repair.[54] A flexible launch mechanism with both inexpensive, partly capable and full-capability replacement satellites could continue essential space missions in spite of losses. Under this construct, after suffering damage to major systems the United States would immediately launch low-cost replacement satellites to restore partial capability, while unmanned aerial vehicles would augment ISR throughout the hostile nation as identified threats to satellites were attacked. This concept is very similar to "Operationally Responsive Space" efforts already under way.[55]

Boost-phase ballistic missile interception is extremely difficult regardless of the medium from which it is conducted; here again, however, there are alternatives to space-based weapons. The airborne and ground-based laser components of EAGLE could be augmented with "airship relay mirrors" operating at up to seventy thousand feet.[56] This arrangement could be effective in confrontations with countries the size of North Korea, but coverage for larger countries, and countermeasures that might be available to them, remains a concern. Other options include ground or air-based high-speed missile interceptors. Mounting such an interceptor on a stealthy, high-altitude, high-endurance UAV would be costly, but perhaps it "would be no more expensive, and would be more technically feasible, than a system which relies on orbital weapons."[57] The possibility that stealth UAVs are in the area could prove more unsettling to a potential attacker than space-based systems, which can be planned against.

Some analyses cast doubt upon the likelihood that any boost-phase intercept systems could be deployed before countermeasures made them ineffective. The American Physical Society recently concluded that neither interceptors nor airborne lasers were likely to be useful against solid-propellant ICBMs, which are more heat resistant and burn faster, reducing engagement time lines.[58] While some of the study's assumptions are open to challenge, there is little doubt that terrestrially based boost-phase intercept against high-end ICBM threats would be challenging.[59] Space-based systems, however, suffer similar drawbacks. The same study calculated that over 1,600 space-based interceptors would be required to eliminate a single solid-propellant ICBM, requiring "at least a five-to ten-fold increase in the current annual U.S. launch capacity."[60] Additionally, most potential countermeasures to and limitations of airborne lasers also apply to space-based laser systems.

Conventional superiority and forward basing provide numerous alternatives having comparable capabilities, in terms of both responsiveness and effect, to space-based weapons. Further, these alternatives confront potential enemies with both conventional superiority and strategic depth.

THE ARMS-CONTROL OPTION

Evidence and analysis show, then, that deployment of space-based weapons will negatively impact U.S. national security—the combination of exploiting alternative capabilities and preventing deployment of space-based weapons represents for the United States the best chance of maintaining and increasing its military advantage. What, then, is the next step?

In the long run, it is unlikely that American self-restraint alone would prevent other nations from pursuing space-based weapons. Some country will eventually calculate that space-based weapons provide unique capabilities or leverage, probably against U.S. dominance. That prospect makes necessary an arms-control regime.

Past arms-control treaty failures, "notably, the Versailles Treaty[,] resulted in part from a failure to devise effective verification arrangements and policies for response to noncompliance."[61] However, verification of a space-based weapons treaty is greatly assisted by the considerable (and highly detectable) energy required to place anything in orbit. Additionally, the relatively low number of space launches and sites, the technical adequacy of current inspection technology, low cost of inspection, and the possibility of delaying the launch if clarification is needed all suggest that the prospects are good for high-confidence verification of any space-based weapons treaty.[62]

There must be a mechanism for response to noncompliance. While most nations would desire to maintain peace, avoid destabilization, and preserve space for peaceful use, rogue states pursuing narrow interests may view weapons in space as a source of leverage over the United States or other nations. While international consultation would be required, unilateral action when a state believes a space-based weapon threatens it should be allowed for. This alone should ensure that all states would assure the international community, particularly the major powers that could interdict a satellite system, of the treaty-compliant nature of their space vehicles. A state refusing to comply could expect rapid counteraction. "Surgical" elimination of an apparently threatening platform in the isolation of space is more likely, and therefore more credible, than the strikes on a state's homeland that might be necessary to counter violation of the Nuclear Non-Proliferation Treaty, the Biological Weapons Convention, or the Chemical Weapons Convention.

While some in the United States inherently distrust arms control, sometimes it is in the nation's interest. The WMD threat has led the current administration not only to call for compliance with the biological and chemical weapons conventions but for strengthening of the Nuclear Non-Proliferation Treaty and the Missile Technology Control Regime.[63]

Unfortunately, the required analysis and decisions have not been made, nor are they in sight—but a national policy with regard to the space basing of weapons is needed now. American leverage to negotiate a favorable treaty will fade over time, and system decisions are currently being made based on presumptions about future environments. In recent congressional hearings, Undersecretary Teets stated that Air Force trade studies are under way to determine if the new Space Based Radar should be in low or medium earth orbit.[64] Its results could be radically different depending on whether its authors assume the presence of defensive counterspace assets or of no space-based weapons at all. Without a cogent policy on space-based weapons, billions of dollars could be spent in a less than optimal manner.

In the military planning process, a mission is refined, friendly and enemy strengths and weaknesses are compared, vulnerabilities are analyzed, and centers of gravity are determined. Potential enemy courses of action are then developed and war-gamed against various friendly options, and the best option is selected. This process recognizes that the enemy's actions are half of any military equation—a reality that, unfortunately, the strongest advocates of space-based weapons appear to have neglected. They have failed to examine even all available friendly courses of action, concentrating instead on "stovepiped," space-centric capabilities.

Before the nation moves forward to develop space-based weapons, it must conduct a thorough military analysis. The U.S. Strategic Command is a logical agent for this critical task.[65] The military analysis should then feed a larger policy debate, with increased emphasis on diplomatic and fiscal factors. But wherever and however it occurs, the debate must fully consider the long-term strategic implications of space-based weapons and potential alternatives to them. To proceed with space-based weapons on any other foundation would be the height of folly.

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