CHAPTER 3

WHAT SHOULD SPACE BE USED FOR? TECHNICAL GUIDELINES

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Currently, satellites serve a multitude of civilian and military functions, from facilitating communications and weather forecasting to providing highly accurate navigational information, and many nations envision making future investments in satellites for such uses. Generally, the missions that are really well suited to space already exist there.

In the US military, there is also a growing interest in broadening the military uses of space to include basing weapons in space, as well as in developing means to attack the satellites of other nations and to protect US satellites from attack. While space has long been home to military systems such as observation, communication and navigation satellites, these new missions would be a departure from long-held norms.

Deploying anti-satellite (ASAT) weapon systems and weapons in space will have serious consequences, many of which will be discussed at the "Safeguarding Space Security: Prevention of an Arms Race in Outer Space" conference. My colleagues and I at the Union of Concerned Scientists have recently completed a report for the American Academy of Arts and Sciences that examines many of the technical and military issues related to the discussion of space security.[1]

In this report, we focus on a number of key questions: What capabilities could ASAT weapons and weapons in space realistically provide? Would these capabilities be unique? How do they compare with alternatives? What would they cost? What options would be available to nations seeking to counter these capabilities? The answers are technical realities that must be considered in any policy analysis of space weapons and ASAT weapons. Unless debate about these issues is grounded in an

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accurate understanding of the technical facts underlying space operations, the discussion and policy prescriptions will be irrelevant or, worse, counter-productive.

In assessing proposed military systems, it is important to distinguish between constraints imposed by financial cost, technology and physics. The cost of operating in space is often high relative to the cost of operating in the air or on the ground. While cost will be important in considering development and deployment, it may not be decisive if the system could provide a unique capability that is deemed important. Available technology places important limits on what systems are currently feasible for a country, but those limits can change over time and do not represent fundamental limitations. Physics, on the other hand, places fundamental limits on space operations that will not change with time and these implications must be taken into account when assessing uses of space.

Several of the key technical conclusions from the report include the following four new proposed military missions for space:

1. attacking targets on the ground or in the air using space-based weapons—the enticing possibility of being able to attack any part of the world quickly and on-demand;
2. intercepting ballistic missiles using space-based interceptors—it is not feasible to stage missile defences from the ground for all potential targets and the Missile Defense Agency is looking to space for this capability;
3. defending US satellites and ensuring US freedom to operate in space: the US military already relies heavily on space for communications, reconnaissance and navigations, and the United States wants to keep these available—for example, precision guided munitions, which have grown hugely in use over the last 10 years, use all three of these types of space assets; and
4. denying adversaries the ability to use space assets—other states have recognized the utility and may want them for themselves.

The first mission, which has attracted considerable public attention and concern, currently appears to be of less interest to the US military than the other missions.

The second mission is an ongoing interest of many missile defence proponents and is leading toward the deployment of prototype weapons in space as part of a space "test-bed". The last two missions reflect the military importance of current US space-based systems. This utility has led to a desire to protect these systems and to deny similar capabilities to potential adversaries.

Before beginning the discussions of the utility of space weapons and how space should be used, it will be very useful to remember two physics facts about satellites (and by satellite, I mean anything that is in orbit). Keeping these two facts in mind will help me illustrate why it is useful to do some things from space and not others.

1. Satellites, by virtue of their great altitude, can see a lot of the Earth at once. This is the biggest driver to putting missions in space—to be able to get a global view. From an airplane, you can see tens of kilometres in your field of view. From the altitude of most weather and intelligence satellites (several hundred kilometres above the Earth), you can see an area on the ground of thousands of kilometres in radius.
2. Satellites must move very fast to stay in orbit. For a comparison, we will go back to the airplane. A jetliner moves about one-quarter of a kilometre per second. A satellite at the altitude of most weather or intelligence satellites moves at 7.6 kilometres per second, 30 times faster than a jet! Because satellites move so fast, it takes enormous effort to change their direction. Thus, satellites are not very good at manoeuvring. And satellites, except under very special conditions, will move with respect to the ground and cannot remain stationary over a given area on Earth.

Thus, space is much better suited to some types of operations than to others. Electromagnetic signals (light and radio waves) can be transmitted over large distances almost instantaneously and with very little energy cost. Space therefore favours activities that entail sending and receiving electromagnetic signals over activities that involve transporting large amounts of mass from the Earth into space or that involve significant manoeuvring in space, which can require a large mass of propellant.

I will briefly discuss the technical issues relevant to these four missions; more detail is available in our paper. But I will spoil the surprise: from our view and from a technical standpoint, only one of these missions has a useful reason to be carried out in space at all. And this capability is unlikely to be unique or decisive.

MILITARY GOAL: ATTACKING TARGETS ON THE GROUND CAN BE DONE AS WELL OR BETTER FROM THE GROUND THAN FROM SPACE, AND AT MUCH LOWER COST

At first it seems like a good idea, since as I mentioned, you can see a lot of the ground from space.

However, the second physics fact is the kicker. Satellites that are close to the Earth move quickly with respect to the ground. For example, to a person on the ground, a satellite in a low-altitude orbit will appear to go from horizon to horizon in about 10 minutes. Thus, soon after a satellite comes over a target, it is gone again, and may not return for hours or days. If the response time necessary to execute a military mission is hours or days, a satellite could be used, but then there are a number of other military options besides satellites.

For the more strict military mission that is envisioned for space-based weapons the time scale is shorter, that is, a response time under one hour to meet its goal and to be competitive with ground-based alternatives. For this timescale, one would need a *number* of satellites, so that as one left a position, another would arrive in position to attack. The exact number of satellites will depend on the altitude of the orbit and the reach of each weapon, but tens of satellites would be required for prompt attack of one target. For example, a constellation, which could attack any point on the Earth within about 30 minutes, would require nearly 100 satellites. If the promptness requirement were relaxed to a 45-minute response time, roughly 50 satellites would still be required.

In addition to needing multiple satellites, there is another important consideration for basing weapons in space: launch. To get a satellite to the high speeds of orbit, it requires an enormous amount of energy—witness space launch rockets. For a space-based ground attack weapon, the satellites must be orbited first, and then de-orbited to return to the ground. This action is enormously costly. For the five nuclear weapon states, the relative cost of a space-based system would be even higher, because they already possess intercontinental range ballistic missiles that could provide a prompt ability to attack ground targets globally.

Efforts to reduce launch costs are continuing, but will not significantly change this situation for the foreseeable future.

MILITARY MISSION ENVISIONED FOR SPACE WEAPONS: MISSILE DEFENCE

The global coverage that space-based weapons can provide is also a key motivation for deploying ballistic missile defence interceptors in space.

In principle, a space-based boost-phase missile defence system could offer capabilities that would not be available with a ground- or air-based system—the ability to intercept an intercontinental ballistic missile during "boost phase", that is, while it is being launched, wherever it is launched on Earth. However, because of the short response time this mission requires, the system would be intrinsically vulnerable to debilitating attack and to being overwhelmed.

The timescale required for boost-phase missile defence is 10 times shorter than that needed for a competitive ground attack weapon—just minutes. And so the number of satellites needed for the mission is 10 times larger and will require many hundreds to thousands of satellites.

Besides the issue with cost, which may not be a conclusive argument since there are no feasible ground-based alternatives for this mission, space-based missile defence has another very serious shortcoming. There are inherent vulnerabilities to a space-based missile defence. To frustrate the defence, the targeted country just needs to be able to "punch a hole" in the system, since only a very few of the hundreds of missile defence interceptors will be near enough to a given ballistic missile launch to intercept the ballistic missile.

A space-based missile defence consists of observable satellites with predictable coverage. An attacker can use a smaller and less valuable missile to attack the missile defence satellite and destroy it, and then send its intercontinental ballistic missile through the "hole". The defence will always be imperfect. If your reaction to this scenario is just to "Make sure there are two interceptors in place!", I draw your attention to the fact that because of the motion of satellites, making sure there are two interceptors in place requires doubling the size of the entire constellation and also points to the ability of an attacker to locally overwhelm the space-based missile defence system.

MILITARY MISSION: SPACE-BASED WEAPONS TO DEFEND SATELLITES

Attacking a space launcher while launching is a virtually identical operation to attacking a ballistic missile while launching. And so the same analysis holds. One cannot reliably deny another country access to space using space weapons.

Using space-based weapons to defend satellites is also subject to the imperfect defence scenario. A "bodyguard" satellite, perhaps based on a micro-satellite, may be able to defend against some of the threats that a satellite would confront, but cannot reliably defend against a concerted or repeated effort by an adversary, especially as the attacks can come quickly.

The best defence is to have a robust satellite system, which has satellites hardened to as many known threats as possible, planned redundancy and spares at the ready; and to have other assets that can provide the lost capability such as uninhabited aerial vehicle-based imagery or laying sufficient fibre optics for communication. This type of planning will need to be done whether or not bodyguard satellites are deployed. In fact, the country with the most dependence on satellites, the United States, is also the best prepared to use other capabilities in the face of their loss.

Making the systems robust has the added advantage of making the satellites less attractive targets because their loss will not pack as big a punch. The commercial satellite industry offers an important example of dealing with component vulnerabilities. The operators of satellite systems must deal with a relatively high rate of failure of space components and minimize the disruption of service to customers.

USING SPACE-BASED WEAPONS TO ATTACK OTHER SATELLITES

In our report, we examine many of the possible modes of attacking satellites, keeping in mind that ASAT weapons will vary in expense, technical expertise required, predictability of success, verifiability of success, whether the effects are temporary or permanent and whether they will be most useful based on the ground or in space. In the table below we show a summary chart of the results. A few of the ASAT techniques are suited to space (the most destructive and permanent techniques), thus space-faring nations will have the most options with regard to ASAT attacks. However, effective ASAT attacks can be mounted from the ground by countries without significant technical expertise; these attacks include many of the temporary ASAT techniques.

	Ground-based	**Space-based**
Uplink jamming	X	
Downlink jamming	X	
Dazzling	X	
Partial blinding	X	X
High-power microwaves		X
Laser damage	X	
Kinetic energy	X	X
Nuclear	X	

Note: “X” indicates that the method of interference is well suited to basing on the ground or in space.

While many ground-based ASAT weapons would be useful for attacking satellites in low-Earth orbits—orbits a few hundred kilometres above the Earth—there are far fewer options for attacking the valuable satellites in geostationary orbits from the ground. Geostationary orbit is 36,000 kilometres above the Earth and is where the orbital period equals one Earth day and the satellite appears to hover over a spot on Earth. It is where a large number of high value commercial and military satellites are stationed.

I want to quickly highlight one of the results from our analysis—it has been suggested by some that a non-space-faring country that possessed a short range ballistic missile such as a Scud could throw up gravel in the path of a targeted satellite and destroy it, and so a non-space-faring nation could hold a space-faring nation's space assets at serious risk. Such an attack would have low probability of success unless the attacker had very good space tracking capability and had very good control over its missile; the understanding of how much control one has over a missile comes from launch tests. Additionally, the owner of the targeted satellite may detect the launch of the attacking missile and move its satellite out of the way; there should be time to do this, and the fuel costs would be modest.

SUMMARY

Based on our analysis of the technical issues, it is possible to circumscribe the space security debate to include the most pressing issues. Of these four potential uses of space that the US military has identified, attacking other satellites is the mission that has some advantages to space basing, and this suggests that there is room for useful discussion and negotiation. The countries that are best able to attack satellites are also those with interest in using space safely themselves. Not to put too fine a point on it, but the United States has more to lose than to gain by opening up space to ASATs and space weapons.

Now, I have been intentionally a bit provocative here. Choices are not always made according to good fiscal sense or technical reality—witness the missile defence programme, which is enormously costly and is without demonstrated capability. However, there are a number of reasons why space weapons could take a different course from missile defence.

Also, I hope that these comments serve to focus our efforts. The initial move to put weapons in space will likely be ASAT weapons or test assets for other programmes such as missile defence—that is, test assets that will have a latent but provocative ASAT capability.

Note

1 The report is available at <www.ucsusa.org/global_security/space_weapons/>