Securing the Skies

Ten Steps the United States Should Take to Improve the Security and Sustainability of Space

Union of Concerned Scientists
Citizens and Scientists for Environmental Solutions

SECURING THE SKIES

Ten Steps the United States Should Take to Improve the Security and Sustainability of Space

AUTHORS

Laura Grego and David Wright, Union of Concerned Scientists

ADVISORY COMMITTEE

Nancy Gallagher and John Steinbruner (University of Maryland);
Ben Basely-Walker, Victoria Samson, Brian Weeden, and Ray Williamson (Secure World Foundation);
Kurt Gottfried and George Lewis (Cornell University); Jeffrey Lewis (New America Foundation);
and Gregory Kulacki and Stephen Young (Union of Concerned Scientists)

Union of Concerned Scientists
Citizens and Scientists for Environmental Solutions

NOVEMBER 2010

Laura Grego is a senior scientist in the Global Security Program of the Union of Concerned Scientists (UCS).

David Wright is a senior scientist and co-director of the UCS Global Security Program.

The Union of Concerned Scientists is the leading science-based nonprofit working for a healthy environment and a safer world. UCS combines independent scientific research and citizen action to develop innovative practical solutions and to secure responsible changes in government policy, corporate practices, and consumer choices.

The UCS Global Security program includes scientists and policy analysts who work to reduce some of the biggest security threats facing the world today, including the risks posed by nuclear weapons, nuclear terrorism, and space weapons. We work with scientists around the globe to increase international understanding of these issues and to foster and strengthen efforts to increase international security.

More information about UCS and the Global Security Program is available on the UCS website at *www.ucsusa.org/nuclear_weapons_and_global_security.*

The full text of this report is available on the UCS website at *www.ucsusa.org/securingtheskies*.

Designed by:
DG Communications, Acton, MA, *www.NonprofitDesign.com*

Cover image: ©iStockphoto.com/loops7

Printed on recycled paper.

Table of Contents

Acknowledgments

The production of this report was aided by the generous support of the Secure World Foundation.

The authors are grateful to the members of the advisory committee for imparting their knowledge and insights to this report. We greatly appreciate the time these distinguished colleagues spent in the initial scoping of the project and in reviewing the manuscript; their contributions significantly enhanced the final product. The authors also express their thanks to Theresa Hitchens, Michael Krepon, and Ambassador Paul Meyer (retired) for their independent expert review of the report.

In addition, we would like to thank Steven Marcus, our editor, for improving the clarity and readability of the text and Bryan Wadsworth and Heather Tuttle for their persistence and expertise in overseeing the editing and production process.

The opinions expressed in this report are solely the responsibility of the authors.

Acronyms Used in This Report

ABL	U.S. Airborne Laser program
APS	American Physical Society
ASAT	Anti-satellite
CD	United Nations Conference on Disarmament
CFE	U.S. Air Force Commercial and Foreign Entities program
CFR	Council on Foreign Relations
DARPA	Defense Advanced Research Programs Agency
DOD	U.S. Department of Defense
GEO	Geostationary orbit
GMD	Ground-Based Midcourse Defense system
GPALS	Global Protection Against Limited Strikes missile defense system
GPS	Global positioning system
HCOC	Hague Code of Conduct
IADC	Inter-Agency Space Debris Coordination Committee
ITAR	International Traffic in Arms Regulations
ITU	International Telecommunication Union
KE ASAT	Kinetic energy anti-satellite weapon
LEO	Low Earth orbit
MDA	Missile Defense Agency
MFP	Major Force Program
NASA	National Aeronautics and Space Administration
NRO	National Reconnaissance Office
NSP	National Space Policy
OST	Outer Space Treaty
PAROS	Prevention of an Arms Race in Outer Space
SBI	Space-based interceptor
SSA	Space situational awareness
SSN	U.S. Space Surveillance Network
TCBM	Transparency and confidence-building measures
THAAD	Terminal High Altitude Area Defense interceptors
UN	United Nations

CHAPTER 1

The Proposal in Brief

The United States has a vital interest in ensuring the sustainability of the space environment, keeping satellites safe and secure, and enhancing stability not only in space but also on the ground. Achieving these goals is becoming more challenging, however. The number of countries and companies with satellites or other important interests in space continues to grow, as does the range of purposes for which satellites are being used. The United States cannot address these space-related issues on its own, therefore, but its international leadership is essential.

The need for constructive action has also become more urgent, as satellites provide information and other services that are increasingly critical for national security, economic vitality, and human well-being. Yet satellites are by nature vulnerable to threats, whether intentional or unintentional, and concerns are mounting. Moreover, deliberate or careless behavior could cause long-term damage to the space environment that may hinder its use for years to come. Recent trends and events—including demonstrations of anti-satellite (ASAT) capability, a collision between satellites, and a dramatic increase in dangerous space debris—make clear that the space environment needs more protection, that satellites face growing risks, and that space activities may be a potential source of mistrust and tension.

Policy makers in the United States and around the world are recognizing that existing international legal agreements and norms are not adequate to ensure the security and sustainability of space. They also realize the pressing need for international discussions to address issues such as the potential military uses of space and the ways in which they could exacerbate geopolitical tensions and cause conflicts.

For its part, the Obama administration has been developing its space priorities and policies. The guiding principles laid out in the president's National Space Policy (NSP), which was released in June 2010, show that the administration is aware of these issues and is open to addressing them by means of international engagement and cooperation. Making significant progress, however, will require the administration to formulate detailed follow-on policies and take specific actions. Progress will also require sustained attention and leadership at the highest levels of government. Otherwise, business-as-usual attitudes and narrowly defined interests are likely to impede progress.

Forward-looking policies will need to be tailored not just to ensure national security but also to support civil and commercial space activities, which today comprise the predominant uses of space. These policies' central goals should be to minimize threats to all satellites, foster coordination of space activities to optimize the utility of space and protect the space environment, and prevent space activities from increasing tensions between countries that could lead to arms buildups or conflicts.

While the issues are complex and the long-term path for addressing them may not be clear, this report recommends 10 practical near-term steps that the United States should take in order to move things in the right direction—toward establishing useful processes and relationships and creating a favorable environment for progress.

The steps build on several concepts, which we discuss in greater depth throughout this report:

- Because of the special nature of space, its security and sustainability cannot be achieved unilaterally. Substantial international engagement, involving coordination and cooperation among its users, is essential.
- Given its preeminence in space, the United States must provide leadership if progress is to be made.
- While national security issues are important, U.S. space policy must better balance military, commercial, and civil interests in space.
- Protecting satellite capabilities requires a range of strategies, including diplomatic approaches to limit threats and "smart planning" aimed at reducing the vulnerability of satellite systems to attack and disruption.

In this report, increasing "space security" means reducing threats to satellites—including military attacks, collisions with other satellites or space debris, or electromagnetic interference—and lowering the risk of arms races or conflicts, whether in space or on the ground. Increasing "space sustainability" means protecting the future space environment by controlling the growth of space debris and more generally by managing activities in space so as to ensure countries' ability to use it in beneficial ways.

Ten First Steps

Developing an international consensus and an institutional framework for enhancing the security and sustainability of space may take many years. Perceived difficulties with the ability to verify agreements, for example, and the lack of political trust between countries will likely limit the scope and pace of progress, at least initially. However, establishing a vision and initial goals for international discussions on space, and getting countries to agree to address these issues, are essential for moving ahead in the meantime. The United States can make a critical contribution by taking steps to establish the underlying conditions that are needed.

Specifically, the Obama administration should take 10 steps to help move the world toward a more secure and sustainable future in space:

1. Elaborate on the administration's National Space Policy and publicly articulate its approach and goals, both to provide clear high-level guidance for U.S. policy makers—military and nonmilitary alike—and to clarify U.S. intentions for the international community.

   The approach and goals should:
   - Emphasize international cooperation rather than unilateral actions.
   - Reaffirm that all countries have the same rights to the peaceful use of space.
   - Take a more balanced view of commercial, civil, and military uses of space.
   - Support and reinforce long-held norms against stationing weapons in space and against disabling or destroying satellites.

2. Declare that the United States will not intentionally damage or disable any satellites operating in accordance with the Outer Space Treaty, and pledge that the United States will not be the first to station dedicated weapons in space. Strongly urge the other space powers to make parallel pronouncements.

3. Declare that the United States will not develop or deploy space-based missile defense interceptors. Pledge not to use any element of the U.S. land-, sea-, or air-based missile defense systems to attack or destroy a satellite. And review plans to sell systems with this capability to other countries in order to ensure that any missile interceptors sold by the United States will not be used as anti-satellite weapons.

4. Vigorously pursue a capability-preserving strategy and make satellites less attractive targets by reducing their vulnerabilities; building in redundancies; improving the capacity to rapidly reconstitute key functions; and developing air-, space-, or ground-based backup systems.

5. Modify U.S. export-control and related regulations to reduce unnecessary barriers to commercial and civil space cooperation.

6. Begin discussions with the international community to identify the most productive venue and agenda for negotiations on space security and sustainability. Play a leading role in setting up these discussions.

7. Assemble a negotiating team and begin building the diplomatic, technical, legal, and other kinds of expertise needed to support negotiations. Encourage other countries to do so as well.

8. Appoint a high-level expert panel to review and prioritize space situational awareness missions and to recommend corresponding improvements to U.S. space surveillance capabilities.

9. Create a standing program to assess and improve options for verifying compliance with potential space security agreements.

10. Develop and implement transparency measures aimed at improving safety and predictability in space.

CHAPTER 2

The Problem

The Space Age is now a half-century old, but while the space-faring countries during this time have negotiated broad principles regarding the use of space, only rarely have they pursued explicit rules or coordination mechanisms to ensure these principles' fulfillment. The matter did not seem to be urgent, given the perceived vastness of space and the relatively limited number of uses and users. Today, however, for a number of important reasons (discussed below) the need for a more comprehensive and forward-looking approach to space management is pressing.

Space Is Increasingly Important—and Crowded

Space has become a crucial global resource, offering a broad range of uses. It is a critical link in the global economy; it provides essential civil functions such as weather prediction, resource and disaster monitoring, navigation assistance, and global communications; and it is integral to U.S. military activities.

But the space environment has changed significantly in recent decades as many more satellites have been placed in orbit.[1] While space once was the exclusive province of the superpowers, today many other countries also own and operate satellites. More than 50 states own a large share in a satellite, and even remote and poorly developed parts of the world use some satellite services.[2] And it is not only nations that own satellites. Businesses, including international consortia, also have sizeable space investments.

The expanded use of space has led to a large growth in the amount of space debris orbiting Earth, most of which is located in the same regions of space that are heavily used by satellites. Depending on its altitude, debris can stay in orbit for decades or even centuries, thus accumulating over time. Currently, more than 21,000 pieces of debris large enough to be detected by the U.S. Space Surveillance Network (SSN) are being tracked as they orbit Earth. As a result, managing traffic in space and controlling and removing debris are becoming increasingly important issues.

The change in space is also qualitative. Commercial satellite companies now offer important capabilities, including high-resolution satellite imagery and secure satellite communications, that used to be the sole province of governments. Currently, commercial satellites carry the majority of satellite communications that support U.S. and coalition military forces, and they provide a growing portion of satellite imagery for other U.S. defense and intelligence missions. This widening range of services provided by satellites now underpins essential aspects not only of military operations but also of civilian, scientific, and economic life.

1 As of October 1, 2010, more than 900 actively working satellites were in orbit. Nearly half of them were owned by or registered in the United States (UCS 2010). The number of actively operating satellites has grown by about 50 percent during each of the last two decades.

2 While more than 50 states own satellites—since 2007, Colombia, Switzerland, Turkey, Venezuela, and Vietnam have joined this no-longer-exclusive club—far fewer have the capability to independently get satellites to orbit. There are 10 such countries (depending on how the capability is assessed): China, France, India, Iran, Israel, Japan, Russia, Ukraine, United Kingdom, and United States. A number of other countries have attempted launches but have so far been unsuccessful.

Particularly profound are the changes in space use for national security purposes. In the early decades of the Space Age, military satellites were used primarily for reconnaissance, early warning of missile launch, collection of weather data, arms control verification, and communications.[3] While they still perform these mainly passive support functions, as suggested above, satellites now play a much more active role in "force enhancement" during wartime. They are extremely valuable for missions such as identifying targets, guiding precision strikes, assessing battle damage, and facilitating inter- and intra-theater communications for command and control. While these applications are pursued especially by the United States, other countries are increasingly able to use satellites for such active military support as well.

At the same time, the United States and other countries are exploring ways to *deny* an adversary the use of satellites during a conflict. And some are weighing the costs and benefits of placing weapons in space to attack other satellites as well as ballistic missiles or targets on Earth.

Risks Are Growing

The growing population of satellites and resultant accumulation of debris, as well as the greater importance of satellites, are leading to greater risks.

First, the crowding of space increasingly poses collision hazards. The high speeds of objects in orbit render debris even the size of a marble capable of damaging or destroying a satellite. Three active satellites are known to have been hit by debris in the past 15 years, and it is estimated that under current conditions a collision between an active satellite and a piece of debris larger than a marble will occur every two to three years (Wright 2009).

The possibility of unintentional interference between satellites—not just physical collisions between satellites but also electromagnetic interference—is also increasing, given that the crowding of space has not been accompanied by a commensurate improvement in coordination or "space traffic management." While satellite positions and frequencies in the distant geostationary orbit (GEO) are managed by the International Telecommunication Union (ITU),[4] no comparable coordination effort exists in closer orbits, even though collisions at these lower altitudes would be at higher speeds and pose greater debris risks.

Second, the innate vulnerability and growing value of satellites may render them increasingly attractive targets in a conflict. Satellites are susceptible to deliberate attack because they follow predictable orbits, have limited protections, are widely visible from the ground, and represent a long-term loss of capability—at present, repair is unlikely and replacement is costly and time-consuming. And with time, more countries will acquire the technical abilities to attack and interfere with satellites. This is particularly likely in that a number of emerging technologies, such as hit-to-kill missile defense interceptors and a spacecraft's ability to rendezvous with another without its cooperation, are "dual-use"—applicable to peaceful and aggressive uses alike.

While a satellite owner would certainly protest the deliberate or careless interference with its asset, satellites do not currently have clearly elaborated legal protections nor is there a systematic process for addressing grievances.[5]

3 While the first satellite launched by the United States was technically a communications satellite, the first set of communications satellites intended for operational capability were the Initial Defense Satellite Communication Program satellites, launched between 1966 and 1968, This experimental system transmitted voice and photography to support military operations in Southeast Asia see USAF n.d.).

4 The ITU's Radiocommunication Sector (ITU-R) is one of the three divisions of the ITU. This sector coordinates the use of the radiofrequency spectrum between users in different countries, and it allocates frequencies and orbital positions of satellites using radio communications. It also investigates complaints about frequency interference and formulates recommendations to resolve such problems. Within each country, there may be additional coordination and regulation as well by domestic agencies.

5 The ITU does have a process for resolving radiofrequency-interference disputes. And, while underused, the OST's Article IX provides for consultations in the case one country believes the other's activities would interfere with the peaceful use of outer space. Beyond these, no formal system exists.

Third, threats to satellites can amplify the risks of other undesirable outcomes, such as the creation or escalation of terrestrial crises. The development of ASAT capabilities by one country could create enough suspicion and tension to spur the development of ASAT weapons by others. Because so much of satellite and space-launch technology is dual-use, development of space systems would increase the chances of dangerous misinterpretations, especially in the absence of clearly stated policies and meaningful communication between countries.

Moreover, if ASAT weapons are being developed and tested, the loss of an important satellite during a time of political tension could be interpreted—rightly or wrongly—as an attack. Quickly determining the reason for the satellite's disruption might be difficult or impossible, and this incomplete information together with the absence of reliable channels for communication between countries that are not close allies could exacerbate the crisis even further, possibly leading to its escalation. Recent "war game" conflict simulations confirm that such a satellite loss could have very serious consequences.[6]

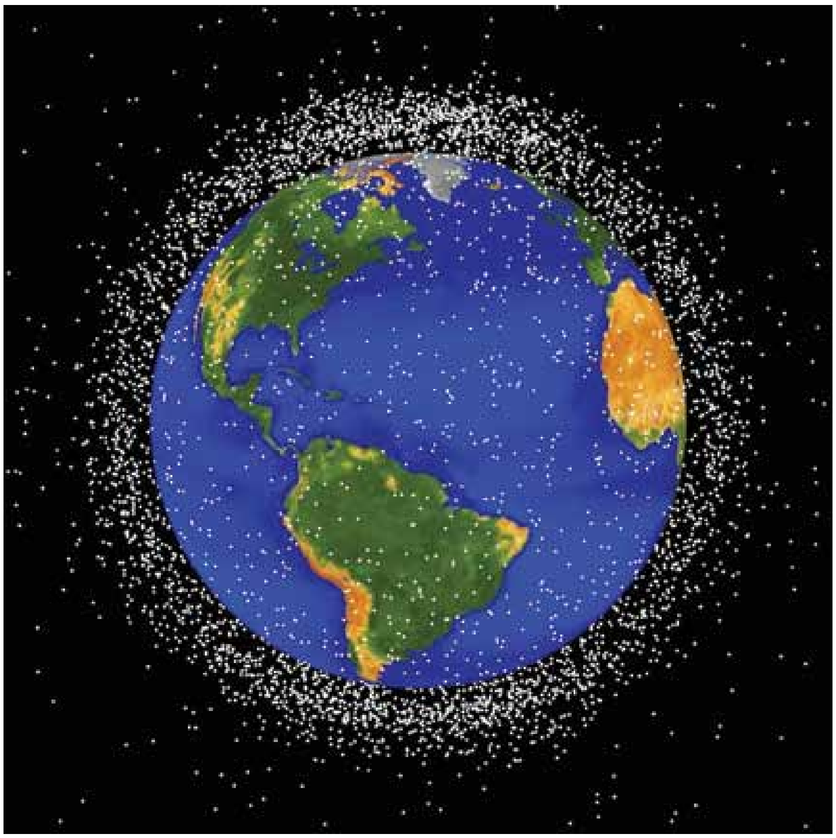


FIGURE 1. Accumulation of Debris

The white dots denote currently tracked objects in low Earth orbit, about 95 percent of which are orbital debris. The orbital-debris dots are not scaled to Earth; they are scaled according to the image size of the graphic in order to optimize their visibility. Computer-generated image courtesy of NASA Orbital Debris Program Office.

The Need for Action Is Urgent

Without near-term attention, some of the aforementioned issues could become much more difficult to address in the future.

Despite the development of international guidelines for slowing the accumulation of debris, the amount of large debris (greater than 10 centimeters in size) in orbit has grown by 50 percent in the past four years, primarily because of events that would not have occurred had there been full compliance with these guidelines (see Figure 1). Half of the known collisions between objects in space have occurred since 2005 (Wright 2009). (See Table 1.)

In 2009, the first collision of two intact satellites, an active Iridium satellite and a defunct Russian Cosmos satellite, produced a large amount of debris. This event demonstrated the need for better coordination among space users and better monitoring of space objects. As more countries launch satellites, the need becomes even more pressing for establishing safety standards—pertinent both to launches and to the satellites themselves—and for improving compliance with debris-mitigation guidelines.

The increase in the number of satellites and debris is also highlighting the existing weaknesses of the SSN to accurately track them in a sufficiently timely manner, in turn limiting the ability of the United States to unilaterally manage space traffic and predict possible collisions.

6 The Schriever war games are battle simulations organized by the Pentagon to assist with military planning, and the increasingly detailed inclusion of space assets and operations in these games has illuminated a number of concerns. For example, the sudden loss of a critical space asset could dramatically escalate a crisis; and the unclear language of deterrence and dissuasion regarding space could easily cause intentions to be misread.

TABLE 1. **Known Collisions Between Objects in Orbit**

Year	Description
1991	**Inactive Cosmos 1934 satellite hit by catalogued debris from Cosmos 296 satellite**
1996	**Active French Cerise satellite hit by catalogued debris from Ariane rocket stage**
1997	Inactive NOAA 7 satellite hit by uncatalogued debris large enough to change its orbit and create additional debris
2002	Inactive Cosmos 539 satellite hit by uncatalogued debris large enough to change its orbit and create additional debris
2005	**U.S. rocket body hit by catalogued debris from Chinese rocket stage**
2007	Active Meteosat 8 satellite hit by uncatalogued debris large enough to change its orbit
2007	Inactive NASA UARS satellite believed hit by uncatalogued debris large enough to create additional debris
2009	**Active Iridium satellite hit by inactive Cosmos 2251**

Source: NASA 2010

The events highlighted involved active satellites. The events in boldface text occurred between two objects that were tracked by the U.S. Space Surveillance Network and listed in its catalogue of orbiting objects. During 2009, NASA-related satellites performed nine collision-avoidance maneuvers.

While the 1967 Outer Space Treaty (OST) provides that all countries are free to use space for peaceful purposes so long as they respect the interests of other space users[7] and operate in accordance with international law, it does not explicitly prohibit deliberate ASAT attacks on satellites or prevent the testing of ASAT weapons in ways that pose risks to other space users. The OST bans orbiting nuclear weapons, but it does not outlaw the possession of other kinds of space weapons. Additionally, few limits or guidelines exist on technologies suited to ASAT use, such as hit-to-kill missiles and high-powered satellite-tracking lasers. The demonstrations of destructive ASAT capability by China in January 2007 and the United States in February 2008, along with recent Indian statements of interest in developing an ASAT capability,[8] indicate that the long-standing restraint regarding such systems has been weakened.[9] Devising effective limits on ASAT capabilities or use becomes increasingly difficult as more weapons are developed and tested and more countries develop policy rationales and military doctrine for using them.

The International Response Has Been Inadequate

No country has used dedicated space weapons[10] or intentionally destroyed another's satellite, and space users have developed voluntary debris-mitigation guidelines to help protect the space environment (NASA 2007). Nevertheless, the failure to develop mechanisms for meeting the growing challenges—such as avoiding collisions between satellites and between satellites and debris, as well as resolving potential conflicts over the uses of space—are serious causes for concern. Cooperative relationships

7 Article IX of the OST specifies that signatory countries "shall conduct all their activities in outer space, including the Moon and other celestial bodies, with due regard to the corresponding interests of all other States Parties to the Treaty."

8 V.K. Saraswat, director-general of the Defence Research and Development Organisation (part of India's Ministry of Defence), stated in a televised press briefing at the 97th Indian Science Congress that India has started research on a system that would destroy satellites by means of a kill vehicle operating just above the Earth's atmosphere (De Selding 2010).

9 China's destructive ASAT test was the first by any country in 20 years, and it created more persistent debris than any previous event in space. And the satellite interception by the United States vividly illustrated the intrinsic ASAT capabilities of missile defense systems.

10 The term "space weapon" commonly refers to:

(1) Any weapons (whether land-, sea-, or air-based) able to damage a satellite or interfere with its functioning—i.e., ASAT weapons. Technologies that interfere with a satellite's ground stations or communications receivers are typically not considered ASAT weapons.

(2) Any space-based weapons intended to attack targets in space or on the ground. These technologies include space-based ballistic missile defense interceptors and ground-attack weapons.

between space-faring nations that might provide reassurances and clarity about each other's intentions in space—between the United States and China, for example—have also been neglected.

The OST—the foundational document of space law—and its supporting agreements set out the essential principles behind space governance. But its usefulness in addressing urgent contemporary issues is limited by the minimal attention the space powers have given to refining the treaty's principles and detailing its rules in the more than four decades since it was signed. Important questions—such as what protections satellites should have from damage and the space environment should have from deterioration, and under what conditions—have been left without clear answers. Additionally, the OST did not set up a forum for resolving differences in interpretation.

Although space was a venue for competition during the cold war, and the United States and the Soviet Union explored means of countering each other's capabilities in space (see, for example, Grego 2010), the two countries both considered unrestrained military competition in space to be counterproductive. Since the cold war ended, civil space cooperation arguably has been one of the most successful aspects of the U.S.-Russian relationship. The two countries have worked together on the International Space Station since the early 1990s, they have cooperated on space launches,[11] and bilateral discussions have been initiated in the wake of the Iridium-Cosmos collision of 2009 to better coordinate space operations. But dialogue on more challenging space issues has yet to be pursued.

The United States suspended space cooperation with China more than a decade ago, ending a cooperative space relationship that had begun under President Ronald Reagan; for 10 years, China launched U.S. commercial satellites despite worsening relations between the two countries. However, in 1999, following the Cox Commission report,[12] this arrangement ceased. In recent years, the possibility of cooperation on civil and commercial projects has been further complicated by U.S. concerns about China's possible military uses of space.

The U.S. Response Has Been Counterproductive

Concerns about vulnerability in space has led some in the United States to advocate "space dominance"—the United States' exploitation of its lead in military space capabilities to physically control who could use space and for what purposes.

Developing the ability to dominate space in this way against a determined adversary is not realistic, however. For a host of practical and technical reasons, the proposed new missions—controlling the use of space via destructive ASAT weapons[13] and satellite-defending weapons and attacking ground targets and ballistic missiles from space—would be ineffective, unreliable, or cost-ineffective when compared with other options. (See the Appendix for a summary of this argument; for an extensive discussion, see Gallagher and Steinbruner 2008 and Wright, Grego, and Gronlund 2005.)

At the same time, U.S. pursuit of new space weapons would be counterproductive. Even while understanding the weaknesses of these systems, other countries may still view their development—and the intentions behind their development—as threatening, since even nominally defensive weapons have intrinsic offensive capabilities. Such a U.S. effort could therefore generate tensions and spur some

11 In 1995, the United States and Russia formed a joint venture called International Launch Services to launch satellites by means of Russian Proton rockets. An industrial consortium (called Sea Launch) of four companies from the United States, Russia, Ukraine, and Norway also was established in 1995 (Sea Launch Company LLC 2009).

12 In January 1999, a select committee of the U.S. House of Representatives chaired by Representative Christopher Cox issued its *Report on U.S. National Security and Military/Commercial Concerns with the People's Republic of China*. The report claimed that China had stolen or otherwise illegally obtained missile and space technology from the United States that would improve China's military capabilities; it also maintained that many of these illegal transfers were the result of the commercial satellite launches (U.S. House of Representatives 2010).

13 "Destructive" ASAT weapons, which permanently disable satellites, are distinguished from those that interfere with or temporarily disable them. Destructive ASAT weapons include but are not limited to "kinetic energy ASAT" weapons, which destroy a satellite via the force of impact.

of these countries to pursue space weapons of their own. It also could undermine the cooperation needed to solve some of the most pressing day-to-day risks in space and the diplomatic efforts for best addressing longer-term issues.

While using space weapons for attacking or interfering with space assets might seem beneficial in some specific situations, from a broader perspective the United States would be more secure in a world in which such activities were limited or banned. But although the United States has thus far allocated few resources to the development of space-based missile defense, ground attack weapons, and space-based ASAT weapons, it also has not formally rejected these options. Moreover, it has dismissed attempts to place legal limits or restrictions on these space-based options or on other types of ASAT capabilities.

In particular, the United States refused during the past decade to discuss diplomatic measures to enhance space security at the Conference on Disarmament (CD)—the international community's body for negotiations—despite the nearly unanimous expressed support of all other countries to begin negotiations on Prevention of an Arms Race in Outer Space (PAROS).[14] In 2006, a provision was even added to the NSP to the effect that the United States would oppose the development of any new legal regimes or other restrictions on U.S. access to or use of space, including any arms control proposals that would impinge on U.S. military space acquisitions or operations.

Christina Rocca, U.S. ambassador to the CD, told the delegates in Geneva on February 13, 2007, that "we continue to believe that there is no arms race in space, and therefore no problem for arms control to solve" (Rocca 2007). And in prepared remarks on October 8, 2008, she stated that "the United States has consistently opposed space arms control proposals, as the existing outer space regime is sufficient to guarantee all nations unfettered access to, and operations in, space" (Rocca 2008).

Categorical rejection of all international efforts to address space security issues has been counter to U.S. interests, however. By forgoing the possibility of new mutually agreed-upon rules or constraints, the United States—rather than keeping its options open—actually limits what futures are possible. Without constraints on ASAT weapons, for example, threats to satellites will continue to proliferate and mature, requiring the United States to expend more effort securing satellites and leading to less predictability and stability in crises.

Fortunately, the Obama administration, as stated in its NSP of June 28, 2010, indicates greater openness to diplomatic processes at the CD and elsewhere:

> *"The United States will pursue bilateral and multilateral transparency and confidence-building measures to encourage responsible actions in, and the peaceful use of, space. The United States will consider proposals and concepts for arms control measures if they are equitable, effectively verifiable, and enhance the national security of the United States and its allies."*

Yet while the Obama administration's new NSP dropped the categorical opposition to arms control that characterized the 2006 NSP, it did not indicate that it would take an active leadership role; the new policy states that the United States will *consider* proposals for arms control, but it says nothing about originating them. In line with this weak support for negotiated agreements, Frank Rose (deputy assistant secretary in the U.S. State Department's Bureau of Arms Control, Verification and Compliance) stated in a speech to the CD that the United States continued to support a "nonnegotiating" discussion mandate on space, should a program of work be adopted (Rose 2010).

14 Each year since 1983, a resolution affirming efforts toward "Prevention of an Arms Race in Outer Space" has been overwhelmingly passed by the First Committee of the United Nations General Assembly in New York. During that time the United States abstained from voting 20 times and voted "no" 8 times (most recently from 2005 to 2008)—sometimes alone, sometimes in the company of a few other states.

Additionally, the new NSP suggests that the administration is primarily interested in voluntary transparency and confidence-building measures (TCBMs) rather than binding legal agreements. And the policy appears to continue to emphasize military approaches, as opposed to diplomatic approaches, to protecting U.S. space capabilities. For example, it lays out much more detailed roles for the secretary of defense and director of national intelligence than for the secretary of state.

The trend in the United States over the past decade to prioritize military uses of space over commercial and civilian uses has had other counterproductive effects as well. An important example is the imposition of a broad set of strict export controls on space technology in the late 1990s. While restriction of some sensitive technology is in the U.S. national interest, the export laws are arguably so broad that they interfere with commerce and collaboration that is not sensitive.[15] This approach has had a marked effect on an industry that is highly international in nature; in the decade since the export controls were put in place, the U.S. commercial satellite industry has lost a significant share of the market that it once dominated. Moreover, the U.S. academic space research community is finding that highly talented foreign space scientists seek positions elsewhere (such as in Russia, China, and India), where the restrictions on collaboration are less burdensome (Kennedy 2010).

Particularly strict provisions have essentially ended cooperative space projects between the United States and China. As noted earlier, this suspension departed from the previous U.S. policy established by the Reagan administration and continued by the George H.W. Bush and Clinton administrations, which saw value in working with China on cooperative civilian space programs.

However, the United States has more productive options for moving ahead. Developing a better balance of civil and military uses of space would improve the health of the U.S. commercial and scientific space sectors. And a better balance of military and diplomatic approaches to resolving space issues would provide a much broader set of tools for enhancing the security of the United States and for sustaining the space environment. Toward those ends, the United States should work with other countries to coordinate activities in space, avoid actions that interfere with stability and predictability in space, and pursue opportunities to strengthen mutually beneficial strategic relationships.

15 Following the release of the Cox Report in 1998, satellites and related technology were mandated by legislation to be classified as munitions, which required that their export be controlled by the State Department. Of all the items on the United States Munitions List, only satellites have been mandated as munitions by law rather than regulation.

CHAPTER 3

Moving Ahead

The Obama administration has pledged international cooperation in space and has even stated its intention to reinvigorate U.S. leadership in that domain. But so far its actions have been incommensurate with the urgency of space security and sustainability issues. In the spirit of correcting that insufficiency, this report recommends a set of 10 near-term steps that the United States should take to help put the world on a path toward reaching several long-term goals:

- Minimization of threats, whether intentional and unintentional, to all satellites (civilian, commercial, and military).
- Coordination of activities in space to optimize its utility.
- Prevention of space activities that could increase tensions between countries and possibly lead to arms buildups or the sparking or exacerbation of crises on the ground.

The 10 steps are designed to help establish useful processes and create a favorable environment for progress while keeping future options open. These recommendations are grounded in a few important concepts, which we discuss below.

Security Cannot Be Achieved Unilaterally

The laws of physics dictate that operating in space differs in meaningful ways from operating on land, sea, and air. Successful space policy must take this fact into account.

One consequence of these physical laws is that satellites travel in predictable and repeated orbits and are visible to much (or all) of Earth. Tracking from the ground allows an observer to predict a satellite's future position. As a result, it is intrinsically vulnerable—a determined adversary will have regular opportunities and multiple means to interfere with that satellite.

A second consequence is that because all satellite orbits encircle Earth, satellites can interfere with each other. Orbits at the same altitude may cross, creating the potential for collisions between orbiting objects, whether satellites or debris. Additionally, the radio signals sent to or from a satellite can interfere with another one that is near or passing by, as recently occurred with the Galaxy 15 satellite (Weeden 2010). This intrinsic entanglement of orbits means that the safe operation of satellites requires coordination between all operators.

A third consequence is that the careless treatment of the space environment by one user can affect all other users. For example, space debris created by any country, whether intentionally or unintentionally, can threaten all satellites at the same altitude. Because debris is the detritus of space operations—it includes spent rocket bodies, defunct satellites, loosened components, and pieces of fragmented satellites—this material typically orbits Earth in many of the same orbits as active satellites. And because debris can stay in orbit for decades or centuries, depending on the altitude, it accumulates over time and poses an ever-increasing threat to satellites.

Given these realities, it is clear that the United States cannot create a lasting and secure space environment on its own. Avoiding inadvertent physical or electromagnetic interference, which is particularly pressing in light of its day-to-day threat to satellites, requires a multilateral approach.

Some coordination already exists. Countries have long agreed to coordinate orbital locations and transmission frequencies in GEO to prevent interference between satellites and more generally to optimize the use of GEO (i.e., squeezing in the maximum number of satellites). This voluntary coordination is managed by the aforementioned ITU, which develops regulations for geosynchronous satellites, oversees the process of assigning orbital slots, and handles complaints and conflicts.

Cooperation is also necessary to address the growing threat from space debris. Providing leadership in the international efforts to address this problem, the United States began working with other countries in the 1990s to develop voluntary debris-mitigation guidelines through the Inter-Agency Space Debris Coordination Committee (IADC);[16] these guidelines were adopted by the United Nations in 2007 (NASA 2007). This mitigation effort has been partially successful and, like the ITU, illustrates the benefits of international coordination. But the IADC guidelines are not binding, and no mechanisms are in place to enforce them. As a result, they are not as successful in stopping debris production as they could be, and not as effective as is necessary.[17]

Debris and overcrowding in space are somewhat less of a problem when satellite operators know where other objects are and can avoid hitting them. Better cooperation in monitoring the orbits of space objects would thus increase the ability of the United States and all other space actors to use this environment safely and efficiently. Toward that end, accurate tracking information about active satellites and debris is needed for managing traffic and coordinating activities in space, and in particular for preventing collisions.

The United States has by far the most capable space surveillance system—the SSN—but this system nevertheless has limitations. For example, it lacks the capability to accurately track all potentially hazardous pieces of debris, and it cannot monitor maneuvers and determine changes in orbit with the timeliness that may sometimes be desired. Some of these shortcomings are due to the limited number of sensors and to their scarcity in certain parts of the globe, particularly the southern hemisphere.

Better tracking would result from the sharing of tracking data between countries, using data not only from government-owned sensors but also from commercial satellite operators. Whether public or private, satellite owners generally have the best and most timely tracking information for their satellites (and they know when orbital maneuvers are planned); thus combining this information with data from sensor networks could be very useful.

To make such data sharing happen on a significant scale and to assure its success, ways to protect sensitive military and commercial information—as well the technical protocols and logistical means to make the shared information useable—need to be developed.

Substantial Diplomatic Engagement Is Essential

The purpose of diplomatic discussions and negotiations on space is to assure the beneficial uses of that environment and prevent hostile or irresponsible ones. This goal may be achieved through agreed-upon rules, institutions, and coordinating mechanisms that would set standards of behavior, create predictability, and define rights, responsibilities, and consequences. Active diplomatic engagement, as well as

16 The IADC is an international governmental forum for the coordination of space-debris-related activities, including research on and the development of mitigation options. The IADC includes representation from all of the major space-faring nations.

17 In the same month as the IADC guidelines were adopted (February 2007), four spacecraft broke up in orbit, generating thousands of pieces of debris. At least three of these breakups could have been prevented by "passivating" them—for example, draining batteries and emptying fuel tanks—at the end of their useful lifetimes, as is recommended by the guidelines. The month previous, China destroyed a satellite in a test of an ASAT weapon, despite the guideline against intentional destruction of spacecraft in orbit.

the agreements it produces, can also help ensure that disputes over the use of space are averted—or at least managed in ways that do not create conflicts or exacerbate crises on the ground.

While efforts to control some dangerous technologies are valuable, the primary emphasis of these efforts should be on regulating behaviors rather than technologies. The fact that much space technology is dual-use can make it difficult to construct a detailed definition of "space weapon." But by focusing on behaviors, making progress on space security does not depend on agreeing on such a definition.[18]

The CD is seen by many countries as the legitimate forum for discussions on space security. However, to make fruitful space talks more likely, the countries involved might also consider new procedures that avoid the CD's requirement of reaching consensus on an agenda, which has linked other issues to space security discussions. For example, countries at the CD could agree to allow an agenda to move forward even without unanimous agreement. Consensus could still be required for any formal agreement resulting from the discussions.

More generally, the best venue, format, and scope of diplomatic engagement should all be part of initial discussions, during which time they could be chosen through agreement among the countries with the biggest stakes in the issues involved. In addition, such initial discussions should consider not only the range of problems but also the range of possible solutions and outcomes. The goal of negotiations should be to reach agreements, while recognizing that those agreements may take different forms.

Less formal types of cooperation—including voluntary codes of conduct, coordination, or transparency measures (which provide information about capabilities or activities but do not constrain them)—may be appropriate solutions to some problems. Other issues may best be addressed with legally binding obligations, verification, and compliance-management mechanisms. These various options should all be considered possible parts of whatever solution is being sought.

The temptation to rely entirely on informal agreements may be hard to avoid, as they are sometimes easier to negotiate and are less constraining. However, formal legal agreements have important benefits. They are binding and more durable than informal agreements, they can include more extensive and effective verification and compliance-management mechanisms, and they often establish a body with the legal authority and resources to facilitate implementation and resolve disputes. Because formal agreements are more likely than informal ones to provide the confidence and predictability that is a key benefit of diplomacy, for some issues they will be the most appropriate solutions.

These solutions must be guided by the interests of the full spectrum of stakeholders. National security issues, while important, are only one aspect of space activities. The U.S. approach to these discussions (and U.S. policy) should reflect this fact by better balancing military, commercial, and civilian interests in space.

Unfortunately, current international forums segregate the discussions of civil and military space issues. The United Nations (UN) Committee on the Peaceful Uses of Outer Space, which works closely with the UN General Assembly, considers only matters of "peaceful" civilian use of space, while the CD committee on PAROS focuses on arms control and military issues. Currently there is little coordination between these two bodies, though the CD may be able to accommodate a wider range of issues in the course of negotiations.

U.S. Leadership Is Necessary

Achieving the long-term goals listed above requires serious and sustained engagement among all space actors. Given the United States' preeminence in space and its recent opposition to negotiations on

18 A well-known example of this principle involves laws against murder. Although there are some regulations on specific kinds of lethal weapons, the law is primary about banning a *behavior*, as there is no unambiguous definition of "murder weapon." These laws are universally seen as important and effective, despite their lack of definition and the fact that they do not stop all murders.

space issues, it should assume a major collaborative role. It needs either to initiate efforts or to respond constructively to others' initiatives so that progress can be made.

The Obama administration has signaled that it is open to discussions, though not to negotiations, on space security issues at the CD. However, making progress at the CD or another forum requires more than just openness to the process; it also requires active commitment by the United States and other nations to find a way forward.

By initiating multilateral discussions or stating its commitment to engaging in them, the United States would show that it is serious about trying to find mutually beneficial solutions to outstanding space security issues. These gestures alone could have important initial effects, such as the building of contacts and the establishment of better channels of communication among appropriate U.S. individuals and their counterparts in other space-faring nations.

U.S. participation would also compel these countries and other interested parties to develop the necessary national expertise on space security—diplomatic, technical, legal, and economic—that dissipated, if it existed at all, during the many years' absence of substantive discussions. Raising the priority of space security and prompting governments to develop nuanced policies would give important domestic stakeholders, who previously may not have been weighing in, a voice in their country's policy discussions. This would be true not only in the United States but elsewhere as well.

Keeping Satellites Safe from Deliberate Attack Requires Multiple Approaches

During a conflict the great value of satellites could make them attractive military targets, especially because, as noted above, they are readily observable and their future positions can be predicted. Satellites are thus intrinsically susceptible to attack. Moreover, they are difficult to protect reliably, and protection techniques often complicate operations or add launch weight. Although space has been optimistically dubbed the "ultimate high ground" by some people, in truth it is a highly vulnerable location: targeting satellites is easier (and generally cheaper) than defending them.

At the same time, it is important to recognize that the technological capability to interfere with one or a few satellites is not the same as the military capability to mount a decisive or strategically significant attack on the ensemble of another nation's satellites. Thus as the technology that could be used to interfere with satellites proliferates, a particularly important role for diplomacy is to prevent these technologies from evolving into operational and deployed strategic systems.

For example, while a negotiated limit on testing missile-defense systems against satellites would not eliminate these systems' inherent ASAT capabilities, the limit could usefully impair the owner's confidence that they would be successful if used; their operational utility would therefore be decreased. Such limits might consequently constrain the development of an operationally active system deployed in strategically significant numbers.

It would be unwise in any case for the United States to rush into developing satellite defenses, which could have the counterproductive effect of increasing the risks of deliberate attack or inadvertent interference. An example is the potential deployment of active defenses such as "bodyguard" satellites, which, as discussed below, could have offensive capabilities that might spur the development of similar technologies by other countries.

Thus the best defense is twofold: to limit others' ability and incentives to attack key U.S. satellites, and to be able to mitigate an attack's potential effects. Fulfillment of this policy requires a range of approaches—diplomatic, technological, and military, among others—which we discuss below.

Creating Limits and Strengthening Norms Reduces the Likelihood of Attack

Because negotiated agreements can reduce the likelihood and effectiveness of a potential attack, a particularly important role for diplomacy is the setting of clear international norms of behavior and specified consequences for violations. Strong norms and penalties increase the political costs of aggression.

Verifiable limits on ASAT-relevant technology and on threatening behavior can also mitigate threats to satellites. Such limits reduce both the readiness of an adversary to interfere with a satellite as well as its confidence that the interference would be successful. Limits also can restrict the operational testing and deployment of dedicated ASAT weapons during peacetime so that they are less reliable and thus less likely to be used in a crisis.

Negotiated restrictions can define appropriate uses and behavior for dual-use technology, and they may strengthen the distinction between legitimate and illegitimate applications of such technology. Examples of limits on uses are technological constraints on the capability of satellites to quickly maneuver in orbit; bounds on the power that a laser may transmit into space; and a restriction against coupling a high-powered laser with a satellite-tracking mirror. A limit on behavior is exemplified by, say, how closely or quickly a satellite may approach another without permission.

Defining the consequences of certain actions against satellites and developing enforcement mechanisms, together with the creation of a better international space monitoring system, will not only help to deter attacks but also to assign responsibility for those that may occur. Active diplomacy can also put mechanisms into place that help prevent misinterpretation of inadvertent interference with satellites and thus help avoid any consequent escalation.

While such measures do not preclude an unpredictable actor—one that is not motivated by "rational" concerns—from doing harm, developing limits is still valuable. Those actors that are most capable of doing significant damage to satellite systems are generally those that are invested in space themselves and likely to see the benefits of these limits.

Smart Planning Reduces the Consequences of Attack

The most important and immediate step the United States can take in planning satellite systems is to establish a guiding principle that satellites be resilient to attack and that their key capabilities be preserved—in other words, to achieve what the (NSP) calls "mission assurance." Based on this principle, defense planning could ensure that attacks on individual satellites, or their failure for any other reason, would not remove the nation's key military capabilities or critical infrastructure.

Useful approaches toward this end (discussed in more detail in Step 4 of Chapter 4) include hardening electronics; building redundancy into satellite systems so that the failure or compromise of one component can be compensated for by another; developing the ability to bypass damaged satellites or to rapidly replace them; distributing a given function among clusters of satellites, rather than limiting it to a single satellite; and developing backup air- and ground-based systems that can provide communication, surveillance, and navigation on a regional basis should satellite systems be impaired.

Well-planned space systems can be robust to attacks on satellites, alleviating concerns about a crippling strategic strike—a "space Pearl Harbor." These systems also diminish the incentives for such a provocative act, as there would be little for an attacker to gain.

Deterrence Does Not Require Attacking Satellites

Potential attackers may be dissuaded from interfering with U.S. satellites by the threat of force under some circumstances, though the nominal effectiveness of this strategy is often overstated. While the concept of deterrence has long been basic to U.S. analysts' strategic thinking about nuclear weapons, in many respects it is not a useful model for space.[19] For example, while response-in-kind is a key

19 For a discussion of the challenges in using nuclear deterrence concepts as a basis for space deterrence, as well as for a study of other deterrence approaches to space, see Harrison, Shackelford, and Jackson 2009. See also Gallagher 2010.

feature of nuclear deterrence, this is because the tremendous destructive power of nuclear weapons sets them apart from other weapons; some view only the threat of a nuclear response as powerful enough to deter a nuclear attack.

This logic does not hold for attacks on space assets. The threat of a response-in-kind in space—i.e., an attack against an adversary's satellites—is unlikely to have a stronger dissuasive effect than the threat of retaliation against other targets that the adversary values. The United States has the ability to retaliate against a range of ground targets, should it decide to, and this could in fact be the most sensible option. Because other countries are less dependent on satellites than is the United States, they may place considerably lower value on their satellites than on other potential targets.

A key conclusion of this report is that it would be counterproductive for the United States to develop weapons designed to damage or destroy satellites, much less actually carry out such an attack. Moreover, as noted above, there is no evidence that having that capability or threatening to retaliate against another country's satellite would strengthen deterrence against attacks on U.S. satellites. As a result, there is no reason to believe that an announcement that the United States will not target satellites would weaken deterrence; in fact, it could actually help to strengthen the norm against such attacks, which would be highly beneficial to the United States.

Even if a deterrence policy were successful, it would only be a partial solution for space security and sustainability issues because it could not address those risks to satellites that are not deliberate attacks. In addition, a narrow focus on deterrence as the sole or primary means of protecting satellites would institutionalize an adversarial and military approach to space security, thereby hindering the cooperation needed to effectively address other pressing space-related issues.

Active Defenses in Space Are Counterproductive

Active defenses have been suggested as another way of protecting satellites from deliberate attacks. These options usually focus on space-based bodyguard weapons that would accompany a high-value satellite and attempt to intercept incoming ASAT weapons.

However, such weapons would not be reliably effective at defending a satellite from a determined adversary, which would likely have many different modes of attack and repeated opportunities to employ them. (This point is discussed in more detail in the Appendix.) Moreover, because of the maneuvering and homing features that bodyguard weapons would need in order to attempt interceptions, they could possess inherent ASAT capabilities. Other countries would find the U.S. pursuit of such capabilities threatening, just as the United States would view these kinds of efforts by other countries.

As a result, these defenses would be counterproductive. While failing to provide an effective response to military threats, they could increase tensions with other countries and create incentives for them to pursue similar weapons. The development of active defenses, if seen as providing an offensive capability, also could undermine the diplomatic efforts and coordinated actions needed to solve some of the most pressing day-to-day threats in space.

As a result, the United States should clearly state that it will not pursue space-based weapons, even in a nominally defensive role, and will instead rely on the range of protective measures discussed above. This position would reinforce the norms of not attacking satellites and of keeping weapons out of space, while maintaining more practical and useful protections.

CHAPTER 4

The Solution

Ten Steps Toward a More Secure and Sustainable Future in Space

The recommendations that follow—a series of 10 mutually reinforcing steps—are addressed to U.S. policy makers, and to the administration in particular.

Step 1. Elaborate on the administration's National Space Policy and publicly articulate its approach and goals, both to provide clear high-level guidance for U.S. policy makers—military and nonmilitary alike—and to clarify U.S. intentions for the international community.

The approach and goals should:

- Emphasize international cooperation rather than unilateral action.
- Reaffirm that all countries have the same rights to the peaceful use of space.
- Take a more balanced view of commercial, civil, and military uses of space.
- Support and reinforce long-held norms against stationing weapons in space and against disabling or destroying satellites.

Such principles, clearly expressed, are necessary to guide those charged with developing and implementing space policy. Moreover, their public expression can help reduce suspicion of U.S. actions and intentions and set a context that is more conducive to international discussion and cooperation.

The Obama NSP does provide some of this high-level direction, albeit at a general level. Greater detail would foster greater progress on space security issues. For example, the policy emphasizes international cooperation but it does not specify what the United States wants to achieve by cooperation or which strategic concept would provide the best guidance.[20] The policy also states that the United States will seek to "assure the use of space for all responsible parties" without defining "responsible." Additionally, the policy charges the defense and intelligence departments to develop the plans and capacity to pursue two related goals—ensure the survivability of space capabilities and deter, defend against, or defeat attempts to interfere with U.S. space capabilities—but the administration has not publicly articulated specific guidance about how these goals are to be achieved and what limits it is willing to consider on related activities. Nor has the administration discussed what steps it will take to ensure that such plans do not decrease security overall—by, for example, appearing to pose an offensive threat to other countries and eliciting a threatening response.

Similarly, while the NSP offers support for voluntary TCBMs, it states that the United States will only consider proposals for arms control that are "equitable, effectively verifiable, and enhance the

20 For a discussion of different strategic objectives for cooperation and how they would shape what types of cooperation the United States might pursue, see Gallagher 2010.

national security of the United States and its allies." Although this is a welcome change in position, as far as it goes, the administration should also articulate specific approaches and measures it believes would be in its interest.

Step 2. Declare that the United States will not intentionally damage or disable any satellites operating in accordance with the Outer Space Treaty, and pledge that the United States will not be the first to station dedicated weapons in space. Strongly urge the other space powers to make parallel pronouncements.

Negotiating limits on ASAT and space weapons is certain to be a long and complicated process. But space-faring countries' declarations that reinforce existing norms of this kind can improve the environment for such negotiations by demonstrating good faith and by reducing the mistrust that arises from concerns about weapons development. The OST requires, among other things: that space activities be undertaken in accordance with international law, including the Charter of the United Nations, as well as with "due regard to the corresponding interests of all other States Parties to the Treaty"; and that if a planned activity could cause "potentially harmful interference with activities of other States Parties in the peaceful exploration and use of outer space," the state planning that activity should consult with other states first.

The United States would face little risk in making such a declaration, as some other nation's decision to be the first to deploy an ASAT or space-based weapon would not confer a significant or lasting military advantage; those following the initiator could do the same soon and well enough. Moreover, the United States has the strongest ability to compensate for, and respond to, other countries' development of space-related weapons.

In any case, its advanced monitoring capabilities would allow the United States to keep track of the activities of other countries, essentially eliminating the risk that they could secretly develop and test capabilities that would pose a significant threat. For example, U.S. early warning satellites could detect launches of any missiles able to carry a ground-launched ASAT weapon; and the tracking of suspicious objects in orbit could be made a priority mission for the SSN, thereby limiting the number and capability of any undetected satellites.

Moratorium on Destructive ASAT Weapons Testing and Use

The United States should unilaterally declare that it will not intentionally damage or destroy a satellite, whether through dedicated ASAT technology or dual-use technology. This declaration would reinforce an important longstanding norm: no country has ever intentionally caused irreversible damage to another country's satellite. It would also be consistent with the U.S. Department of Defense's (DOD's) preference for temporary and reversible means of satellite interference.

Moreover, the declarations should go beyond this norm by ruling out tests of destructive ASAT weapons directed against a country's own satellites. Because it would limit the operational development of such weapons, such a declaration would help assure other countries that the United States is serious about seeking mutually agreed constraints on dangerous technologies. It would also set a standard that other countries should meet to become more credible partners in space security negotiations.

This moratorium would ban the use of ASAT weapons that destroy or permanently disable satellites but would not be a comprehensive ban on all ASAT weapons. A second category includes those whose effects are temporary and nondestructive; the United States has already deployed some of these types of weapons, such as satellite signal jammers, for which the technology is widely available. There is less agreement on the implications of these latter weapons, on what kinds of limits regarding them would be useful, and on whether they are appropriate responses to the threat posed by the military utility of satellites.

Pledge Not to Be the First to Station Weapons in Space

Stationing destructive weapons in space is without precedent. Despite research and development efforts over the years, no dedicated space weapons are known to have been deployed.[21] This has been the case for various reasons, the main ones being that they are costly, technically challenging to develop, and unpopular with policy makers and the public.

Space basing is a poor choice for many kinds of weapons. For example, ground-attack weapons based in space would be 50 to 100 times more costly than ground-based alternatives with comparable delivery times, as discussed in the Appendix. Similarly, a system for defending against only one or two ballistic missiles launched from the main geographic regions of concern would be enormously expensive because hundreds of interceptors in space would be required. Even then, the system would fail to provide a reliable defense. (Space-based missile defenses are discussed in more detail in Step 3.) While there may be other missions that military leaders believe would be better suited to space-based weapons, the marginal military capability that the United States might gain from these missions must be weighed against the substantial costs.

Pursuing such weapons would legitimize those uses of space and encourage other countries to develop similar capabilities, which could subsequently be used against the United States. Even if never used, these capabilities could increase tensions and hinder the coordination and cooperation needed for the international community to solve pressing problems in space.

The United States would gain much by publicly stating its intent not to deploy space-based weapons. Making such a statement would not lock the United States into a position of inferiority, as it would imply the reconsideration of U.S. plans if another country started to place weapons in space. Moreover, the United States has the capability to catch up quickly. In short, it is not in the U.S. interest either to lead in the weaponization of space or to be encouraging others to do so by a lack of clarity about its position.

In the absence of an official statement of intent by the administration, other countries trying to figure out U.S. intentions are likely to turn to other evidence (such as military writings or politicians' declarations), which not only may be unrepresentative of official policy but also may appear needlessly aggressive. For example, the discussion of space weapons in documents such as the Air Force's *Vision for 2020*, the interest in them among some policy makers and military leaders, and the continued funding of research and development of relevant technologies[22] could raise concerns in other countries about U.S. intentions.

Verification

Given the U.S. ability to observe satellites and detect launches of missiles as well as of space-launch vehicles, it could have a high degree of confidence about how well other countries were abiding by their declarations not to deploy dedicated space-based weapons. The United States can determine the launch trajectory of a missile, the orbit of a satellite, the types of orbital maneuvers a satellite undergoes, and the physical attributes and appearance of a spacecraft—all of which are closely related to its

21 The Soviet Co-Orbital ASAT system, tested from 1968 to 1982, is alleged by some to have been stationed in space. The ASAT weapon would approach the target after following part of an orbit, or at most two orbits, after launch before intercepting the target. See Table 2 in Appendix II of Stares 1985.

22 The FY2010 budget requested funding for a number of space-weapons-relevant technology-development projects, e.g., research into high-energy laser systems, technologies for approaching and grappling with a satellite that is not cooperating. No specific unclassified funding was sought for space-based interceptors. See, for example, Black and Samson 2010a.

mission. For example, U.S. sensors observed the demonstration of Chinese ASAT capability in 2007, the previous nondestructive tests of this technology, and China's January 2010 missile defense test.

The declarations need not be made overly complicated by including a detailed definition of a space-based weapon. It should be sufficient to describe it as a spacecraft purposely designed to damage or destroy another object that is in orbit, is transiting space, or is on or near Earth's surface.[23] Combined with a moratorium on testing and using destructive ASAT weapons, these straightforward declarations would go a long way toward reducing threats from space both to space- and ground-based assets.

Step 3. Declare that the United States will not develop or deploy space-based ballistic missile defense interceptors. Pledge not to use any element of the U.S. land-, sea-, or air-based missile defense systems to attack or destroy a satellite. And review plans to sell systems with this capability to other countries in order to ensure that any missile interceptors sold by the United States will not be used as anti-satellite weapons.

Pledging to close off or limit these activities would reinforce the U.S. moratorium on using destructive ASAT weapons and the pledge not to be the first to deploy space weapons. It could also help avoid reactions by other countries concerned that the United States may pursue these options. While little unclassified effort is currently being made to pursue space-based missile defenses, this absence does not accrue the benefits that a clear declaration would.

Space-Based Interceptors

A U.S. decision to develop and test space-based interceptors (SBIs) would be problematic for space security. A space-based ballistic missile defense system, even if eventually built, could not reliably provide such a defense. However, developing the technology for it could spur other countries' pursuit of similar capabilities or of systems intended to counter the SBI. This would pose a risk to U.S. satellites as well as legitimize the development and deployment of space weapons.

Because a space-based missile defense system requires very large numbers of orbiting interceptors to defend against even a single ballistic missile, and because such a system has intrinsic vulnerabilities that undermine its effectiveness, the United States is not likely to attempt to build such a system in the foreseeable future (see the Appendix for a discussion of these issues). However, political pressures may create an incentive for a compromise that would support development and deployment of a handful of interceptors in a "space test bed." The Missile Defense Agency (MDA) has proposed such a program[24] in recent years, and space-based interception continues to be discussed as part of a "layered" missile defense. While Congress has consistently declined to fund the Space Test Bed program and the Obama administration has not requested money for it, no official positions have been articulated that constrain space-based interceptors (SBIs) as an option.

Even fielding a few SBIs under the guise of research and development in a program such as the Space Test Bed would be problematic for at least three reasons. First, putting an interceptor in space would cross a significant threshold. It would for the first time place a dedicated weapon in orbit, effectively preempting broader congressional decision making about the wisdom of deploying space-based weapons.

---

23 Phillip Baines, a Canadian diplomat, has suggested that a weapon, including one orbited in space or used against a satellite, be defined as "a device, based on any physical principle, specially designed or modified for military use, to injure or a kill a person, damage or destroy an object, or render any place unusable" (Baines 2010).

24 The George W. Bush administration requested funding for the Space Test Bed (Program Element 0603895C) to start in FY2008 and continue through FY2013, but Congress did not approve these funds. No funding was included in the FY2010 or FY2011 budget requests. The stated goals of the program were to develop a space-based interceptor; to develop the command, control, battle management, and communications structures for space-based missile defense; and to launch prototype interceptors into orbit and test them against ballistic missiles.

Second, while SBIs may nominally be defensive, they are also suited to offense; by their nature they would have or could be modified to have the ability to intercept satellites. The large amount of thrust an interceptor needs to perform boost-phase missile defense from space means that the interceptors could reach and attack satellites in geosynchronous orbit in addition to those in lower orbit. Understanding that a full space-based missile defense is unlikely to be built in the foreseeable future and that it would be vulnerable to attack if it were built, an adversary might reasonably assume that the real purpose of developing SBIs was to attack satellites.

And third, if a working space-based missile defense system were built, it could be used to target space launchers as well as ballistic missiles. Thus pursuit of such a system would raise questions about U.S. intentions, particularly regarding the United States' interest in controlling access to space. Some countries could certainly see the system's capability as threatening, not defensive. Their concerns might induce them to preemptively attack the SBI, pursue the means to do so, or develop similar systems for themselves.

ASAT Capabilities of Ground-, Sea-, and Air-Based Missile Defense Systems

Because missile defense systems are intended to destroy ballistic missile warheads, which travel at speeds and altitudes comparable to those of satellites, such defense systems also have ASAT capabilities. In fact, while the technologies being developed for long-range missile defenses might not prove very effective against ballistic missiles—for example, because of countermeasure problems inherent in midcourse missile defense—they could be far more effective against satellites.

In many ways, attacking satellites is an easier task. Satellites travel in predictable orbits that ground facilities can accurately determine by tracking them. An attacker would have time to plan an attack against a satellite, could choose the time of the attack in advance, and would be able to take as many shots as necessary to destroy it. In addition, an interceptor attacking a satellite would not have to deal with the same countermeasure problems that a midcourse missile defense system would face. For example, in the Ground-Based Midcourse Defense (GMD) system and the Aegis missile defense system, the inability of the interceptors to distinguish between warheads and countermeasures (such as decoys) limits their ability to defend against ballistic missiles.

The GMD interceptors deployed at Fort Greely in central Alaska and at Vandenberg Air Force Base in California each consist of a three-stage rocket booster that carries a kill vehicle into space. The kill vehicle, which is intended to intercept above the atmosphere, carries its own fuel for maneuvering as well as an infrared sensor. The sensor is intended to guide the interceptor toward an object and allow it to home on and destroy the target by direct impact. If launched against satellites in low Earth orbit (LEO), the interceptor could use some of its fuel to reach out laterally over thousands of kilometers, allowing it to hit satellites in orbits that do not pass directly over the launch site. Thus even interceptors at a fixed ground site in Alaska could reach a large fraction of satellites in LEO.

Similarly, the hit-to-kill intercept technology used by China for its January 2007 satellite destruction was apparently developed as a system that could be used either for ballistic missile defense or ASAT attacks. It is likely that China's first ballistic missile defense test on January 11, 2010, used this same technology.[25]

In February 2008, the United States demonstrated the ASAT capability of its Aegis sea-based missile defense system: the Aegis SM-3 Block IA interceptor destroyed a nonresponsive U.S. satellite at an altitude of 240 kilometers (km). U.S. officials said this task required a modification of the missile defense software; however, other countries may assume that this change could readily be made again to give any Aegis interceptor the ability to intercept other satellites. Officials have also stated that the

25 See Jacobs and Ansfield 2010. See also the blog post and the references therein at Taiwan Link 2010.

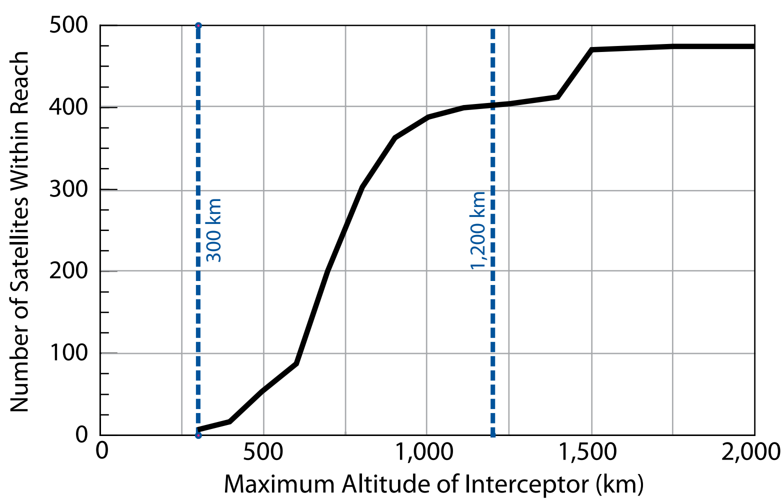
U.S. GMD and Terminal High Altitude Area Defense (THAAD) interceptors have similar capabilities.[26] The current Aegis interceptor could reach only the relatively few satellites in orbits below 300 km to 400 km altitude, but the GMD interceptors and future Aegis interceptors would be able to reach satellites throughout LEO (see Figure 2).

The demonstrated ASAT capability of the Aegis missile defense system poses additional challenges because the system is likely to be owned by other countries besides the United States. The Aegis system's interceptor technology is being codeveloped and operated by Japan, and its sale to additional users, including several European countries as well as South Korea, is expected in the future.[27] Consequently, the United States should review carefully its plans to sell this capability to other countries.

The U.S. Airborne Laser (ABL)[28] program is charged with creating a powerful aircraft-borne laser system that could be used to destroy missiles during their boost phase. A system that included a laser with enough power to damage missiles and the ability to focus the laser on a target moving at missile speeds would also be able to attack and damage lower-altitude satellites and their launchers. To be used against ballistic missiles, the aircraft would need to loiter in the adversary's airspace to wait for the missile launches, and it would have to overcome countermeasures such as protective coatings on the missile body. Given such operational problems in using the ABL in a missile defense role, the system may actually be more useful in an ASAT role.

However, a public pledge not to use missile defense systems against satellites would be an important statement of U.S. intent and would help to reinforce the norm against attacking satellites. Moreover, the decision not to test missile defenses in an ASAT mode would prevent this intrinsic capability from becoming an operationally tested one, thus limiting the confidence that military leaders would have in the system for ASAT use.

FIGURE 2. Missile Defense Systems' ASAT Reach



The solid line denotes the number of operational satellites with perigee (closest distance to Earth during its orbit) at or below the given altitude. These are vulnerable to an ASAT interceptor that can reach to that altitude. The dashed line at 300 km indicates the approximate reach of the current Aegis missile defense system operated in ASAT mode; it can intercept few satellites. The dashed line at 1,200 km indicates the approximate lower bound on the reach of the SM-2 Block II interceptor that is planned for the Aegis follow-on. It could intercept nearly all low Earth orbiting satellites.

26 At an April 23, 2008, hearing of the Defense Subcommittee of the Senate Appropriations Committee, General Henry Obering, director of the Missile Defense Agency, testified as follows: "It took us a couple weeks to analyze, and it turned out that both the ground-based midcourse THAAD and the Aegis all had capability, if they were modified, to go do this mission [to shoot down the failed USA 193]. The Aegis was the easiest to modify and also represented the most flexibility and the minimum impact to our program overall."

27 The United States has asked Japan to permit the export of the new versions of the SM-3 missile to third-party countries (Japan Today 2010).

28 The MDA's Airborne Laser, as designed, has the capacity to target low-altitude satellites at least as well as it does ballistic missiles. Because the ABL laser beam is intended to fire at missiles that are at much higher altitudes than the ABL aircraft, it would also be able to fire upward at satellites (Stupl 2010). However, the program has had deep funding cuts, with the prototype aircraft now being a science and technology research test bed for directed-energy experiments rather than a development project, and the planned second aircraft was canceled.

There may be exceptional times when the use of such a capability is deemed important for public safety reasons, as some argued was the case when the United States destroyed its own satellite in February 2008 over stated concerns that it might survive reentry of Earth's atmosphere and injure people on the ground. Under such circumstances, the country arguing for the ASAT use should consult and seek agreement with other space-faring nations before taking action, and then carry out the mission in as transparent a manner as possible.

If another country were to test or use a missile defense system against a satellite, there could be strong pressure for the United States to drop its moratorium and conduct a similar test. However, doing so would undermine U.S. efforts to delegitimize such actions and could encourage other countries to conduct similar tests. Such U.S. action would also be unlikely to strengthen deterrence against the use of such a system against U.S. satellites, given that the United States already has a recognized intrinsic ASAT capability.

A more productive course of action for the longer term would be for the United States to strengthen the norm against such actions—by leading the international condemnation of the act—while at the same time strengthening its satellite systems against interference.

Step 4. Vigorously pursue a capability-preserving strategy and make satellites less attractive targets by reducing their vulnerabilities; building in redundancies; improving the capacity to rapidly reconstitute key functions; and developing air-, space-, or ground-based backup systems.

Multilateral coordination, agreed-upon rules for operating in space, norms of behavior, and deterrence can all reduce risks to satellites. During a conflict, however, satellites' great value could make them attractive targets for deliberate interference despite these protections. Because satellites are readily observed and their future positions can be predicted, they are intrinsically vulnerable to attack.

But if smart planning becomes a central guiding principle for U.S. space policy, space cannot become the Achilles heel of the nation's military. Moreover, an effective capability-preserving strategy will diminish the incentive for other countries to interfere with U.S. satellites in the first place.

Useful approaches (discussed in more detail below) include:

- Building key satellites with protections against interference
- Embedding redundancy into satellite systems so that the failure or compromise of one component can be compensated for by another
- Developing the capability to bypass damaged satellites or to rapidly replace them
- Distributing a single satellite's function among clusters of satellites
- Reproducing lost satellite's functions on a regional basis by using backup air- and ground-based systems.

Smart Planning: Reducing the Vulnerability of Individual Satellites

Individual satellites can be made less vulnerable to some types of interference, such as the jamming—whether intentional or accidental—of communication links between the satellite and the ground.[29] Some protections are currently available; for example, communication channels of critical military satellites include sophisticated onboard electronic anti-jamming technology. Providers of commercial satellite communications services are being encouraged to adopt such protections too, in part because

29 Communications links both from the ground station to the satellite (the uplink) and from the satellite to the ground receivers (downlink) can be jammed. Downlink jamming is generally a local effect; it is the receivers that are being affected and not the satellite. The most useful remedies in each case can be quite different, and they may not involve the actual satellite at all.

commercial satellites now carry a large fraction of U.S. military communications.[30] Some cooperation already exists between the U. S. government, commercial and foreign-government satellite-service providers, and nongovernmental organizations, and it has fostered the development of measures that could help ensure the availability of secure satellite-based commercial communications channels.[31]

If jamming does occur, governmental and commercial services developed for this purpose can locate its source increasingly quickly. The United States may opt to resolve the problem through diplomatic initiatives or by disabling the jammers.

Physical shutters or filters on satellite sensors can help limit damage from laser weapons, and electronic filters can protect against microwave attacks. Shielding can be added to protect sensitive parts of satellites against collisions with debris of up to about one centimeter in size. But because launch costs scale with satellite mass, such shielding is infrequently implemented. This could change if the danger from space debris increased or if the cost of shielding important satellites were government subsidized. Armoring satellites to survive collisions with significantly larger objects is not feasible.

A frequently discussed scenario for attacking satellites is a nuclear weapon launched on a medium-range ballistic missile and detonated at an altitude of a few hundred kilometers. Without sufficient shielding, satellites in the line of sight of a detonation would immediately sustain damage or ultimately cease to function from exposure to X-rays. Depending on the altitude of the detonation, such an attack could affect 5 to 10 percent of LEO satellites. The surviving LEO satellites would be exposed to radiation generated by high-energy electrons—by-products of the blast—that were trapped in Earth's magnetic field. Damage incurred by cumulative exposure over the subsequent months could cause the onboard electronics to fail if the satellites were not sufficiently shielded.

Radiation shielding can be incorporated, however, for about 2 to 3 percent of the cost of the satellite. Satellites such as NAVSTAR and military communications satellites, which operate in naturally occurring high-radiation environments, are routinely hardened against radiation, thereby demonstrating the possibility of effective shielding (Defense Threat Reduction Agency 2001). For other important satellites, the cost of shielding could also be seen as a reasonable investment.

Space-based "bodyguard" weapons, which would be placed in orbit near a valuable satellite in order to intercept an approaching object, cannot provide reliable protection and their testing and deployment may generate additional problems. (See Appendix for details.)

Smart Planning: Reducing the Vulnerability of Satellite Systems

In addition to taking the kinds of useful steps outlined above, the United States should design systems and capabilities so that they cannot be impaired by attacks on individual satellites. In some cases, lost satellites can be bypassed or replaced. For example, to maintain service in the event of a transponder or satellite failure, commercial satellite operators routinely develop plans for rerouting communication traffic from the failed transponder or satellite to an operating one; or, in the most extreme cases, for moving a satellite that is on standby into the failed satellite's position, as Iridium did after the 2009 collision that destroyed one of its communication satellites.[32]

30 Since September 11, 2001, most of the communications bandwidth supporting the U.S. military has been carried by commercial providers, some of which are based outside the United States. The converse is not true—the U.S. military does not use a majority of the commercial bandwidth—and commercial providers have so far been reluctant to incur the added expenses associated with hardening their satellites to military specifications. The U.S. defense and intelligence communities also rely to an increasing degree on imagery from commercial satellites. This imagery provides a potential backup to some kinds of military surveillance.

31 The Commercial SATCOM Mission Assurance Working Group is a forum where the DOD and the commercial satellite industry can discuss improvements to "policies, programs, and processes" to best assure the availability of the industry's services. The issues covered include cooperation on "neighborhood watch"—assessment of threats, cooperation on evaluating close approaches of satellites, and detection and resolution of radiofrequency interference (Denman 2006).

32 The Iridium satellite lost in the 2009 collision was replaced by an on-orbit spare three weeks later (Iridium 2009).

Additionally, satellite constellations can be organized not just with mission performance in mind but also with an eye toward reducing both their vulnerability to attack and the impact of the loss of an individual satellite. The Global Positioning System NAVSTAR constellation is a good example of this kind of architecture.[33]

In the future, technological advances may reduce satellite systems' vulnerability to disruption. Smaller (and less expensive) satellites are becoming more sophisticated, and for certain applications a cluster of small satellites may be able to provide capability similar to that of a large satellite in operation today. Distributing the capacity in this way could allow the owner to preserve capability despite the loss of one or a few satellites. Moreover, smaller satellites can be placed in orbit by smaller launch vehicles, which carry reduced launch costs and are able to launch satellites more quickly than large launchers. The promise of such rapid-response and affordable satellite launch has not yet been realized, however.

Air- and ground-based backup systems could provide, on a regional basis, some of the militarily relevant and time-urgent capabilities that would be lost if a satellite system were disrupted or destroyed. Routing communications, relaying navigation signals, and collecting imagery can be usefully done from the air, and some communications and navigations tasks may be supported via ground-based assets such as ground-based navigation-signal repeaters and fiber-optic links.

While it is often noted that United States has the most assets to lose in space, it also has the greatest ability to compensate for the loss of its satellites; the nation has the technological and economic resources to provide backup capability for its critical missions. A potential adversary should know not only that an attack on a satellite may not have a serious or lasting effect on U.S. capabilities but also that the attacker would still bear the consequences of such an action.

Step 5. Modify U.S. export-control and related regulations to reduce unnecessary barriers to commercial and civil space cooperation.

Over the past decade, these restrictions have impeded U.S. participation in legitimate space-related commerce, cooperation, and scientific collaborations while having a questionable impact on preventing the spread of sensitive space technologies.[34] Current restrictions grew out of a view of space strongly dominated by military considerations and driven primarily by concern about China. But this approach is widely viewed as counterproductive to long-term U.S. interests, in part because of the deleterious effect it has had on the U.S. satellite industry.

Because the problem is complex and entrenched, it will take a sustained effort by the White House and Congress to solve it. Resolution also requires the administration to reframe space issues in a way that balances the military, commercial, and civil uses of space and that recognizes the benefits of cooperation.

In an effort to ensure that export regulations on space technology and related legislation are best meeting U.S. needs, the administration has begun to systematically review and modify these rules.[35] Its efforts have already led to some changes, including the announcement in June 2010 that the White

33 Global Positioning System (GPS) satellites are arranged in widely separated orbital planes, making an attack on large numbers of these satellites more difficult. The satellites also have slight phasing irregularities that would frustrate attempts to use an ASAT weapon designed to "loop" back around Earth and return to the same spot to attack another satellite. The GPS constellation itself is designed, moreover, so that the navigation signal service degrades gradually, instead of abruptly, as satellites are lost (Carter 1986).

34 Exports of satellites and satellite technology can be controlled by two different sets of regulations. Dual-use items—those that have both military and civil applications—are subject to Export Administration Regulations, which are administered by the Department of Commerce as part of the Export Administration Act. Items that have been placed on the U.S. Munitions List are instead subject to the International Traffic in Arms Regulations (ITARs), which are administered by the State Department as part of the Arms Export Control Act.

35 On August 13, 2009, President Obama directed the National Economic Council and National Security Council to initiate an interagency review of the U.S. export control system, including both the dual-use and defense trade processes (White House 2009).

House had created a new independent agency, under a cabinet-level board of directors reporting to the president, for overseeing all military and dual-use export licensing activities (Tiron 2010). The administration should make it a priority to keep up the momentum behind such efforts.

While restriction of some sensitive technology is in the U.S. national interest, the nation's current export controls on space technology are not appropriate. They are arguably so broad that they interfere with commerce and collaboration that is *not* sensitive.

Engagement and cooperation between space-faring countries can form the basis of a stable and secure space regime. Such activity fosters important contacts and relationships, provides a foundation that can support transparency and information exchange, and builds confidence in each actor's stated intentions. Commercial and civil space cooperation is especially important, as operating costs are high; partners can share the burdens of development and then later the benefits of an open market.

However, current export restrictions are problematic, particularly in the case of China, which has the third-largest share of satellites. The United States has a special set of restrictions that makes cooperation between the United States and China very difficult to pursue, even on matters of mutual interest. Although China had successfully completed three piloted space missions through the end of 2009, it is the only major space-faring country that has not been invited to participate in the International Space Station. China sees its exclusion as a sign of mistrust and disrespect, which will complicate diplomacy and encourage Chinese decision makers to plan for an independent future in space—in which all countries would be less bound by international norms and less likely to coordinate activities.

Space cooperation with China began under the Reagan and George H.W. Bush administrations.[36] President Bush also began the shift of dual-use space technology, including some communications satellites, from oversight by the State Department as "munitions" to oversight by the Department of Commerce (Zelnio 2006). This shift continued under the Clinton administration.

By the late 1990s, however, space technology had become a highly politicized issue in Congress, especially following the 1998 Cox Report (U.S. House of Representatives 2010). A new view emerged in Washington that China's space systems could in the future pose a grave threat to U.S. national security, and that selling China technology or cooperating on civil space projects might benefit its military capabilities. Congress' response was to legislate that all satellites and "related items"[37] were to be classified as munitions, with their export once again controlled by the State Department. Of the items on the United States Munitions List, satellites alone have been mandated as munitions by law rather than by regulation.

These changes under the 1999 Defense Authorization Act (U.S. Congress 1998) have had negative and durable effects. To export satellites to countries that are not NATO members or major allies of the United States, companies have had to provide technology-transfer control plans and fund launch monitoring by the DOD. Many of the new rules have applied to U.S. allies as well.[38]

The Act also created special policies that applied only to China, effectively shutting down the nascent cooperation with China that had begun a decade earlier.[39] Since 1999, not a single Chinese satellite operator has purchased a satellite with parts made in the United States, given the U.S. export

36 In 1988, President Reagan signed an agreement with China to launch nine U.S.-built communications satellites. After the events at Tiananmen Square in 1989, President George H.W. Bush imposed economic sanctions on China, including suspension of the export of U.S. satellites to be launched by China. But he waived the sanctions on launching satellites three times.

37 Related items included "satellite fuel, ground support equipment, test equipment, payload adapter or interface hardware, replacement parts, and non-embedded solid propellant orbit transfer engines." (U.S. Congress 1998)

38 For a discussion of these rules, see Lewis 2002.

39 The Act requires that before the export of any missile equipment or technology to China can proceed, the U.S. president must certify to Congress that the export "is not detrimental to the United States space launch industry" and that it "will not measurably improve the missile or space launch capabilities of the People's Republic of China."

controls in place. This has led foreign satellite companies to avoid buying U.S. satellites and satellite technology,[40] and U.S. manufacturers have declined to bid on some contracts because of the fear of delays that export regulations could cause.

Since these policies have come into effect the United States has lost a significant part of its once-dominant share of the satellite market.[41] In addition, the U.S. academic space research community is experiencing a "reverse brain drain" as foreign space scientists seek positions in countries (such as Russia, China, and India) where the restrictions on collaboration are less burdensome (Tarantino 2008).

At the same time, despite being targeted by these regulations China has significantly improved its space capabilities. The country has increased its share of the satellite export market and has pursued a successful piloted space program. China has also developed collaborative space projects with Russia, the European Union, and Brazil,[42] and it has built and launched satellites for Nigeria and Venezuela.

Policies made legislatively, like those derived from the 1999 Defense Authorization Act, must be changed legislatively, and this process has been initiated by the House of Representatives and is awaiting consideration by the Senate.[43] The administration should continue to actively press for positive legislative changes of this kind.

During President Obama's visit to China in November 2009, the two nations released a joint statement that read in part: "The United States and China look forward to expanding discussions on space science cooperation and starting a dialogue on human space flight and space exploration, based on the principles of transparency, reciprocity, and mutual benefit."

But without changes to the current limitations on space technology and cooperation, the president's ability to follow through with this pledge, build on it, and more generally to begin to effectively engage China on space issues will be severely limited. While export controls are a complicated and politically charged issue, the administration must nevertheless begin to address it in earnest.

Step 6. Begin discussions with the international community to identify the most productive venue and agenda for negotiations on space security and sustainability. Play a leading role in setting up these discussions.

As noted in Chapter 3, addressing urgent space security issues requires coordination and agreement among all the countries using space. The administration should articulate that its interests are enhanced by international diplomacy, and it should announce its intention to pursue mutually beneficial limits and controls that will improve stability and security overall.

The administration should place a high priority on getting broad-based international discussions started. The goal of discussions—and, ultimately, negotiations—is to protect the beneficial

40 In the early 1990s, the European satellite manufacturer Alcatel (later Alcatel Alenia Space) began advertising an "ITAR-free" satellite, and it sold a number of them to China or for launch by China. Alcatel Alenia Space doubled its market share between 1998 and 2004 (Bini 2007).

41 In testimony to the House Foreign Affairs Committee, the Satellite Industry Association's president, Patricia Cooper, stated that the current 40 percent market share held by satellite prime manufacturers could be compared with the 65 percent market share of 10 years before (Cooper 2009).

42 China and Russia cooperate on a number of space projects, including some involving deep space missions. In October 2009 China and Russia signed the "2010–2012 China-Russia Space Cooperation Project Outline." China was the first non-EU state to join the Galileo project; it has since largely left the project to focus on its own satellite navigation system, called Beidou. The Chinese National Space Agency and the European Space Agency signed a space cooperation agreement in 2005. China and Brazil have collaborated on remote sensing satellites.

43 The 2010 House authorization bill for the State Department (H.R. 2410) would require the department to review 20 percent of the technologies and goods on the ITAR list and the United States Munitions List in each calendar year. The bill would permit the president to remove satellites and related components from the Munitions List, except if they were slated for export to China. The bill was passed by the House in June 2009 and referred to the Senate, where it is being considered by the Foreign Relations Committee.

uses of space and prevent hostile or irresponsible uses through agreed-upon rules, institutions, and coordinating mechanisms that set standards of behavior, establish predictability, and define rights and responsibilities.

The United States should begin by announcing its interest, and willingness to engage constructively, in these discussions; the administration should then gain a commitment to this process from the other actors with the biggest stakes in space. To encourage progress on the wide-ranging and sometimes thorny set of space security and sustainability issues, the initial exchanges should include discussions of the appropriate venue, format, and goals of the talks to follow.

More specifically, participants should start to identify and prioritize the issues, as well as the most effective and appropriate mechanisms for addressing each one. Less formal types of cooperation, including voluntary codes of conduct, coordination mechanisms, or transparency measures that provide information about capabilities or activities but do not constrain them—may be appropriate for some issues. By contrast, some problems are best addressed with legally binding obligations, complete with verification and compliance-management mechanisms. The full range of options should be considered in each case.

To make the process more manageable, one possibility is to begin the discussions with a relatively small number of interested countries rather than all members of the CD. Initial talks should identify the other important stakeholders, including those that are not countries, that need to be included in discussions on each issue.

The range of issues to be addressed is wide, encompassing space environmental and security issues and involving stakeholders from civil, governmental, and commercial sectors. Because civil and commercial satellites predominate in space,[44] diplomatic efforts must be sensitive to the need for space policies to balance the full spectrum of interests in order to succeed. Thus policies should include, but not be dictated by, military concerns.

As the dominant civil and military space user,[45] the United States' leadership would give this diplomatic process the most momentum. The administration must therefore make clear its commitment to moving the process ahead.

It is important to remember that reaching agreements will take time, but also that *beginning* the process is especially important. Starting a credible high-level discussion will require countries to identify key domestic stakeholders, assemble teams of experts on relevant issues, and develop detailed policy positions. The resulting informed dialogue will increase understanding between countries, identify important areas of agreement and disagreement, clarify intentions, and establish better channels of communication.

Diplomatic engagement on space security has a strong and broad base of political backing in the United States. It has been supported, for example, by the Council on Foreign Relations (CFR) Task Force on U.S. Nuclear Weapons Policy, headed by former Secretary of Defense Dr. William J. Perry and former National Security Adviser Brent Scowcroft; and by the Congressional Commission on U.S. Strategic Posture, chaired by Dr. Perry and vice-chaired by former Secretary of Defense James R. Schlesinger.

The international community, including the major space powers, also has called for discussions on outstanding space issues.

The United States should carefully consider its first steps. For example, the CFR Task Force has recommended developing a ban on testing ASAT weapons as an initial effort: "Propose a trilateral

44 As of October 1, 2010, nonmilitary satellites comprise approximately 75 percent of all operating satellites. Those that serve both military and nonmilitary users have been classified with the predominant user (UCS 2010).

45 As of October 1, 2010, the United States owns about half of all operating satellites and half of the military satellites in orbit (UCS 2010).

ban with China and Russia on tests of kinetic anti-satellite weapons that can destroy both civil and military satellites with projectiles fired from land-, air-, or space-based launching systems. Discuss with China and Russia how to expand such a ban to the global level and the broader issue of space weapons."

A ban on kinetic energy anti-satellite (KE ASAT) weapons would indeed be desirable. It would help protect the space environment, given that these weapons produce tremendous amounts of debris, and it would eliminate a demonstrated threat to satellites. And both China and Russia have expressed their willingness to discuss a ban on ground-based ASAT weapons as part of wider negotiations on banning space-based weapons. However, singling out KE ASAT weapons for limitation may be seen as self-serving for the United States, as it has the strongest ability to interfere with satellites using methods other than kinetic-kill attack. China in particular may view a U.S.-sponsored KE ASAT ban, in the absence of other limits, as an indication that the United States is not serious about the process, instead seeing a KE ASAT ban as a restriction directed at, and not benefiting, China.

A lack of interest by Russia and China in such an opening proposal may not be a true indication of their interest in space weapons agreements in general. A set of limits on ASAT weapons as part of a package that addresses China's and Russia's expressed security concerns, such as space-based weapons overall, would more likely generate a positive response.

Step 7. Assemble a negotiating team and begin building the diplomatic, technical, legal, and other kinds of expertise needed to support negotiations. Encourage other countries to do so as well.

To develop detailed space security proposals and engage in fruitful discussions, the United States and the other stakeholders must assemble teams of experts that can address the relevant diplomatic, technical, and legal issues, among others. This should begin immediately, as opposed to waiting for the details of a negotiating process to be decided.

Until such expertise is built up, participants are likely to come to the discussions without detailed and carefully considered positions, and progress may be frustratingly slow. Many countries possess some expertise in individual areas. But because of the lack of meaningful diplomatic engagement on space security issues for many years, few if any of them have in place the range of dedicated expertise needed to address these issues in sufficient detail to make significant progress.

While encouraging them to begin the process of assembling expertise, the United States must be careful not to assume that other countries' initial lack of progress in discussions necessarily reflects their lack of commitment to working on space security issues. For example, in recent years the Chinese Foreign Ministry was instructed to develop language and positions that reflected China's longstanding support for negotiations on PAROS. However, it did not have a mandate to actually negotiate or even develop serious proposals designed to move the CD toward negotiations, which were seen as highly unlikely.[46] The Chinese Foreign Ministry is charged with communicating with the outside world on arms control treaties,[47] but because of the lack of an agenda at the CD and the absence of arms control negotiations, other important parts of the Chinese government, including the Party leadership, have

46 The lack of communication and coordination between the Foreign Ministry and the country's other stakeholders was glaringly evident in the aftermath of the Chinese ASAT test in January 2007. China made no official acknowledgement of the test for two weeks, and even after news of the test had been leaked in the United States, China still remained silent for another five days.

47 It is important to recognize that the Chinese Foreign Ministry plays a role different from that of the U.S. State Department. The Foreign Ministry does not formulate policy but rather communicates and implements foreign policy decisions made by the Party leadership. Consequently, the Ministry's research and analytic capabilities are less robust, and Ministry representatives are not empowered to discuss—especially with foreigners—technological and policy-related information that has not been properly vetted. Its flexibility in formal, and even informal, talks is thus rather limited.

not yet been meaningfully engaged. Moreover, experts from groups outside the Foreign Ministry, who years ago may have been prepared to represent their bureaucratic interests, have moved on in their careers and there has been no need to replace them.

If, however, negotiations on space security move forward and potential agreements are on the table that could affect the interests of the Chinese military and aerospace sectors, these domestic stakeholders will likely insist on participating; they will weigh in heavily, in fact, just as nuclear stakeholders did when China began negotiating the Comprehensive Test Ban Treaty in the 1990s. Foreign Ministry representatives will have an important role to play, but technical and military matters will need to be resolved by others who understand the implications and who will eventually be constrained by any agreement that might be negotiated. Moreover, because China's space sector has experienced incredible growth and numerous reforms over the last decade, its own perspectives must necessarily be included.

The United States has some updating to do as well. Decades have passed since the nation took part in high-level international discussions on space security.[48] Additionally, in the intervening years new and powerful space stakeholders have emerged—such as the commercial satellite and launch industries and users of satellite-provided data—and their perspectives must also be included.

Step 8. Appoint a high-level expert panel to review and prioritize space situational awareness missions, including verification missions, and to recommend corresponding improvements to U.S. space surveillance capabilities.

Space situational awareness (SSA) is essential for space security and sustainability. SSA allows for the coordination of space traffic, and it is necessary for understanding what other actors are doing in space and whether their actions comply with their stated intentions and agreements.

The U.S. military has developed and is implementing a plan for SSA improvements based on its anticipated needs.[49] The Obama administration, recognizing the importance of improving SSA, has proposed a significant increase in funding for the 2011 fiscal year (FY2011); this request was about 70 percent greater than the estimated FY2010 funding (Black and Samson 2010b). These improvements will require time and sustained support, and the improvement plan itself should be reviewed in a broad and forward-looking manner that examines the system's current and potential roles and priorities.

In particular, the plan should adequately serve the needs of important nonmilitary users of SSA data, such as the commercial space industry and those responsible for monitoring compliance with space agreements, and it should aim to increase cooperation where useful. Additionally, given the growing importance of nonmilitary applications of SSA, the United States should review whether it makes sense for the military to be the sole agent for providing information and services to all these disparate users.

The United States has by far the most highly developed SSA capabilities of any nation. The SSN detects and tracks objects in space and can also be used to image many types of satellites. The SSN currently includes ground-based optical sensors and radars, as well as a staff that plans, performs, and analyzes the observations (Secure World Foundation 2008).

48 The Outer Space Treaty negotiations concluded 40 years ago, and while in 1985 the CD established an ad hoc committee on PAROS, the PAROS committee made little progress and ceased to exist after 1994. Since 1996, the CD has been unable to reconvene any ad hoc committee or agree on a program of work that would allow negotiations on any issue. Some countries pressed for negotiations on PAROS issues during this period—for example, Russia and China submitted to the CD a working paper on PAROS with other countries in 2002 and they also submitted a draft PAROS treaty in 2008.

49 In 2007, the Air Force was tasked to make a "clean sheet" study of the SSN to recommend improvements and help set priorities (Sirak 2007).

The SSN allows this country to keep a current inventory of space objects (satellites and debris), as well as timely and accurate information about their orbits. Precise orbital information makes it possible to predict satellites' future positions, which is important for avoiding interference (both physical and electronic) between satellites; for predicting and avoiding collisions with space debris; and for assessing collisions that do occur. Another important use of the SSN is to determine the operational status, purposes, and capabilities of satellites not owned by the United States.

The SSN currently tracks more than 21,000 objects in space by taking periodic measurements of their locations and using those data to determine their orbits and predict their future locations.[50] Because the system cannot watch all of these objects all of the time, planners must decide how to best use the limited SSN resources—in particular, how often to observe different objects and which objects should be given top priority.

These decisions depend not only on the nature of each object but also on the SSN's primary missions, which can change. Similarly, prioritizing improvements and expansions of the SSN requires a clear understanding of its primary missions. When the network was initially developed, its primary missions included tracking the relatively small number of satellites, warning the National Aeronautics and Space Administration (NASA) when objects would be passing near the space station, and predicting reentries and preventing them from triggering false ballistic missile warnings.

Today, however, the information that the SSN provides is increasingly being used to track debris and predict potential collisions in space. And in the future, it may be called on to play a central role in space traffic management and in monitoring compliance with voluntary agreements or legal obligations about space activities.

As a result, making decisions about the future of the SSN and how to improve it will first require clarifying and potentially revising the primary roles of the system. Then, in light of these roles, analysts must identify and prioritize the most important and cost-effective improvements for sensor systems and how they are to be used and managed.

These two steps require a detailed understanding of the set of technical and operational issues related to the SNN and of the breadth of changes that are possible. In that spirit, the administration should create a panel of experts tasked with (a) evaluating, clarifying, and potentially changing the roles of the SSN, and (b) recommending improvements to the system and its management consistent with those roles. This assignment could be carried out by the National Academy of Sciences, the President's Council of Advisors on Science and Technology, or an ad hoc panel.

As a result of longstanding procedures and bureaucratic interests, actually bringing about some of these changes may require sustained engagement by the White House.

Measures to enhance U.S. SSA include:

- Improving U.S. ability to collect and use data from the SSN. The improvements would address:
  - Technological limitations due to the number, type, and location of sensors
  - Operational limitations due to inefficiencies in the use of existing sensors
  - Analytic limitations due to outdated procedures for processing data
- Sharing information with partner states and organizations about the location and orbit of objects
- Increasing transparency about launches and current positions of satellites

We discuss these measures in more detail below.

---

50 For objects in LEO, the SSN sensors track objects down to about 10 cm or slightly smaller in size. For objects in GEO, which are roughly 50 times further away, the SSN tracks objects down to about one meter in size. The United States maintains a catalogue of space objects, which is the subset of these 21,000 objects for which the United States knows the object's origin. There are currently more than 15,000 objects in the catalogue.

Improving the Sensor Network. Building more and better sensors is the most obvious and visible step—and the most expensive. Key issues are:

- Improving sensor coverage in the southern hemisphere, particularly for objects in LEO.
- Improving sensor resolution (the ability to measure small spatial details) and sensitivity (the ability to measure faint objects) to better detect small objects in orbit. This is a particular concern as the amount of small but dangerous space debris continues to grow and the size of useful satellites continues to shrink.[51]
- Improving the network's ability to track objects in GEO during the daytime or when it is cloudy, given that the current capability relies primarily on ground-based optical telescopes.

Operational Improvements. Because the amount of debris being tracked has increased by more than 50 percent in the past five years, a plan for efficiently tracking debris now and in the future is particularly important. Operational procedures should therefore be reviewed to ensure that the SSN sensors are being used efficiently—even optimally, when practical—to carry out the priority missions of the network. This objective could require a shift in how sensors are used and tasked.

In addition, because much of the SSN staff consists of Air Force officers who cycle through this posting on a short-term basis, the system may benefit from being operated by a larger percentage of long-term professional staff.

Better Data Analysis. The SSN needs to make better use of the data it collects. The outdated legacy algorithms typically employed to process SSN data produce less accurate orbits than are possible and desirable.

Increasing the size of the SSN's long-term staff may be another priority. As the number of space objects grows, so does the number of potential collisions requiring detailed assessment by staff members.[52] More staff time could also be needed to support verification missions for the SSN.

Sharing Information with Partner States. The operator of a satellite typically has the most accurate and timely information on that satellite. Thus while the United States devotes more resources to space surveillance than any other country, it could still benefit from additional data collected by sensors in other countries or in commercial operation.

The United States currently provides orbital information on satellites free of charge to the public—and it supplies other (tailored) data privately[53]—but the data it offers are neither comprehensive nor always of the highest accuracy. Although in some cases national security legitimately requires limits on the information about particular satellites, having as much SSA data as possible available to all space users ultimately benefits everyone.

Sharing positional and orbital data requires space users to develop and adopt corresponding guidelines and data-exchange methods. The technical basis for achieving this goal is being developed at the International Organization for Standardization (ISO 2006) and elsewhere.

---

51 Although the SSN can reliably track only objects that are larger than 10 cm, there are hundreds of thousands of LEO objects sized between 1 and 10 cm. These objects and even smaller ones could potentially damage or destroy a satellite.

52 The February 10, 2009, collision of an Iridium communications satellite with a nonoperational Russian satellite not only destroyed a working satellite but was one of the worst space debris-generating events to date. The SSN did keep track of both satellites, but neither one was among the approximately 150 satellites that the system was closely monitoring. By the end of March 2009, the number of closely monitored satellites had been increased to about 330, with the goal of eventually extending such monitoring to all of the roughly 800 active satellites capable of maneuvering to avoid a collision.

53 In December 2009, the U.S. Strategic Command assumed responsibility for sharing SSA data and analysis with satellite owner/operators. Initiated as the Air Force's Commercial and Foreign Entities (CFE) program in 2004, it provides data from the SSN via the website *www.space-track.org*.

The ability to exchange data in a useful way will also be important to future efforts aimed at better integrating SSA data from many countries and satellite operators. For example, an international data center would be better able to provide space traffic management as well as to support verification of international agreements.

Step 9. Create a standing program to assess and improve options for verifying compliance with potential space security agreements.

As discussions on space security get under way, the United States should develop a sophisticated sense of how restrictions on technology and rules for behavior can be appropriately verified. Such understanding will help inform discussions and set realistic expectations, and it will help identify useful investments the United States might make, for example, in personnel or in SSA capabilities.

While some reject the utility of space arms control by arguing that it is "unverifiable," a number of useful rules and limits are indeed verifiable in principle. Some verification could be accomplished by the United States or other parties through their own resources ("national technical means"), while others might require more cooperation—such as by the exchange of data among space actors or by the conducting of inspections.

To support informed discussions of space security, the United States should create a standing verification program complete with technical, political, economic, legal, and strategic expertise. The program would carefully appraise a spectrum of possible rules, agreements, and limits and evaluate what capabilities and processes would allow the United States and other countries to verify as well as demonstrate compliance with them. As part of this study, the program would consider realistic ways in which countries might attempt to evade detection of noncompliance, how difficult such evasions would be to detect and counter, and to what degree successful evasion would be significant.

In addition to producing classified reports, the program should release detailed unclassified versions that could inform the public and stimulate U.S. and international discussion of space issues.

The extensive space surveillance capabilities of the United States, including the SSN, would provide the backbone of the national technical means that may be brought to bear on verifying space security agreements. However, verification is not currently a mission of the SSN. The verification program should consider how capable the current SSN system would be for various kinds of verification missions, what additional resources it would require, and how shifting resources to include these new missions would affect the SSN's ability to carry out its current primary missions.

The U.S. early-warning satellites may also be useful for verification tasks. These satellites monitor a large fraction of Earth's surface, and by detecting bright launch plumes (including those of short range missiles) they can provide data on the launch site, launch direction, and type of missile launched. This capability can be used to globally monitor launches of spacecraft as well as of ground-based ASAT weapons. For example, China's demonstration of ASAT capability in 2007 was preceded by two tests of the technology, both of which were observed by the United States, as was the January 2010 missile defense test that destroyed a suborbital object. U.S. missile defense sensors are increasingly being used for collecting other types of data as well, and they could be valuable additions to space surveillance.

The verification program should consider new assets—for example, sensors mounted on key satellites to monitor the surrounding regions. Such innovations could help detect violations of a keep-out zone around the satellite or help distinguish a debris collision from a deliberate attack.

The program should also consider an international center that would support verification by collecting and analyzing data from a worldwide network of sensors, similar to the one operated by the Comprehensive Test Ban Treaty Organization's International Monitoring System. The center could be part of a broader cooperative effort on SSA.

Step 10. Develop and implement transparency measures aimed at improving safety and predictability in space.

The administration should develop and implement TCBMs as a means of improving coordination and predictability in space and of reducing undue suspicion about U.S. space plans. Voluntary TCBMs would be most effective as part of an overall space security strategy that included negotiated agreements. But just by announcing such measures the United States could alert the world that it is serious about increasing space security and sustainability.

While the Obama NSP asserts that the United States will employ TCBMs, it does not indicate what kinds of measures it believes could be useful or what it intends to pursue. Meanwhile, the United States has begun adopting transparency measures in a limited way—for example, it is engaging in discussions with the Russian Federation (in the wake of the February 2009 satellite collision) and planning bilateral diplomatic and military exchanges with Russia on spaceflight safety and other TCBMs. The United States also has pursued discussions with European experts on the European Union's proposed Code of Conduct for Outer Space Activities.

In addition, the Obama administration has stated that it will begin prelaunch notification of commercial and NASA satellite launches, as well as of the "majority" of intercontinental ballistic missile launches and submarine-based ballistic missile launches, though it makes no commitment to notification of military satellite launches (Jahn 2010). While an improvement over current practice, which is not systematic, this policy pledges less than the Bush administration did upon signing the Hague Code of Conduct against Ballistic Missile Proliferation.[54]

While a useful start, these limited TCBMs are not commensurate with the problem. Additional transparency measures could include:

Policy transparency. As discussed in Step 1, publicly articulating the guiding principles and primary goals of U.S. space policy clarifies this country's intentions and may encourage other space actors to do likewise. Such gestures would increase predictability in space and could act as an important confidence-building measure.

While the new NSP is a first step in policy transparency, it is by nature relatively general. Thus additional statements that clarify key aspects would be useful. For example, the unclassified summary of the policy vaguely instructs the Secretary of Defense to "maintain the capabilities to execute the space support, force enhancement, space control, and force application missions."

While this same language has been part of the national space policies of a number of administrations, the interpretations have differed. The Obama administration should clarify what it means and how it diverges from the approaches of its predecessors. For example, the Obama NSP does not indicate the administration's policy on the development and use of ASAT weapons.

Clarity in such high-level documents is particularly important, as observers in other countries can have a difficult time differentiating official U.S. policies and goals from statements made by members of Congress or in military reports.

Coordinating measures. In addition to prelaunch notification, full compliance with the Registration Convention[55] for satellites would also be useful. Notices of launch by the United States are not always timely, and the final satellite orbits are not always included in the posted information.

54 The Hague Code of Conduct (HCOC) signatories resolve to "exchange pre-launch notifications of their Ballistic Missile and Space Launch Vehicle launches and test flights" (HCOC 2002).

55 For a discussion of instances of noncompliance with the Registration Convention, see McDowell 2009.

A particularly helpful transparency step would be release of the locations of satellites that are difficult to track or that are classified but nonoperational. For example, the United States should release updated orbital data about U.S. early warning satellite DSP-23, which failed in the fall of 2008. This satellite is drifting in GEO, where it threatens to interfere with satellites owned by other countries, but the United States has not released information about its location. Because it is not functioning, there would seem to be little rationale for keeping the satellite's orbit secret.

Budget transparency. Increased budget transparency would provide greater accountability and oversight of the planning and acquisition process; help the administration, Congress, and Pentagon better set priorities; eliminate inefficiencies and duplications of effort between programs; and provide reassurance to other space actors that the United States' actions mirror its stated intentions.

No centralized information is currently available about the space budget, even for use by the Pentagon or Congress. And no central authority consistently tracks the money spent on space-related U.S. national security activities that are distributed over the military services as well as other offices and agencies. While the Air Force has the lead on most space activities, the Navy, MDA, and National Reconnaissance Office (NRO), among others, also have their own significant space budgets.

Several measures would help government staff and outside observers better understand space spending. They include providing a top-line budget number that comprehensively includes both classified and unclassified military space expenditures; breaking out funding by function for unclassified programs; and providing more complete space budget-justification documents.

For many years, most recently in the FY2010 budgetary process, Congress has urged the Secretary of Defense to create a Major Force Program (MFP) category for space—a budgetary tool that would track space-related programs across the DOD's agencies and services. The DOD did create a "virtual" space MFP, intended to identify and aggregate spending on space activities across departments and to provide information by functional area. But the numbers compiled by this program have been of limited use because it has not included some important sources of space-related spending—such as the MDA and the Defense Advanced Research Programs Agency (DARPA)—and its top-line number has not been publicly released in recent years.

The summary budget documents currently provided share many of the same deficiencies. For example, the "Space-Based and Space-Related Systems" section of the DOD Comptroller's *FY 2011 Program Acquisition Costs by Weapons System* neglects much of the research and development costs, and it does not include programs in the MDA, DARPA, and NRO.

The administration should take the steps needed to ensure that the Pentagon and other governmental agencies provide this information in a comprehensive and timely way.

Demonstrating compliance with agreements. As part of its mandate, the space verification program discussed above should regard transparency measures as an integral part of verification. It should examine which TCBMs would be most useful for helping space actors demonstrate their compliance with certain regulations or for assisting others in their own monitoring activities. An example of such a measure might be the addition of simple lightweight radar reflectors to microsatellites in LEO to make them more observable.

Conclusion

By taking the above 10 steps, the United States would further its NSP's goals—notably the expansion of international cooperation in space, strengthened stability, and assurance of the essential military, civil, and commercial functions enabled by satellites. In so doing, the United States would also greatly improve the prospects for space security and sustainability into the future.

References

Baines, P. 2010. *Space security—the middle ground: One view from Canada*. UNIDIR space security conference 2010: From foundations to negotiations.

Barton D.K., R. Falcone, D. Kleppner, F.K. Lamb, M.K. Lau, H.L. Lynch, D. Moncton, D. Montague, D.E. Mosher, W. Priedhorsky, M. Tigner, and D.R. Vaughan. 2004. Report of the American Physical Society study group on boost-phase intercept systems for national missile defense: Scientific and technical issues. *Reviews of Modern Physics* 76(3):S1–S424. Online at *http://prola.aps.org/pdf/RMP/v76/i3/pS1_1*, accessed on September 19, 2010.

Bini, A. 2007. Export control of space items: Preserving Europe's advantage. *Space Policy* 23(2):70–72.

Black, S., and V. Samson. 2010a. *Space security programs of interest in the FY2010 Department of Defense budget proposal.* Online at *http://www.secureworldfoundation.org/siteadmin/images/files/file_372.pdf*, accessed on September 19, 2010.

Black, S., and V. Samson. 2010b. *Space security programs of interest in the fiscal year (FY) 2011 Department of Defense budget proposal.* Online at *http://www.secureworldfoundation.org/siteadmin/images/files/file_465.pdf*, accessed on September 19, 2010.

Canavan, G. 2004. *Estimates of performance and cost for boost phase intercept*. Washington Roundtable on Science and Public Policy. Washington, DC: George Marshall Institute. Online at *http://www.marshall.org/pdf/materials/262.pdf*, accessed on September 19, 2010.

Carter, A.B. 1986. Satellites and anti-satellites: The limits of the possible. *International Security* 10(4):49–98.

Cooper, P. 2009. Written testimony for a hearing on "Export Controls on Satellite Technology" of the Subcommittee on Terrorism, Non-Proliferation, and Trade of the House Foreign Affairs Committee. April 2. Patricia Cooper is president of the Satellite Industry Association.

Defense Threat Reduction Agency. 2001. *High altitude nuclear detonations (HAND) against low earth orbit satellites ("HALEOS").* Online at *http://www.fas.org/spp/military/program/asat/haleos.pdf*, accessed on September 19, 2010.

Denman, B. 2006. *Commercial SATCOM mission assurance*. Briefing to the Satellite Industry Association. December 7. Major Brian Denman is with U.S. Strategic Command. Online at *http://www.sia.org/2007DoDSatcomWorkshop/Thursday/DoD/MAWG.ppt#1*, accessed on September 19, 2010.

De Selding, P.B. 2010. India developing means to destroy satellites. *Space News*, January 4.

Gallagher, N. 2010. *Space governance and international cooperation.* Astropolitik. In press.

Gallagher, N., and J.D. Steinbruner. 2008. *Reconsidering the rules for space security*. Cambridge, MA: American Academy of Arts and Sciences.

Grego, L. 2010. *A history of anti-satellite (ASAT) programs*. Online at *http://www.ucsusa.org/nuclear_weapons_and_global_security/space_weapons/technical_issues/a-history-of-anti-satellite.html,* accessed on September 19, 2010.

Hague Code of Conduct against Ballistic Missile Proliferation (HCOC). 2002. Online at *http://www.unhcr.org/refworld/docid/3de488204.html*, accessed on September 19, 2010.

Harrison, R.G., C.G. Shackelford, and D.R. Jackson, 2009. Space deterrence: The delicate balance of risk. *Space and Defense* 3(1):1–30.

International Organization for Standardization (ISO). 2006. *Space data and information transfer systems—Orbit data messages*. Online at *http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=42722*, accessed on September 19, 2010.

Iridium Communications, Inc. 2009. *Iridium provides update on satellite constellation*. Online at *http://investor.iridium.com/releasedetail.cfm?releaseid=429183*, accessed on September 19, 2010.

Jacobs, A., and J. Ansfield. 2010. With defense test, China shows displeasure of U.S. *New York Times,* January 12.

Jahn, G. 2010. US agrees to announce missile launches. Associated Press, May 20.

Japan Today. 2010. Japan set to approve exporting new SM3 interceptors. *Japan Today*, July 25.

Kennedy, L.E. 2010. *U.S. space policy review and perspectives on various challenges*. Remarks at the UNIDIR space security conference 2010: From foundations to negotiations. Laura E. Kennedy is the U.S. ambassador to the United Nations Conference on Disarmament. Online at *http://geneva.usmission.gov/2010/03/29/ambassador-kennedy-space-policy-review*, accessed on September 19, 2010.

Lewis, J.E. 2002. *Preserving America's strength in satellite technology: A report of the CSIS Satellite Commission*. Washington, DC: Center for Strategic and International Studies. Online at *http://csis.org/publication/preserving-americas-strength-satellite-technology,* accessed on September 19, 2010.

McDowell, J. 2009. *Adherence to the 1976 convention on registration of objects launched into outer space*. Online at *http://www.planet4589.org/space/un/un_paper1.html#Tab2*, accessed on September 19, 2010.

National Aeronautics and Space Administration (NASA). 2010. Avoiding satellite collisions in 2009. *Orbital Debris Quarterly News* 14(1):2. Online at *http://orbitaldebris.jsc.nasa.gov/newsletter/pdfs/ODQNv14i1.pdf*, accessed on September 19, 2010.

National Aeronautics and Space Administration (NASA). 2007. United Nations adopts space debris mitigation guidelines. *Orbital Debris Quarterly News* 11(2):1–2. Online at *http://www.orbitaldebris.jsc.nasa.gov/newsletter/pdfs/ODQNv11i2.pdf*, accessed on September 19, 2010.

Rocca, C. 2008. Statement delivered in the general debate of the United Nations' First Committee. Ambassador Christina Rocca is permanent representative of the United States to the Conference on Disarmament. Online at *http://www.reachingcriticalwill.org/political/1com/1com08/statements/8OctUS.pdf*, accessed on September 19, 2010.

Rocca, C. 2007. Statement delivered to the United Nations' Conference of Disarmament on Prevention of an Arms Race in Outer Space. Geneva, February 13. Online at *http://www.reachingcriticalwill.org/political/cd/speeches07/1session/Feb13USA.pdf*, accessed on September 19, 2010.

Rose, F.A. 2010. Remarks to the Conference on Disarmament, Geneva, Switzerland. July 13. Online at *http://geneva.usmission.gov/2010/07/13/das-frank-rose-space-policy*, accessed on September 22, 2010.

Sea Launch Company, LLC. 2009. Sea Launch history. Online at *http://www.sea-launch.com/history.htm,* accessed on September 19, 2010.

Secure World Foundation. 2008. *Space situational awareness factsheet*. Online at *http://www.secureworldfoundation.org/siteadmin/images/files/file_21.pdf*, accessed on September 19, 2010.

Sirak, M. 2007. Air Force mulls path ahead for protecting satellites. *Defense Daily*, September 25.

Stares, P. 1985. *The militarization of space: U.S. policy, 1945–1984*. Ithaca, NY: Cornell University Press.

Stupl, J. 2010. Assessment of long range laser weapon engagements: The case of the airborne laser. *Science and Global Security* 18(1):1–60.

Taiwan Link. *China's missile defense interceptor program: An independent Chinese analysis*. Online at *http://thetaiwanlink.blogspot.com/2010/01/chinas-missile-defense-interceptor.html*, accessed on September 19, 2010.

Tarantino, F.A. 2008. *The impact of export controls on nonprofit and university R&D Efforts.* Briefing for the Congressional Export Control Working Group. Frederick A. Tarantino is president and chief executive officer of the Universities Space Research Association. Online at *http://www.usra.edu/galleries/ipc_files/itar.pdf*, accessed on September 19, 2010.

Tiron, R. 2010. New Agency will house export rules. *The Hill*, June 30.

Union of Concerned Scientists (UCS). 2010. UCS satellite database. Online at *http://www.ucsusa.org/satellites,* accessed on September 19, 2010.

U.S. Air Force (USAF). No date. Space and Missile Center. Chapter V: Satellite systems. Online at *http://www.losangeles.af.mil/shared/media/document/AFD-060912-025.pdf,* accessed on September 19, 2010.

U.S. Congress. 1998. Strom Thurmond National Defense Authorization Act for Fiscal Year 1999. Public Law 105-261. Oct. 17.

U.S. House of Representatives. 2010. *U.S. national security and military/commercial concerns with the People's Republic of China*. Report 105-851. Online at *http://www.house.gov/coxreport*, accessed on September 19, 2010.

Weeden, B. 2010. Dealing with Galaxy 15: Zombiesats and on-orbit servicing. *Space Review*, May 24. Online at *http://thespacereview.com/article/1634/1*, accessed on September 19, 2010.

White House. 2009. Statement of the press secretary. August 13. Online at *http://www.whitehouse.gov/the_press_office/Statement-of-the-Press-Secretary*, accessed on September 19, 2010.

Wright, D. 2009. *Colliding satellites: Consequences and implications.* Online at *http://www.ucsusa.org/assets/documents/nwgs/SatelliteCollision-2-12-09.pdf*, accessed on September 19, 2010.

Wright, D., L. Grego, and L. Gronlund. 2005. *The physics of space security: A reference manual.* Cambridge, MA: American Academy of Arts and Sciences.

Zelnio, R. 2006. The effects of export control on the space industry. *Space Review*, January 16. Online at *http://www.thespacereview.com/article/533/1*, accessed on September 19, 2010.

APPENDIX

Analysis of New Space-Weapon Missions

What follows are brief summaries of some of the technological issues discussed in the text.

Destructive Anti-satellite (ASAT) Weapons

Developing offensive capabilities to damage or destroy an adversary's satellites, and reserving the right to use such weapons, would be contrary to U.S. self interests. Because targeting satellites is much easier than defending them, a world without constraints on interfering with satellites would necessarily be riskier for all countries' space operations.

Satellites are inherently vulnerable to various kinds of attack, both from space and the ground, as they move in predictable and repeated orbits and generally are visible to much of Earth. For example, Earth-monitoring satellites follow low-altitude orbits and circle from pole to pole while the planet turns beneath them, permitting them to view (and be viewed by) each spot on Earth twice a day. A determined adversary would thus have multiple opportunities, as well as a variety of means, to interfere with a given satellite.

While the United States would likely possess the most sophisticated versions, other countries could also develop ASAT weapons. By developing such weapons and hence legitimizing their use, the United States could increase the risk that these kinds of technologies would be used against its own satellites. Moreover, pursuing offensive weapons could undermine the efficacy of diplomatic and cooperative initiatives to solve other space issues.

The existence of ASAT weapons might lead to the inadvertent escalation of a crisis. If a satellite failed, it could be difficult or impossible for a country to quickly determine the reason for the failure. If the event occurred during a time of political tension, it could very well be interpreted as an attack even if it were due to natural causes, such as an electronic malfunction or a collision with debris.

In fulfilling their missions, destructive ASAT weapons could also create large amounts of orbiting space debris of their own, posing a significant risk to other (non-target) satellites that orbit near the same altitude. While technologies that damage or destroy satellites without producing large amounts of debris may be feasible, their success could be less predictable and verifiable than a debris-producing attack, which in turn could make them less desirable options when assured damage or destruction of a satellite is the objective.

Active Defense of Satellites

Space-based "bodyguard" weapons—satellites intended to orbit near a valuable satellite and intercept an approaching ASAT weapon—would not solve the problem of keeping satellites reliably safe. Their development and deployment could also generate new problems.

Bodyguards against Space-Based Threats

Bodyguard weapons are unlikely to be effective against a space-based ASAT weapon in a "crossing orbit"—one that crosses (or nearly crosses) the orbit of a target satellite.

As the target satellite and ASAT weapon passed near the same point, the weapon would change its orbit slightly and attempt to home on and collide with that satellite. Such a collision would take place at a very high relative speed (roughly 10 kilometers/second) and would destroy the satellite, as the bodyguard would not likely be able to respond in time to intercept the crossing-orbit attack. Because the ASAT orbit change would take place shortly before the intended collision, the U.S. space surveillance system would not have enough time to detect the change, predict the ASAT weapon's new path, and cue the bodyguard.

Additionally, the bodyguard's own sensors would be incapable of monitoring all possible directions an ASAT weapon might come from, and they could not detect it at a distance great enough for the bodyguard to engage it with any confidence.

If the bodyguard were indeed able to engage an ASAT weapon as it approached the target satellite, this intercept would still be unlikely to protect the satellite. The ASAT weapon would merely collide with its target as a "shotgun blast" instead of a "bullet," as a large fraction of the fragmented weapon's mass would continue orbiting along its original path. Because debris fragments—even those that are one centimeter or smaller—can cause severe damage to a satellite at these speeds, this shotgun blast could still destroy the satellite.

Another potential space-based ASAT weapon is one that is placed in the same orbit as the target satellite (called a *co-orbital ASAT*) or in a nearby orbit. Such a weapon would approach the target satellite relatively slowly, and when it was close enough it would attempt to destroy the satellite by, for example, exploding or shooting a burst of pellets. While there are some scenarios in which a bodyguard might be able to defeat certain types of ASAT attacks of this kind, an intelligent adversary could avoid using such strategies if it suspected the satellite's owner might deploy bodyguards. These considerations might also induce the adversary to instead employ an ASAT weapon on a crossing orbit. As a result, the satellite owner could not rely on bodyguards for protection.

Bodyguards against Ground-Based Threats

A bodyguard satellite is also unlikely to defend against a determined adversary using ground-based ASAT weapons. The adversary could attack a target satellite in low Earth orbit (LEO)—as well as any bodyguards there—from the ground by using a missile that lofted a homing weapon to the altitude of the target satellite but did not place the weapon in orbit. Because the launcher would not need to reach the high speeds needed to get the ASAT weapon in orbit, the attacker could use a relatively inexpensive medium-range missile to loft it.[56]

If the bodyguard were designed to intercept a ground-based ASAT-weapon launcher in boost phase, it could not do so—the medium-range missile's boost phase would end too quickly to be targeted from space.

In any event, because the launcher would be relatively inexpensive, and the target satellite (if it merited such an attack) would likely be quite valuable, the attacker could launch multiple ASAT weapons at the same time so as to overwhelm the bodyguards.[57] Moreover, the limited ability to test bodyguards under diverse real-world scenarios would provide little confidence in their effectiveness.

---

56 This is the kind of ASAT technology that China demonstrated in January 2007.

57 The target satellite itself might attempt to maneuver, but the much less massive homing ASAT weapon could outmaneuver it.

Potential Offensive Uses of Bodyguard Weapons

Despite its inability to provide an effective defense, a nominally defensive bodyguard weapon could have intrinsic offensive capability against other satellites as a result of its homing features. Other countries would certainly recognize or assume this. Therefore their reaction, including the development of similar weapons, could result in a more dangerous space—and geopolitical—environment.

Space Control and Space-Based Ballistic Missile Defense

A space-based boost-phase missile defense system would target ballistic missiles during launch, while the boosters were burning. Proponents argue that by engaging a missile during boost phase, space-based interceptors (SBIs) could avoid the crippling problems that plague interceptors designed to engage warheads during midcourse phase, when the warhead is above the atmosphere. In particular, decoys and other countermeasures can keep a midcourse interceptor from identifying the warhead amidst other objects and therefore keep the warhead from being intercepted.[58] And a boosting missile is a more attractive target than a warhead because it is large, easy to detect (given its large plume), and vulnerable to attack (as it is not hardened).

However, such a system would require many hundreds of orbiting interceptors to defend against one or two missiles, and it would have serious inherent vulnerabilities that would render it ineffective. Thus a full system is unlikely to be built in the near future.

Space Basing Requires Many Interceptors

Given that the boost phase of long-range missiles lasts for only three to four minutes,[59] the interceptor must be based near the launch site. Because in some cases it is not possible to station interceptors on Earth close enough to the site, placing interceptors in orbit would in principle allow global boost-phase coverage.

However, to reach attacking missiles during this very short time, SBIs would have to be stationed in low-altitude orbits.[60] This requirement, together with the need to provide reasonably wide geographic coverage, means that the system would need a large number of SBIs in orbit.

Because the laws of physics require that objects orbiting in LEO move rapidly with respect to the ground and cannot stay over any given area on Earth, ensuring that at least one interceptor is positioned to reach a given missile launch site at all times requires many SBIs in orbit. As one moves out of position, another must move into position.

A 2003 American Physics Society (APS) study showed that hundreds to thousands of SBIs would be required to provide global coverage against a launch of one or two ballistic missiles from a launch site (Barton et al. 2004). This estimate is consistent with the size of the space layer in the Global Protection Against Limited Strikes (GPALS) missile defense system, which was proposed (but not built) by the George H.W. Bush administration in the early 1990s. GPALS called for 1,000 to 5,000 SBIs (Barton et al. 2004, Canavan 2004).

Doubling the number of missiles that such a defense could engage would require doubling the size of the entire constellation of SBIs.

58 There are other countermeasures that an attacker could use against boost-phase interceptors, some of which are discussed in Barton et al. 2004.

59 Shorter-range missiles would have shorter burn times.

60 A typical altitude discussed for such orbits is 500 kilometers.

Moreover, the APS study showed that for the foreseeable future each SBI would require a mass of many hundreds of kilograms.[61] As a result, deploying such a system would not only be enormously expensive and but actually would exceed U.S. launch capabilities.[62] Additionally, such a system would raise significant issues for LEO crowding and traffic management.

Defense Is Not Reliable

If such a large system were built and the technology worked perfectly, it would still not provide a reliable defense, for two reasons. First, even if the constellation of hundreds to thousands of interceptors described above were in place, only one or two SBIs would be in position to reach any given launching missile in time to destroy it. Consequently, the defense could be overwhelmed by simultaneously launching multiple missiles from one location.

Second, the system could not protect itself from attacks intended to remove interceptors. Because SBIs would be in low-altitude orbits they could easily be detected and tracked from the ground; an adversary would know their current and future locations. As a result, any SBI would be vulnerable to attack by inexpensive short- or medium-range missiles. These missiles would burn out at too low an altitude to be intercepted by the SBI, but they could loft homing ASAT weapons at it.[63] By destroying relatively few SBIs in this way, an attacker could create a gap in the defense through which it subsequently could launch its long-range missiles. In short, a defense based on deploying hundreds or thousands of SBIs at enormous cost could be defeated by a handful of enemy missiles.[64]

Potential Offensive Uses of SBIs

Deploying even a small number of SBIs might negatively affect strategic relations because the SBIs could have a significant ability to destroy satellites, which travel in predictable orbits and achieve speeds similar to those of long-range missiles. Homing on a satellite rather than a boosting missile would require a different (possibly additional) sensor on the SBI, but an observer on the ground would not be able to tell which sensor the SBI was carrying. U.S. budget descriptions have suggested that the boost-phase missile defense system might also be designed to intercept warheads during the midcourse phase of flight.[65] The sensor needed for such midcourse intercepts would allow an interceptor to home on a satellite.

Additionally, the large amount of thrust of interceptors, which they would need to perform boost-phase missile defense from space, means that they could reach and attack satellites in GEO as well as those in lower orbits.

Space-Based Ground-Attack Weapons

Space-based ground-attack weapons would be 50 to 100 times more expensive than ground-based alternatives with a comparable delivery time.[66]

---

61 Each interceptor would have a larger mass than that of an Iridium satellite communications satellite at launch (700 kilograms).

62 Depending on how space-launch capacity is counted—mass launched per year or total launches per year—deploying the APS Study Group baseline system would require roughly a five- to tenfold increase in the U.S. space launch capacity (Barton et al. 2004).

63 A short- or medium-range missile could loft a homing ASAT weapon to the altitude of the SBI but would not need to place it into orbit. If the launch of the attacking missile caused the SBI to fire in an attempt to protect itself, that would also remove the SBI from the system.

64 See "Section 9: Space Basing," in Wright, Grego, and Gronlund 2005.

65 Allowing the SBI to engage its target during midcourse is intended to extend the time available for an intercept to occur. However, midcourse interception is susceptible to countermeasures. Avoiding the countermeasures problem is a key rationale for pursuing boost-phase (and thus SBI) ballistic missile defense, rather than midcourse defense, in the first place,

66 See pp. 89–96 of Wright, Grego, and Gronlund 2005.

To have a delivery time of less than an hour, space-based weapons would be placed in low-altitude orbits and move quickly relative to the surface of Earth. A space-based system intended for global coverage and prompt on-demand attacks would therefore require a large number of weapons in orbit to ensure that one was in the right place for a mission at any given time. For global coverage and a delivery time of 30 minutes, such a system would require a constellation of roughly 100 weapons in orbit to ensure that just one weapon was in position; if two weapons were needed in position, the constellation would need to be twice as large.

In addition, a space-launch vehicle would have to launch not only the orbiting weapon but also the fuel that the weapon would need to accelerate out of orbit and down toward its target on Earth. Placing this combined mass into orbit would require significantly more launch capability than simply launching a ground-based weapon on a suborbital path to its target.

SECURING THE SKIES

Ten Steps the United States Should Take to Improve the Security and Sustainability of Space

Space has become an essential part of the modern world, with satellite services playing increasingly central roles in civil, scientific, commercial, and military affairs. The number of countries and companies with satellites or other important interests in space continues to grow, as does the range of purposes for which satellites are used. While space was once seen as vast and empty, recent trends and events make clear that the space environment needs more protection, that satellites face growing risks, and that space activities may be a potential source of mistrust and tension.

Policy makers in the United States and around the world are recognizing that existing international legal agreements and norms are not adequate to address these issues.

The United States has a vital interest in ensuring the sustainability of the space environment, keeping satellites safe and secure, and enhancing stability not only in space but also on the ground. The United States cannot address these space-related issues on its own, but its international leadership is essential.

This report recommends 10 practical near-term steps that the United States should take to protect its own assets and to move the world toward a more secure and sustainable future in space.

Union of Concerned Scientists
Citizens and Scientists for Environmental Solutions

Printed on recycled paper using vegetable-based inks.

The Union of Concerned Scientists is the leading science-based nonprofit working for a healthy environment and a safer world. The full report is available on the UCS website at *www.ucsusa.org/securingtheskies*.

National Headquarters
Two Brattle Square
Cambridge, MA 02138-3780
Phone: (617) 547-5552
Fax: (617) 864-9405

Washington, DC, Office
1825 K St. NW, Suite 800
Washington, DC 20006-1232
Phone: (202) 223-6133
Fax: (202) 223-6162

West Coast Office
2397 Shattuck Ave., Suite 203
Berkeley, CA 94704-1567
Phone: (510) 843-1872
Fax: (510) 843-3785

Midwest Office
One N. LaSalle St., Suite 1904
Chicago, IL 60602-4064
Phone: (312) 578-1750
Fax: (312) 578-1751