SUMMARY

Space weapons for terrestrial conflict have been the subject of intense debate twice in the modern history of space. The first time, at the beginning of the Cold War, was over the possibility of bombardment satellites carrying nuclear weapons. The second time, at the end of the Cold War, was over the possibility of space-based defenses against nuclear missiles. Now, well past the Cold War, the topic of space weapons seems headed again for public debate, this time based on ballistic missile defense. National policy documents tacitly include the development of advanced technology to improve ballistic missile defense options. The latest space policy document from the Department of Defense (Cohen, 1999) supports "ballistic missile defense and force projection." To this end, the United States is developing space-based laser technology, which is approaching the demonstration phase. For these reasons, as well as the threat that space weapons could pose if developed by an adversary, it is time for public discussion of the subject.

This report does not present an argument either for or against space weapons but instead describes their attributes and sets out a common vocabulary for future discussions. The report classifies and compares these weapons and explains how they might be used. It also explores ways in which the United States and other countries might decide to acquire them and the potential reaction of other countries if the United States or some other nation fielded such weapons. The report dispels some of the myths regarding space weapons to help ensure that debates and discussions are more fact based.

SPACE WEAPONS COMPARED

It is important to understand that "space-based weapons" generally includes several distinct classes of weapons:

- directed-energy weapons
- kinetic-energy weapons against missile targets
- kinetic-energy weapons against surface targets
- space-based conventional weapons against surface targets.

Directed-energy weapons, which destroy targets with energy transmitted at the speed of light over long distances, are in a class of their own. The other three weapon types destroy targets by delivering mass to the target using either the kinetic energy of their own velocity and mass or the stored chemical energy of conventional explosives to destroy the target. Each type of weapon operates in different ways, is suitable for different kinds of targets, has different response times, and requires different numbers of weapons in orbit to achieve the degree of responsiveness required to reach a particular target when needed. Table S.1 summarizes these distinctions.

DIRECTED-ENERGY WEAPONS

Directed-energy weapons include a range of weapons from electronic jammers to laser cutting torches. While jammers need to transmit only enough power to compete with the targeted receivers' intended signals, destroying ballistic missile boosters would require developing and deploying lasers with millions of watts of power directed by optics on the order of ten meters in diameter.

Directed-energy weapons could destroy targets on or above the earth's surface, depending on the wavelength of the energy propagated and the conditions of the atmosphere, including weather. Although the energy a laser delivers propagates at the speed of light, the laser has to hold its beam on a target until energy accumulates to a destructive level at the target. After destroying a target, it can retarget as quickly as it can point at the next missile, should it have sufficient fuel. When defending against a salvo of missiles, the laser will only be able to destroy a certain number of missiles while they

Table S.1

Space Weapon Comparison

	Directed Energy	Mass-to-Target Weapons		
	Laser, radio frequency, particle beam, etc., weapons	Kinetic energy against missile targets	Kinetic energy against surface targets	Space-based conventional weapons
Targets	Soft, located from the surface to space,[a] any speed	Hardened targets above 60 km moving at great speed	Hardened fixed or slow-moving targets on earth	Hardened targets, either fixed or moving at moderate speeds, surface or air
Effects	Range from nonlethal jamming to lethal heating; finite, inherently "thin" defense	Lethal impact	Vertical, limited-depth penetrator	Inherited from conventional munitions
Responsiveness[b]	Seconds	A few minutes	A few hours	About 10 min plus time it takes weapon to reach target after delivery from space
Number of weapons in constellation	Several dozens	Several dozens for each needed to reach a particular target in desired time	About six in reserve for each needed to reach a particular target in desired time	About six in reserve for each needed to reach a particular target in desired time

[a]Depending on wavelength.

[b]Time from weapon release to target effect.

are in their vulnerable boost phase. That number will depend on the laser's distance from the launch position and the hardness of the missile target. The farther the laser weapon is based from the target and the harder the material of the target, the fewer missiles the laser will be able to destroy during boost phase. Because the distance of laser satellites from missile launch points fluctuates in a predictable way, an opponent launching missiles will be able to choose to launch at times that allow the maximum number of missiles to penetrate the defense.

Kinetic-Energy Weapons Against Missile Targets Above the Atmosphere

Kinetic-energy weapons come in two types: those designed to destroy targets outside the earth's atmosphere and those that can penetrate the earth's atmosphere. The first type, described here, could conceivably provide an additional layer of defense against targets that leak through the laser weapons' boost-phase defense. They would destroy targets using the kinetic energy of high-velocity impact and would require very little weapon mass. As with directed-energy weapons, the short response time for missile defense would require dozens of weapons in space for each one within reach of a potential target.

However, kinetic-energy weapons for use against missile targets are handicapped in their ability to respond quickly to the missile threat. They are not able to engage targets below 60 km because the interceptor needs to stay out of the atmosphere. This may mean that the intercept could only occur after the missile's boost phase, when multiple warheads and decoys may have been deployed, creating the potential for saturation an order of magnitude greater than for boost-phase defense with directed-energy weapons.

Kinetic-Energy Weapons Against Surface Targets

Space-based kinetic-energy weapons for surface targets also destroy targets by using their own mass moving at very high velocities. Unlike weapons that engage targets outside the earth's atmosphere, these must be large enough to survive reentry through the earth's atmosphere with a speed high enough to be destructive. To preserve accuracy and energy through reentry, they have to attack targets at

steep, nearly vertical trajectories. This would mean having either a great many weapons in low orbits to have one within reach of a target whenever needed or a smaller number at higher orbits with longer times to reach targets. A reasonable high-altitude constellation would place about six weapons in orbit for each target to achieve response times of two to three hours from initiation of the attack to destruction of the target.

The effort required to deliver one of these weapons to orbit and then to a target would be similar to that required for a large intercontinental ballistic missile (ICBM). Such weapons could be effective against stationary (or slowly moving) surface targets that are vulnerable to vertical penetration of a few meters, such as large ships, missile silos, hardened aircraft shelters, tall buildings, fuel tanks, and munitions storage bunkers. Because of their meteoroidlike speed entering the atmosphere, these weapons would be very difficult to defend against. Although they would be of little interest to the United States because it already has weapons that are effective against this class of targets, kinetic-energy weapons could be desirable for countries that seek global power projection without having to duplicate the U.S. investment in terrestrial forces.

Space-Based Conventional Weapons Against Surface Targets

Space-based conventional weapons would inherit their accuracy, reach, target sets, and lethality from the conventional munitions they deliver. Such weapons could engage a broader range of targets than kinetic-energy weapons, including maneuvering targets and more-deeply buried targets. They could use "old" technology. The systems used to deliver them from space might resemble those developed for the return of film and biological specimens from orbit in the 1960s.

The effort to deliver conventional weapons to orbit and then to a terrestrial target is similar to that for space-based kinetic-energy weapons, but conventional weapons are much more responsive. They would take about 10 minutes from weapon release to deployment in the atmosphere, plus whatever time the conventional munitions need to reach the target after that. Small, precision weapons would be preferred for space basing, since their launch costs are higher than the costs of delivering them from aircraft or ships. It

would take about six weapons in orbit to keep one within 10 minutes of a target on earth.

OVERVIEW OF CAPABILITIES

Taken together, space weapons provide a number of distinct advantages and disadvantages:

Advantages

Access and reach. Space weapons can attack targets that may be inaccessible to other weapons, could provide access to targets without concern for transit of denied airspace, and could provide global power projection to nations that possess them.

Rapid response. In contrast to weapons launched from ships or aircraft, which could take a few days to some weeks to reach a theater of operations far from the United States, space-based weapons could offer response times from several minutes to several hours. Only long-range ballistic missiles can achieve similar performance.

Distance. The great distance of space-based weapons from earth and from other objects in space has two key advantages. First, it makes space-based weapons less vulnerable to attack. Second, it would help distinguish them from terrestrial ballistic missiles carrying nuclear weapons.

Difficulty of defense. Space-based kinetic-energy weapons directed at surface targets are very difficult to defend against because of their very high velocity and very brief flight through the atmosphere. The difficulty is similar to that involved in defeating reentry vehicles from ICBMs but is complicated by the possibility of a much-shorter warning time.

Disadvantages

Static defense. Space weapons are static in the same way that stone fortifications are static; for this reason, they can be saturated by an opponent that is able to concentrate an attack against them. This limitation could be an advantage if a limited defense against a limited threat were needed, one that would be incapable of destabilizing a deterrence relationship with another more-capable opponent.

Stable, observable, predictable orbits. The positions of space-based weapons are predictable. As defenses, their effectiveness will fluctuate over the course of their orbits in predictable and exploitable ways. Stable orbits also mean that a weapon destroyed on orbit would leave a persistent cloud of debris, in a shell of nearby orbits, that would pose a hazard to other satellites.

Logistic expense. Space-based conventional or kinetic-energy weapons require greater transportation effort than do ICBMs delivering the same weapons to targets, roughly equivalent to launching the missile's payload a second time to medium range. Space-based chemical lasers that use technology now in development would consume laser reactants weighing as much as a small satellite to kill a missile target. The space-based laser weapons themselves are extremely large satellites to lift into orbit.

Large numbers required. It would generally be necessary to have multiple weapons in orbit to ensure that one of them would be in the right place when needed. Space-based ballistic missile defenses would require dozens of weapons in orbit for each needed to engage targets at a particular time and place. For other kinds of force application, constellations could be as small as three to six weapons for each needed to engage a target at a particular time and place. This is roughly comparable with terrestrial weapon platforms.

Legal consequences. Existing treaty provisions explicitly restrict the basing of missile defenses or weapons of mass destruction in space. A decision to base missile-defense weapons in space would require changing or abandoning the Anti-Ballistic Missile Treaty and related arms control treaties (as would most national missile defenses contemplated). Use of a space-based weapon against a terrestrial target could result in claims of absolute liability for damage caused under Article II of the Space Liability Convention. However, Article VI of that convention should insulate the launching state from claims of absolute liability by the targeted country if the weapon is used in legitimate self-defense.

USE AND COMMAND

One could imagine special, limited cases in which space forces could be employed in isolation from other forces, but space-based weapons would be most effective used in combination with other

forces. The military functions they might serve include prompt long-range force projection, strikes against highly defended surface targets, and attacks on large ships. The one military function that directed-energy weapons would be uniquely suited for is boost-phase missile defense in locations that cannot be reached by other means.

It should be possible to develop effective concepts for the employment of space-based weapons in the context of joint warfare, but it is critical that they be integrated effectively into the command structure. A commander of theater forces having tactical control over all terrestrial assets devoted to a particular function, such as counter-air or strategic attack, should have similar control over the space assets that contribute to the mission in his area of operations.

UNDER WHAT CIRCUMSTANCES MIGHT THE UNITED STATES ACQUIRE SPACE WEAPONS?

A U.S. decision to acquire space weapons could come about under a variety of circumstances. Among them are:

- defending against a threat to national security posed by an adversary who is undeterred by other capabilities (including the case of denied-area, boost-phase missile defense)
- responding in kind to the acquisition of space weapons by another nation, whether ally or adversary
- acquiring space weapons in coordination with another nation or nations to forestall, control, or influence their independent acquisition of space weapons
- unilaterally undertaking the acquisition of space weapons on the basis of any one of several purposes, for example, to demonstrate global leadership, to protect U.S. and allied economic investments, or to improve the efficiency and effectiveness of military capability.

Although there is currently no compelling threat to U.S. national security that could not be deterred or addressed by other means, the United States could consider space-based weapons as a component of its vision of global power projection for 2010 and beyond.

WHAT MIGHT LEAD OTHER COUNTRIES TO ACQUIRE SPACE WEAPONS?

The opportunity to acquire space weapons is not limited to the United States. Only the option to acquire lethal, directed-energy weapons is proprietary to the United States, and not inherently or indefinitely, but simply as a consequence of the current state of technology.

Why would another country choose to acquire space-based weapons? The report offers answers to that question for several types of countries: peer competitors of the United States; countries that are friends or allies of the United States; non–peer competitors, neither friend nor foe; or a nonstate coalition of entities.

Although motives and opportunities may exist, there is no immediately compelling threat driving any country to choose space weapons, unless it is the overwhelming advantage in terrestrial weapons that the United States enjoys. The United States needs to be aware that a few dozen space-based kinetic-energy weapons against terrestrial targets could threaten its maritime means of power projection. The technology, numbers, and supporting space-based sensing and command and control are reasonably within reach of countries that, like India and China, have only modest spacefaring capabilities. Such space-based weapons could be a high-leverage, asymmetric response to U.S. military strengths.

Before deciding to acquire or forgo space weapons for terrestrial conflict, the United States should fully discuss what such weapons can do, what they will cost, and the likely consequences of acquiring them. The discussion should also address whether other countries might acquire them, which ones would be most likely to do so, and how the United States could discern these developments and respond effectively.