Monitoring Space Weaponry: Detection and Verification Issues

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MONITORING SPACE WEAPONRY: DETECTION AND VERIFICATION ISSUES

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SUMMARY

The United States and the Soviet Union are finding outer space to be an increasingly attractive medium in which to deploy and utilize advanced military systems, potentially including weapons. At the same time, the two superpowers have indicated an interest in expanding arms control to regulate military activities in space. The most prominent examples of these two trends are the U.S. Strategic Defense Initiative (SDI) program and its Soviet counterpart, which are currently the subjects of negotiation in the Geneva Nuclear and Space Talks (NST).

If agreements that affect the research, development, testing, or deployment of space weapons are to be reached, the United States must be able to monitor the treaty-limited systems and verify compliance with the agreement. And even beyond treaty verification concerns, the United States will inevitably have new and more demanding requirements to monitor the increasing number and types of activities undertaken by various nations in space. This report attempts to establish guidelines for future space monitoring technologies by briefly examining key types of potential arms control constraints on space weapons; considering the impact of those constraints on current and potential U.S. military capabilities, including the consequences of treaty violations; defining generic monitoring/verification requirements and difficulties for these arms control regimes; and deriving future verification and intelligence collection requirements and technology challenges.

The report postulates a continuum of possible space/strategic defense arms control agreements in order to explore a wide range of space detection and verification requirements. These hypothetical agreements are as follows:

- Comprehensive or limited ban on "space strike weapons" (space-space, earth-space, space-earth);
- Modification or replacement of the Anti-Ballistic Missile (ABM) Treaty;
- Comprehensive or limited ban on anti-satellite (ASAT) weapons;
- Ban on nuclear and nuclear-driven space weapons;
- Confidence-building measures (CBM).

Examination of the verification requirements for these hypothetical agreements reveals a number of serious technical challenges that cannot be met by current or projected monitoring capabilities.

To explore the general technical problem of monitoring the *testing* of space weapons, the report recommends an approach that relies upon the detection of signals, either natural or stimulated, that emanate from the exercise of a weapon. These signals, called "observables," are system determined by the characteristics of the weapon and its location on the ground or in space. Some of these observables can be monitored with the suite of photographic, infrared (IR), radio frequency (RF), and microwave detectors used in current and prospective national technical means (NTM). (This is especially true of the observables associated with the testing of nuclear or nuclear-driven systems.) In other cases, notably ground or space-based directed energy weapon (DEW) tests, the United States lacks the technical capability to detect characteristic signatures, or does not have sufficient information about the nature of those signatures, or both.

The detection of space weapon *deployment* presents different and more difficult problems than the detection of testing. Space weapons may give very little evidence of their true nature once on station. They may emit no signals at all, or no signals at presently detectable levels, when not in active use. The monitoring of deployed weapons may therefore require technical verification measures of unprecedented intrusiveness, whether the suspect object is on the ground or in space. Active NTM technologies may be necessary to induce an observable physical or chemical reaction that will indicate the nature of the system being interrogated. These active detection techniques are not now in hand, especially for use in space; current U.S. space monitoring capability is based largely on passive measures (e.g., photography) that do not raise issues of violation of national sovereignty.

To address these monitoring deficiencies, the report's analysis suggests the value of a tripartite technology development effort:

> **Create a Working Data Base of Observable Signatures.** This data base would consist of information about the unique physical, chemical, electromagnetic, and operational characteristics associated with nuclear, kinetic energy weapon (KEW), and DEW space weapons. The construction of this data base should benefit greatly from a close analysis of the signatures generated by equivalent U.S. programs (e.g., the neutral particle beam and free-electron laser).
>
> **Develop Enhanced or New Sensors Optimized to Detect Space Weapon Tests.** Four technology approaches seem especially noteworthy here: (1) enhance current NTM systems (photographic, IR, RF) specifically for use in space; (2) continue to develop space-based radar techniques and systems; (3) develop new particle detectors for use in monitoring low-level intrinsic signatures, and as detectors for active stimulation and imaging techniques; and (4) investigate chemical-detection sensors that can be used in a space environment.
>
> **Explore Techniques for the Active Probing and Imaging of Space Objects.** One of the most promising new active technologies is the use of radiography, which can derive images of the interior of objects using neutrons or gamma rays. Radiography appears potentially useful in analyzing a variety of ground or space-based systems, both nuclear and non-nuclear. If these active techniques are designed to be non-destructive or "non-interfering" with normal system performance, they may ease otherwise difficult questions about national sovereignty as well as arms control verification.

CONTENTS

ABSTRACT

If agreements that affect the research, development, testing, or deployment of space weapons are to be reached, the United States must be able to monitor the treaty-limited systems and verify compliance with the agreement. This report attempts to establish guidelines for future space monitoring technologies by briefly examining key types of potential arms control constraints on space weapons; considering the impact of those constraints on current and potential U.S. military capabilities, including the consequences of treaty violations; defining generic monitoring/verification requirements and difficulties for these arms control regimes; and deriving future verification and intelligence collection requirements and technology challenges.

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I. INTRODUCTION

At the December 1987 Washington summit meeting between President Reagan and Soviet General Secretary Gorbachev, the United States and the USSR agreed to "work out an agreement that would commit the sides to observe the ABM Treaty, as signed in 1972, while conducting their research, development, and testing as required, which are permitted by the ABM Treaty, and not to withdraw from the ABM Treaty, for a specified period of time. Intensive discussions of strategic stability shall begin not later than three years before the end of the specified period, after which, in the event the sides have not agreed otherwise, each side will be free to decide its course of action."[1]

Immediately after the summit, U.S. and Soviet officials issued divergent public statements which revealed that substantive Soviet-American differences over defense and space issues had not actually been resolved, and that the compromise language of the summit communique merely avoided the subject through traditional diplomatic methods.[2] In essence, the United States is currently undertaking a program of research, development, and testing designed to determine the feasibility of a comprehensive strategic defense system, which would include substantial space-based components. If feasible, the U.S. would hope eventually to deploy such a system. Although the USSR has now admitted the existence of its own research and development program for space-based strategic defenses,[3] the Soviets appear to argue that any testing of ballistic missile defense (BMD) components and systems in space would be a violation of the ABM Treaty. They have clearly stated that deployment of weapons in space would be highly destabilizing and would prevent reductions in strategic offensive arms.

Whatever the immediate outcome of this U.S.-Soviet controversy over strategic defenses and the ABM Treaty, it now appears that any future U.S.-Soviet strategic offensive arms control agreements will probably be associated with some agreements or understandings about strategic defenses. Any such defensive agreements or understandings, in turn, will inevitably touch upon the issue of weapons systems and components in space. Even without arms control, the United States will inevitably have new and more demanding requirements to monitor the increasing number and type of activities undertaken by the Soviet Union and various nations in space.

The purpose of this analysis is to begin to establish guidelines for future space monitoring technologies by briefly:

1) examining types of potential arms control constraints on space weapons;

2) considering the potential impact of those constraints on current and potential U.S. military capabilities, including the consequences of treaty violations; and

3) defining generic monitoring/verification requirements.[4]

II. POSSIBLE TREATIES AND DETECTION AND VERIFICATION CONSIDERATIONS

Until quite recently, the American government operated on the assumption that, for technical and political reasons, space does not represent an attractive theater for the deployment or operation of weapons systems. The United States, however, has traditionally favored the use of space systems for other critical military missions — strategic early warning, reconnaissance, meteorology, navigation, and communications. The Soviet Union apparently operated its space program along similar lines. As a result, the two sides tacitly agreed not to challenge, legally or militarily, the use of non-weapon space systems by their adversary in peacetime.[5]

To help codify this practice, the United States and the Soviet Union have agreed not to test or deploy nuclear weapons in outer space (the Limited Test Ban Treaty and the Outer Space Treaty); not to interfere with the other side's national technical means, i.e., satellite surveillance capabilities (Strategic Arms Limitation Talks — SALT I and II); and not to develop, test, or deploy ballistic missile defenses in space (the ABM Treaty). As long as this long-standing military, political, and technical "regime" in space held, the United States did not believe it necessary to develop the technology to detect and monitor weapons in space.

The American perception of the *potential* military utility of space systems has changed dramatically over the past several years. The U.S. Strategic Defense Initiative reflects this changed perception, but it did not cause the change, nor is the change limited to SDI. Advances in military technology make it possible to conceive of space platforms that would serve as an integral part of sophisticated terrestrial weapons systems — for instance, satellites might contain sensors that could target highly-accurate conventional munitions on the tactical battlefield of Europe, or locate mobile strategic targets in real time.[6] For some concepts of strategic defense, space platforms could be used to carry chemically-powered interceptors, directed energy generators, electromagnetic rail guns, or relay mirrors for use against ballistic missiles.

In the context of changing technological prospects for military activities in space, there has been growing Western interest in a renewed effort at space arms control. Some proponents of space arms control advocate negotiated agreements with the Soviets that would attempt to perpetuate the perceived sanctuary status of space — i.e., to prevent deployment of advanced weapons technologies. On the other hand, some proponents of increased military activity in space do not regard arms control as being an appropriate instrument of national policy in this case.[7] Another perspective, that taken by the Reagan administration, regards at least some kind of arms control as an important and perhaps essential mechanism to introduce space-based strategic defenses.[8]

On the basis of such views and already formulated positions, one can postulate a continuum of possible space/strategic defense arms control agreements — extending from the Soviet proposal for a comprehensive treaty banning all space weapons, to the official American position which would encourage the development and possible deployment of BMD weapons. [The range of possible agreements has been increased, at least in principle, by the recent willingness of the United States and the Soviet Union to permit cooperative measures and on-site inspection as part of the Intermediate-Range Nuclear Forces (INF) Treaty verification scheme.]

Within the spectrum of possible agreements, this report will consider the detection and verification requirements of the following:

A. Comprehensive or limited ban on "space strike" weapons (space-space, earth-space space-earth);

B. Modification or replacement of the ABM Treaty;

C. Comprehensive or limited ban on ASAT weapons;

D. Ban on nuclear and nuclear-driven space weapons;

E. Confidence-building measures.

This list is not intended to be definitive or predictive; these hypothetical agreements were chosen to include a wide range of reasonable space detection and verification requirements. Of course, it is possible that a formal treaty would encompass more than one of these types of agreements. Indeed, in the case of "grand bargains" that involve offense-defense trade-offs, a formal treaty might include several of these types of agreements in explicit combination with reductions in strategic and theater nuclear forces. Nevertheless, because each type of space agreement mentioned above would have its own internally consistent set of detection and verification requirements, they shall be considered individually.

A. Comprehensive or Limited Ban on "Space Strike Weapons"

The Soviet Union's stated interest in the demilitarization of outer space preceded President Reagan's March 1983 "Star Wars" speech. In August 1981, the USSR tabled a draft Treaty in the United Nations that proposed a prohibition on the use of force in space and a ban on the stationing of "weapons of any kind" in orbit. Two years later, the Soviets presented a second draft U.N. Treaty, which called for a ban on the testing and deployment of "any space-based weapons intended to hit targets on earth, in the atmosphere, or in space;" a prohibition on the testing and creation of "new anti-satellite systems;" and a ban on the testing and use of "manned spacecraft for military, including anti-satellite purposes."[9]

The USSR's focus on space arms control continued in the Defense and Space component of the Geneva Nuclear and Space Talks, which formally opened in March 1985. Here the Soviets initially proposed to ban all research, development, testing, and deployment of "space strike weapons." Space strike weapons were defined as those deployed in space or on the ground which were capable of destroying objects in space, and weapons in space capable of destroying objects on the ground (space-space, ground-space, space-ground). The Soviets have apparently indicated some flexibility in this formulation, especially as it pertains to the meaning of "research;" however, they continue to link progress in the

Defense and Space Forum with agreement on negotiated reductions in strategic offensive weapons (START). The United States has been unwilling to negotiate with the Soviets on such vague, all-inclusive terms as "space strike weapons," and argues that any prohibition on research is fundamentally unverifiable. The Reagan administration does agree that one purpose of the NST negotiations is to "prevent an arms race in space," but claims that this is best achieved through a negotiated transition to a defense-dominant strategic environment.[10]

What would a comprehensive ban on space strike weapons along the lines of the original Soviet proposal entail? It would prohibit the use of force in space, from space against objects on earth, and from earth against objects in space. It would also prevent the research, development, testing, and deployment of all weapons and their components in space and on celestial bodies. In effect, a comprehensive ban would preclude research, development, testing, and deployment (RDT&D) of the following: space-based ballistic missile defenses, space and ground-based ASAT interceptors, and ground-based BMD systems that intercepted warheads outside the atmosphere. It could also prohibit electronic or other interference with non-weapons systems in space.

This comprehensive agreement would require that some sort of operational constraints be placed on all existing or future systems with residual BMD or ASAT capabilities, but which have other primary purposes (e.g., intercontinental ballistic missiles — ICBMs, space shuttle, space station). It would permit RDT&D on other types of space systems that have civil or military uses, such as navigation, surveillance, and communications satellites — subject to appropriate operational restrictions, and possibly to the inspection of space assets and related ground facilities. The ban would also prohibit the RDT&D of space-to-ground weapons, an area that does not seem to hold any military interest to either side at the present time.

In place of a comprehensive ban on the research, development, testing, and deployment of space strike weapons, the two sides could in principle agree to a more limited ban on outer space weaponry. Such a limited agreement on "preventing an arms race in space " would probably have many of the same features of a total ban, but could allow one or more of the following: existing ASAT and ABM systems; expanded ground-based ASAT and BMD but no space-based system; any ASATs but no BMD; certain types, or numbers, of space strike weapons systems; or unlimited R&D, but no testing or deployment of ABM/ASAT systems and their components.

Impact of a Space Strike Ban. From the U.S. perspective, a comprehensive ban would affect virtually all of the systems and components now associated with SDI, possibly excepting low-altitude terminal ABM interceptors (such as the proposed high-endoatmospheric defense interceptor, or HEDI). It would prohibit space-based kinetic kill interceptors or directed energy weapons; pop-up directed energy weapons systems; ground-based lasers and any associated mirrors; and ground-launched mid-course interceptors (e.g., the proposed exoatmospheric reentry vehicle interceptor system, or ERIS). The same generic restrictions would apply to the Soviets, who would also be required under a strict ban to dismantle the exoatmospheric interceptors now associated with the Moscow ABM system.[11]

A comprehensive ban would also require both sides to decommission their existing ASAT hardware: for the Soviets, this would affect their existing co-orbital interceptor systems;[12] for the United States, the F-15 launched miniature homing vehicle weapon.[13] No further dedicated anti-satellite RDT&D would be allowed.

Depending upon how it was formulated, a comprehensive or a limited agreement on space weaponry could adversely affect the U.S. ability to fulfill certain key military missions in space (e.g., force projection), or from countering Soviet military activities in space (e.g., enhanced targeting).[14] For example, banning any or all of the most promising space-to-space weaponry, including lasers, particle beams, and non-nuclear kill missiles could effectively eliminate U.S. options for boost-phase ballistic missile defenses. Only the hybrid ground-based laser (GBL), with limited boost-phase capability, would remain.[15] Such a ban would also narrow ASAT and defensive satellite (DSAT) options. Moreover, some limited agreements could lock the United States into an inferior position, or open up the prospect of militarily significant asymmetries if the Soviets did not fully comply.[16]

To avoid such difficulties, the agreement could be structured to allow a robust R&D program that would limit the danger of Soviet cheating, and to preserve the option of responding to a Soviet creep-out or break-out from treaty obligations. A space strike ban could specifically be structured to strengthen the ABM Treaty if this were desired, and to minimize or eliminate the vexing problems of verifying the decommissioning of existing ASAT and BMD systems.

Verifying a Space Strike Ban. Clearly, the verification demands for a comprehensive or limited agreement would depend upon the details of the agreement and the strategic significance of noncompliance. For instance, an agreement precluding RDT&D of important sets of weapons (e.g., ASATs, DSATs, space-based BMD) would have demanding verification requirements, because the limited, clandestine deployment of certain types of these systems in violation of the treaty could be militarily significant. Verification requirements for a total ban on space weapons would have to be especially stringent and would probably include:

- locating, identifying, and interrogating all orbiting space objects;
- determining technical capabilities of all individual platforms;
- discriminating between BMD, ASAT, and other space systems;
- detecting interrogation or interference with U.S. non-weapons platforms;
- discriminating and identifying suspicious systems on earth;
- verifying total numbers of relevant systems in space and on earth.

To meet these requirements, the following verification measures might need to be considered:

- traditional NTM, with enhanced sensing capabilities;
- open telemetry on all space objects, including civilian and military support satellites;
- mandatory identification and interrogation of all orbiting space objects;
- inspection of payload before launch;

- intrusive on-site inspection for dedicated R&D, testing (including nuclear weapons test sites), production, and decommissioning facilities;
- challenge inspections for suspected R&D, testing, or deployment; and
- CBMs which would facilitate verification.

B. Modification or Replacement of the ABM Treaty

The ABM Treaty is one of the three critical institutional pillars of traditional space arms control (the others being the Limited Test Ban Treaty and the Outer Space Treaty). If the United States and the Soviet Union are to create a new outer space treaty regime to accommodate or prohibit advanced weapons technologies that have been developed since the late 1960s and early 1970s, they may be required to modify, supplement, or replace, if not abolish, this agreement.

According to the *traditional* U.S. government interpretation of the ABM Treaty, neither side is permitted to develop, test, or deploy ABM systems or components which are space-based (or sea-based, air-based, or mobile land-based). In 1985, however, the Reagan administration concluded that another, *broad* interpretation was actually correct: i.e., the ABM Treaty prohibited only the deployment, not the development and testing, of space-based systems based on "other physical principles" (i.e., technologies not known or not developed in 1972).

Although the United States has not yet applied the broad interpretation to its SDI research and development program, Reagan administration officials argue that doing so in the future would be legally correct, and technically and fiscally prudent. In particular, the United States would be permitted to test SDI components and systems in space much more quickly and realistically under the broad interpretation than otherwise. Arguably, the United States might have an absolute requirement to test SDI systems under the broad interpretation if it is to make an informed technical decision about the deployment of space-based defenses.[17]

In the Defense and Space negotiations, the USSR has flatly rejected the terms of the U.S. broad interpretation, and at least until recently demanded that the United States agree to an *absolute* ("stricter than strict") interpretation of the ABM Treaty — i.e., that neither side conduct research on, much less test and develop, space-based BMD systems. In its extreme formulation, the Soviet's proposal required the cessation of laboratory research into space-based defensive systems.

If there were to be a harmonization of positions, the two sides might attempt to *modify* or supplement the ABM Treaty to take into account the technological advances which have occurred since 1972. For example, the United States and the Soviet Union might negotiate precise qualitative distinctions between "traditional" BMD technology and technology based on other physical principles, or make functional distinctions between types of space-based systems (e.g., permitted sensors and prohibited weapons). The USSR has reportedly suggested such an approach to the United States, under which certain technical thresholds would be set — e.g., the size of mirrors, the velocity of space-based interceptors, and the power of directed energy weapons.[18] Tests and possibly deployment of systems below the threshold would be allowed, while tests and deployments above the threshold would be prohibited. Depending on how such thresholds were categorized and sized, they could effectively permit, retard, or preclude the development of space-based BMD weapons.

Another related approach might be to build mutual confidence by increasing the transparency of defensive research and development programs on both sides. Under this kind of arrangement, for example, the two sides might negotiate the legality of specific tests on a case-by-case basis, or reveal the relevant technical parameters of proposed tests in advance to permit the other side to judge the tests' scope and intent.[19]

Impact of a Modified ABM Treaty. Because of the wide range of possible ABM Treaty modifications or interpretations that might be adopted by the United States and the Soviet Union, if agreement were to be reached, it is impossible to consider fully the implications of a new Treaty regime. In any case, however, one key technical issue does emerge: the pace and kind of permitted testing of space-based ballistic missile defenses.

The Reagan administration has established the early 1990s as the point of decision for full-scale development with respect to a strategic defense system. To meet this date with high technical confidence, the administration has argued that it must be able to test space-based systems under the broad interpretation. Critics of deployment, on the other hand, argue that such testing is technically unnecessary before the late 1990s, and express concern that insisting upon the broad interpretation will inevitably drive the Soviets toward accelerated strategic offensive and defensive programs when U.S. SDI policy under a future administration remains unknown.[20] Whichever position ultimately prevails, adherence to or modification of the ABM Treaty will inevitably affect the pace as well as the type of ongoing BMD research, development, and testing — and hence the timing and character of possible future strategic defenses on both sides.

Verifying a Modified ABM Treaty. Under any of the four cases — traditional, broad, absolute, and modified versions of the ABM Treaty — the United States will have to develop and employ much broader means of space verification than it has in the past. These would include:

- locating, identifying, and interrogating all orbiting space objects;
- determining technical capabilities of all individual platforms;
- discriminating between BMD, ASAT, and other systems;
- detecting interrogation or interference with U.S. non-weapons platforms;
- discriminating and identifying suspicious systems on earth;
- verifying total numbers of relevant systems in space and on earth.

Verification measures that would need to be considered, at a minimum, are:

- traditional NTM, with enhanced sensors; and
- challenge inspections of production and possibly deployment sites.

C. Comprehensive or Limited Ban on ASAT Weapons

Over the past decade, both the United States and the Soviet Union have considered negotiated measures that could place restrictions on the testing or deployment of anti-satellite weapons. During the abortive 1978–1979 bilateral ASAT negotiations, the two sides reportedly discussed the possibility of an ASAT testing moritorium and a non-use/non-interference agreement. The talks were delayed during the domestic U.S. debate over ratification of the SALT II Treaty, and then halted as a consequence of the Soviet invasion of Afghanistan.[21]

The Soviets continued to pursue ASAT limitations despite the failure of the 1978–1979 talks. Article III of the USSR's 1981 U.N. Draft Treaty stated that the parties "shall be bound not to destroy, damage, or disturb the normal functioning and not to alter the flight trajectory of space vehicles of other member states where the latter have, for their part, been put into orbit in strict accordance with [the non-weapons provisions of the treaty]...". Similarly, Article II of the 1983 draft provides, in part, that the parties undertake not to destroy, damage, or disrupt the normal functioning of other states' space objects, nor change their flight trajectories; not to test or develop new antisatellite systems and to eliminate such systems already in their possession; and not to test or use for military, including antisatellite, purposes any manned spacecraft. The Soviets have also declared a unilateral moritorium on the testing of their existing co-orbital ASAT interceptor, which was last exercised in 1982.

For its part, the Reagan administration has shown no interest in the general Soviet proposals in the United Nations, and has not reopened negotiations aimed specifically at banning or limiting ASATs. The administration has concluded that, although U.S. interests could theoretically be served by some sort of ASAT constraints, it cannot "identify a specific ASAT proposal which meets the Congressionally mandated requirements of verifiability and consistency with U.S. national security."[22] Despite the administration's decision not to pursue ASAT arms control, a substantial body in Congress remains quite determined to prevent any further U.S. military development in this area as long as the Soviets seem to be exercising similar restraint. This sentiment has led to a Congressional ban on further testing of the U.S. F-15 launched MV ASAT program. Many in Congress would favor going further — toward negotiation of an ASAT ban or limitation with the USSR.

A total U.S.-Soviet ASAT ban would preclude: T&D, and perhaps R&D, of ground-based, air-based, sea-based, space-based, or pop-up ASAT interceptor systems or components; the testing of related weapons systems and components in an ASAT mode; the use of "other physical principles" to substitute for ASAT systems or components; and the use of force against satellites.

In lieu of such a comprehensive agreement, the two sides might consider a more limited ASAT ban. A limited agreement might set aside the difficult question of how to eliminate existing operational ASAT systems on either side, and avoid issues associated with regulating of the residual ASAT capabilities of ICBMs and maneuverable satellites and spacecraft. In theory, a limited ASAT ban could be structured to preserve the exploration of promising advanced BMD technologies, as well as to allow the shuttle and other space assets to undertake their military missions.

A limited ASAT ban might involve accepting an ASAT testing moratorium of limited duration; limiting T&D, and perhaps R&D on any but existing ASAT systems; placing numerical limits on some number of specific ASAT systems; limiting ASAT testing above a certain altitude; limiting types of kill mechanisms (e.g., permitting KEW but prohibiting DEW systems); establishing keep-out zones around some or all space objects; establishing rules of the road for all space objects; and placing operational restrictions on space objects, objects launched into space, or ground-based systems capable of destroying or affecting the operations of space assets. A limited ASAT ban might specifically allow existing ASAT systems (i.e., the U.S. F-15 MV or the Soviet co-orbital interceptor) and perhaps permit their modernization; one or more new dedicated ASAT systems; ASAT systems with certain types of kill mechanisms; or DSAT development and deployment.[23]

Impact of ASAT Limitations. A total ASAT ban would require the decommissioning of existing U.S. and Soviet kinetic kill ASAT systems — the F-15 launched MV and the co-orbital interceptor, respectively — and any ground-based laser facilities with an ASAT capability. Neither the United States nor the Soviet Union could continue to develop new types of ASATs or ASAT launchers, which would affect current U.S. research toward a higher-altitude ASAT capability,[24] along with any similar Soviet program. It could also place restrictions on active measures designed to protect satellites (e.g., DSATs), and limit operations of other space-based civil and military systems with residual ASAT capabilities, such as the space shuttle and ICBMs. An ASAT ban could allow RDT&D of BMD systems not otherwise restricted by treaty; however, given the inherent ASAT capability of many BMD devices, especially those in space, a comprehensive ASAT ban could limit many SDI-related programs. As a result, a total ASAT ban would close a "loophole" in the ABM Treaty, which either side could use in principle to pursue advanced BMD research and development without violating the Treaty.[25]

Verifying ASAT Limitations. Noncompliance of one party with a total ASAT ban could provide both tactical and strategic military advantages. In a theater conflict being fought with conventional weapons, an ASAT attack that blinded the military space assets of one side could decisively affect the course of the conflict, or create a perceived need for recourse to nuclear weapons. In the strategic context, a crisis in which ASATs were used by one side could lead to uncontrollable escalation. Given the relatively small number of space assets on which the U.S. and the USSR depend for vital military activities (such as those for early warning, surveillance, and C3I), even a small number of clandestine ASATs could pose unacceptable threats to either side. In either tactical or strategic warfare, the advantage to the non-complying party stems first, and perhaps foremost, from the other side's inability to respond "tit for tat," which effectively reduces or eliminates that side's viable options.[26]

As a consequence of the significant military impact of ASAT use, verification requirements for a total ban would have to be especially stringent. The verification requirements for a limited ASAT ban are likely to be less stringent than for a comprehensive ban because the military significance of cheating would be smaller. Under a limited ban, both sides would be permitted some dedicated ASAT systems and would retain their respective residual ASAT capability, as a hedge against cheating and breakout. If the limited ban did not require the decommissioning of existing systems, the verification requirements would be further reduced.

The detection and verification requirements for either the comprehensive or the limited ban on ASAT weapons would involve:

- location and discrimination of ASAT systems from all other systems in space;
- location and discrimination of ASAT systems on earth;
- detecting interrogation of or attacks on satellite platforms;
- verifying total numbers of systems;
- discriminating prohibited systems from allowed ones;
- determining capabilities and power levels of systems.

Verification measures necessary for a treaty banning or limiting ASATs could include:

- traditional NTM, with enhanced sensors;
- mandatory identification and interrogation of all orbiting space objects;
- inspection of payload before launch;
- intrusive on-site inspection of dedicated R&D, testing, production, and decommissioning facilities;
- challenge inspections for suspected clandestine facilities; and
- CBMs to facilitate verification.

D. Ban on Nuclear and Nuclear-Driven Space Weapons

The United States, the Soviet Union, and other signatories are currently prohibited by the Limited Test Ban and Outer Space Treaties from exploding nuclear devices or deploying nuclear weapons in space. These two multilateral agreements, which were negotiated and signed during the 1960s, are intended to prevent the deployment of weapons of mass destruction in space. As a means of reaffirming these treaties and providing a framework for the future regulations of non-nuclear space-based defenses, the U.S. and the USSR might specifically agree to ban research, development, and testing of nuclear and nuclear-driven weapon systems that could be deployed in space or launched against targets in space.

The scope of such an accord is difficult to predict, but it could prohibit or restrict RDT&D of ground-based, space-based, or pop-up nuclear weapons systems or components that are capable of destroying objects in space; ban the testing and deployment of nuclear fractional orbital bombardment systems (FOBS);[27] permit or require the decommissioning of existing/allowed nuclear ABM systems; and prohibit or regulate underground nuclear tests dedicated to this purpose. By itself, this agreement would allow RDT&D of non-nuclear ASATs, BMD, or other space weaponry, although the ban on nuclear and nuclear-driven weapons could be combined with a parallel accord that would regulate these non-nuclear systems.

Impact of a Nuclear Weapons Ban. This agreement could be designed to limit or prohibit U.S. and Soviet nuclear-pumped x-ray laser BMD/ASAT programs, as well as any space program which sought to use nuclear effects for military purposes in space. It might also affect the deployed Soviet nuclear exoatmospheric ABM interceptor, and any U.S. interest in developing a Spartan-type nuclear ABM warhead.[28] A ban on FOBS would replace a similar restriction which was part of the SALT II Treaty. Finally, the agreement might require testing and operational restrictions on related systems, such as ICBMs, that could substitute for dedicated nuclear BMD and ASAT weapons.

Verifying a Nuclear Weapons Ban. Because nuclear systems offer promising short-term and long-term options for BMD, and because the Soviets now have a deployed ABM system using nuclear warheads around Moscow (with the presumed capability to expand those defenses), the military-strategic consequences of Soviet noncompliance could be serious for the United States. As a consequence, verification requirements would need to be particularly stringent.

The verification of a comprehensive ban would be difficult, particularly in the R&D phase, because research on nuclear BMD concepts can be conducted using underground nuclear explosions. Verification of Soviet and U.S. decommissioning of existing nuclear ABM systems and warheads would also be problematic.

The detection and verification requirements of this agreement could involve:

- remote detection of faint nuclear signatures;
- discrimination between "weapons" and "power" systems;
- discrimination between prohibited and allowed nuclear tests.

Verification measures considered for such an agreement might involve:

- traditional NTM, with enhanced sensing capabilities;
- mandatory active and passive interrogation of objects in space;
- highly intrusive, on-site monitoring of underground nuclear tests;
- inspection of payload before launch;
- on-site inspection of dedicated R&D, testing, production, and decommissioning facilities; and
- challenge inspections for suspected clandestine activities, facilities, and stores.

If existing systems were "grandfathered," and research on nuclear and nuclear-driven space weapons was not prohibited, the verification problems would be lessened along with the military-strategic consequences of noncompliance. Verification measures might include:

- traditional NTM, with enhanced sensing capabilities;
- active and passive interrogation of objects in space; and
- challenge on-site inspections.

E. Confidence-Building Measures

In recent years, the United States and the Soviet Union have formally and informally adopted a variety of military confidence-building measures: for example, the Incidents at Sea Agreement; notification of military maneuvers above a certain size in the European theater; and the prohibition of multiple missile flight tests. In principle, CBMs can be designed to assure each side about the benign military intentions of the other; to provide strategic warning if those intentions prove less than benign; to increase stability by improving both sides' ability to defend against a surprise attack; and to improve the effectiveness of arms control verification techniques.

There are two prominent types of CBMs for space systems that could involve some means of verification:

Rules of the Road. Such an agreement would specify certain operational procedures for space systems. Such an agreement might prohibit simulated attacks (e.g., high-velocity approaches), require notification of passage or maneuver near other nations' satellites, and ban the illumination of foreign satellites (e.g., with low-powered lasers).

Keep-out or Self-defense Zones. This kind of an agreement would set up minimum separation distances between the satellites of different nations, with the actual distance presumably depending on such factors as the orbital altitude and declared purpose of the satellites in question.[29]

Impact of Confidence-Building Measures. There are few if any formal CBMs that currently apply to space systems, although several arms control treaties now prohibit interference with national technical means of verification. If specific space arms control agreements are achieved along the lines outlined above, CBMs are likely to be an important and necessary element of the new treaty regime. Even if formal agreements are not reached to limit or prohibit space weaponry, CBMs may still provide military-strategic benefits to both sides. To be sure, CBMs could limit desired testing of strategic defensive platforms, but they could also improve survivability and deception of defensive constellations and reduce the frequencies of potentially hostile encounters — thereby theoretically increasing the capability of the defensive system. On the other hand, CBMs may not be sufficient to deter or divert a determined aggressor, and could be irrelevant and dangerous in times of impending crisis and the initial stages of conflict.[30]

Verifying Confidence-Building Measures. The verification requirements associated with such CBMs could include:

- locating, identifying, and interrogating all orbiting space objects;
- determining technical capabilities of all individual platforms; and
- detecting interrogation or interference with U.S. non-weapons platforms.

One other important point: certain types of technologies that may be necessary to verify formal space arms control agreements — especially active interrogation techniques that require close-in detection (described below) — may not be compatible with CBMs like rules of the road and keep-out zones. The advantage of increased confidence in verification that close-in active detection systems might provide must be weighed against the potential drawbacks that would inevitably arise on confidence-building grounds. Conversely, total and absolute prohibitions on entering certain volumes of space are probably not desirable. Confidence-building requires information, and limited rights of penetration of keep-out zones for challenge inspection purposes should be established to assure *mutual* confidence.

III. DETECTION TECHNOLOGY REQUIREMENTS FOR SPACE MONITORING AND VERIFICATION

The nature of possible space weapon treaties and the detection and verification requirements outlined in the previous section raise important technical questions about whether (and how) it is possible to detect the testing and deployment of space weaponry. In this section we will consider the requirements for the technologies that could be used for monitoring a selected group of space weapons.

Our discussion of verification technologies follows the premise that, in order to monitor (or even find) a weapon system we must be able to detect signals, either natural or stimulated, that emanate from the weapon. These signals, called "observables," have a nature which is determined by the characteristics of the weapon, its test or deployed state, and its location on the ground or in space. The requirements for the detection system, in turn, are determined by these observables and the location of the detector relative to the weapon. A critical distinction must also be made between the observables associated with the testing of a space weapon and those associated with its deployment.

Our ability to *detect the testing of space weapons* depends to a large extent in which phase of the weapon's development program the test is conducted. Testing of space weapons in the early stages of development can almost always be carried out in laboratories or underground in such a manner that little evidence of the exact nature of the test becomes available to U.S. monitoring systems. (This is true for either space-based or ground-based detection sensors.) Once the weapon, or system, has exceeded the laboratory stage of development, however, its testing usually results in one or more active physical or chemical signals emanating from the area of the test, and we are better equipped technologically to look for and detect such signals. Thus, if detection of early testing becomes necessary, then on-site inspections will be required; on the other hand, for tests of weapons systems or major components outside of the laboratory, current or enhanced NTM technologies may prove adequate.

The *detection of the deployment of a new space weapon* or system, or of a previously deployed system, presents a rather different problem than the detection of its testing. Space weapons, whether space-based or ground-based, may give very little evidence of their true nature once on station. They may emit simply no signals, or no signals at presently detectable levels, when not in active use. For example, a laser or a beam weapon may have little or no intrinsic radiation or emanations; the power supplies servicing directed energy weapons may provide little detectable activity until they are called on to provide a usable weapon capability; and even the intrinsic radiation from a nuclear explosive may not be detectable from a distance. In the absence of remotely sensible observables, the high-confidence detection of deployed ground-based or space-based weapon systems may thus require on-site or active examination of facilities, launchers, missiles, satellites, and other hardware.

If detecting deployed systems is as difficult as expected, then the best intelligence may come from the activity related to deploying the system, particularly if the suspected deployment follows a period of observed testing. Activities such as ground construction, space launches, or in-space assembly of facilities or objects that show little activity when completed, may indicate the deployment of a space weapon. Beyond this, the need to detect the actual deployment of space weapons, whether in space or ground-based, may also call for technical verification measures of unprecedented intrusiveness. Active NTM technologies may be necessary to induce a physical or chemical reaction that will indicate the nature of the object being interrogated. These induced observables will in many instances be different from those associated with testing, and hence require different technologies for detection sensors.

In summary, the technical basis for detecting either the testing or the deployment of space weapons will be the observation of characteristic emanations or residual signals (observables) that result from testing or deployment activities. The means of detecting these observables may exist within current NTM technologies or, as in the case of detecting already deployed systems, may require an entire new set of probes and sensors. It must also be emphasized that the actual characteristic signatures of many weapons systems under development, or at the research stage, are not yet known, and tests of some of them (including tests of full-scale systems in space) may be required to establish an adequate data base of observables.

To aid in determining the technical monitoring requirements for a selected class of space weapons we have, in the Appendix, enumerated testing and deployment observables for nuclear and nuclear-driven weapons, for directed energy weapons, and for kinetic energy weapons. The nuclear and nuclear-driven weapons include missile launched warheads, space mines, and other weapons that may use nuclear explosives for power sources. The DEWs include lasers, radio frequency sources, neutral particle beams (NPB), and other optical weapons. The KEWs include rocket launched projectiles with or without explosive warheads, and rail gun launched projectiles. These weapons and their observables are then categorized according to the relation of weapon location to target location, (i.e., ground-to-space, space-to-space, or space-to-ground). The detection systems, as mentioned above, will be a function not only of the observables but also of the location of the weapon and the target; this point is emphasized in the following discussion of the detection technologies.

Detection of Testing

The use of NTM to monitor arms control agreements is well established, and traditional NTM platforms can be applied directly or adapted to monitor space weapons tests as well. For instance, existing and planned remote technical intelligence capabilities will be available to monitor ground sites, facilities, and special radars and missiles with the potential for military space missions. The suite of photographic, infrared, radio frequency, and microwave detectors used in current and prospective NTM systems, however, may not be entirely adequate to monitor various types of weapons tests in space. The United States may find it necessary to develop new families of sensors especially designed to detect testing observables. In some cases, new families of sensors may also require a new generation of space monitoring platforms with the capability to maneuver into orbits suitable for the observation of specific targets or tests. The observables identified in the Appendix give an indication of the variables for different weapons tests that could be monitored from either space or ground.

For the detection of tests involving *nuclear explosives* — intended for use either as space weapons or power sources for other space weapons — the techniques developed for current atmospheric and ground monitoring programs can be applied to the detection of ground-based and space-based testing of new nuclear space weapon concepts. Existing resources provide a capability to detect nuclear explosions in the atmosphere, in near-earth space, or in deep space. Current systems on the GPS satellites and on the follow-on to the Vela satellites are designed to monitor optical signals from atmospheric explosions, and x-rays and nuclear emissions from exoatmospheric explosions. Natural energetic particles and plasma background are also monitored. Enhancements to current systems may be needed to extend the covered range of yields and volume of space, or to monitor for new observables characteristic of NDEW or other exotic nuclear weapon tests.

For the detection of *directed energy weapons* tests, the working data bases of the characteristic observable signatures are currently less well known than signatures of nuclear systems. These signatures will emanate from the generator, the beam, and the target, and will be a function of ground-based or space-based testing. Sensor concepts and systems, both ground-based and space-based, could be developed to detect disturbances in the atmosphere due to the propagation of optical, microwave, or laser transmissions — e.g., detectors for the Rayleigh scattering or for locally excited atmospheric conditions. One can develop sensor systems specifically to detect the characteristic emissions from laser power sources on the ground or in space — e.g., detectors for chemical exhaust from chemical lasers or RF emissions from free-electron laser accelerators. Particle beam weapon tests in space can be detected by the x-ray, gamma-ray, and optical emissions from the accelerator operation or by detecting infrared signals from power sources; targets for such weapons may also emit detectable signals when the weapon is tested against them.

For the detection of *kinetic energy weapons* tests, one must depend primarily on signals from the energy sources — e.g., infrared signals from large or small rocket motors, or electromagnetic signals from rail gun drivers. The signals from the projectile(s) or from the effects on targets may not be uniquely identifiable with a given weapon test and therefore would not provide adequate detection. As in the case of the directed energy weapons, the working data base of the characteristic observable KEW signatures is currently not adequate.

Detection of Deployed Systems

As discussed above, the detection of deployed space weapons systems presents different and perhaps more difficult problems than the detection of testing. NTM methods may not be adequate for the task in many cases. For nuclear, directed energy, and kinetic energy space weapons, it is obvious from the Appendix that successful detection and identification will require the development of new techniques for obtaining information on objects in space.

The best results may come from monitoring the deployment of systems which have previously been tested as space weapons. As seen from the Appendix, the observables for deployed ground-based systems relate strongly to construction activities that can be detected by NTM and perhaps further verified by on-site inspections. Existing and enhanced NTM will therefore be the first means of detection. Just as in the case of testing, NTM and intelligence analyses need to be oriented specifically toward objects on the ground such as special nuclear facilities for directed energy weapons, tunnel emplacements, special RF antennas, and optical components for non-nuclear directed energy systems, dispersed radar systems, and suspect missile launchers. In this regard, enhanced photographic intelligence of both ground and space objects should be devoted to detection of the very large accelerators, laser radars, optical systems, and mirrors that will be part of many space weapon systems. The size of an object may be a significant indicator of most potential space weapons, with the exception, perhaps, of nuclear space mines. Some chemically-powered space systems might be effectively monitored for capability and mission if chemical "sniffers" can be brought close enough to them. But even the most sensitive chemical detector may not be sufficient to prove the deployment of a weapon, for many of the chemicals used to power lasers (e.g., hydrogen) have many other highly efficient uses in space (e.g., generation of electrical power).

This gives special importance to the fact that many weapons deployed in space may well have no observable emanations until called on to perform. As a consequence, it will be necessary to monitor continuously the behavior of suspicious objects for changes in orbit, for increased temperature, or other signals that indicate a new mode of operation. We cannot continue the current practice of neglecting space objects simply because they appear inactive. To provide this attention, in some cases, the United States will require maneuverable satellite platforms that are capable of approaching an orbiting object and co-orbiting with it, perhaps for extended periods. These satellites would carry the sensors required for close-up examination of suspected weapon systems. Such examinations would search for previously detected signatures of tested space weaponry — e.g., intrinsic nuclear radiation or electromagnetic emanations. Other sensors could use imaging techniques to determine the external physical characteristics of the object (e.g., imaging radar, infrared imaging systems, or enhanced video techniques).

In the absence of intrinsic emanations, it will be possible to gain information about the internal characteristics of a space system only by active techniques. Techniques for stimulating emissions of radiation by active pulsing and interrogation are possible, as are uses of radiographic techniques for imaging the interior of vehicles. The use of computer aided tomography has also been suggested. The use of active interrogation techniques will, of course, be constrained by the necessity to avoid damaging the interrogated object. This constraint may be especially binding in certain locations in space, such as geosynchronous orbit, because of the very high background radiation levels encountered naturally; dose levels sufficient to establish definitive imaging may be indistinguishable from destructive attack on a space object. And even to be possible, active interrogation techniques will require sensor platforms that can approach the object and co-orbit with it as needed, a capability now possible only at great cost.

In addition to these technical issues, active interrogation techniques raise serious questions about national sovereignty in space, questions that neither side may yet be willing to resolve in favor of active measures. Furthermore, proposals for using close-in space detection technologies would conflict with the desire of military planners to keep threats away from valued non-weapon space assets, such as early-warning satellites.

IV. TECHNOLOGY REQUIREMENTS

Arms control agreements that affect space weaponry clearly pose considerable technical and political challenges to our ability to monitor and verify compliance. Detecting tests of space weapons will demand unprecedented vigilance in space and time; and detecting deployment may call for technical verification measures of unprecedented intrusiveness. Precisely for these reasons, there are areas of technology development that should be considered to improve our capability to detect, monitor, and verify testing and deployment of space weapons. This will require the establishment of an active program of research and development to address the need for enhanced sensors, to develop the techniques for active probing and imaging of space objects and, perhaps most important, to create a working data base of observable signatures of potential space weapons.

- The development of new sensors should include: 1) the enhancement of current NTM systems (IR, RF, and photographic) particularly for applications in space; 2) the continued development of space-based radar techniques and systems; 3) the development of new particle detectors for use in monitoring of low-level intrinsic signals, and as detectors for active measures of stimulation and imaging and; 4) investigations into chemical-detection sensors that can be used in a space environment.

- One of the most promising new active techniques is the use of radiography for imaging. This technique can derive images of the interior of vehicles or packages using neutrons and gamma rays. Unlike techniques for stimulating nuclear radiation, this can be accomplished at dosage levels relatively small compared to background. Radiography appears potentially useful in analyzing a variety of threats, both nuclear and non-nuclear. Although various means can be used to camouflage optical, infrared, and microwave signatures, it is much more difficult to defeat transmission radiography without paying a very large weight penalty. This and other active imaging techniques which may hold the promise of non-destructive, perhaps even non-interfering inspection, should be rapidly examined.

- The creation of a data base of observable signatures for possible space-based weapons must be an integral part of the overall detection technology R&D program. The signatures available will depend on the ability of the sensors to detect critical features of the weapon system. These signatures, whether sensed through emissions from the equipment or obtained through various imaging techniques, will have to be generated from individual signals obtained from monitoring testing related to the weapon development.

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REFERENCES

1. Relevant portions of the Joint U.S.-Soviet Communique are published in *Arms Control Today* (January/February 1988): 16.

2. For an account of the U.S.-Soviet summit negotiations over SDI which led to the compromise communique language, see Michael R. Gordon, "How the U.S. and Soviet Officials Agreed to Disagree on 'Star Wars,'" *New York Times* (12 December 1987): 1.

3. In a November 1987 television interview, General Secretary Gorbachev stated for the first time that "the Soviet Union is doing all that the United States is doing, and I guess we are engaged in research, basic research, which relates to these aspects which are covered by the S.D.I. of the United States." *New York Times* (1 December 1987): A12.

4. In exploring these issues, the authors have benefited greatly from the background material in G. H. Canavan, "Technical Issues Associated with Controls," unpublished paper, Los Alamos National Laboratory, June 1985.

5. The evolution of this so-called "peaceful sanctuary" status of space is recounted in Walter A. McDougall, *...the Heavens and the Earth: A Political History of the Space Age* (New York: Basic Books, 1985), especially chapters 8, 16, and 17; Paul Stares, *The Militarization of Space: U.S. Policy, 1945–84* (Ithaca, NY: Cornell University Press, 1985); and John Lewis Gaddis, *The Long Peace: Inquiries Into the History of the Cold War* (New York: Oxford University Press, 1987), pp. 195–214.

6. To deal with Soviet relocatable targets, such as mobile missiles, the U.S. Air Force is now exploring the use of manned penetrating bombers that will rely "on space systems to cue the bomber [in regard to] where he is going to have his initial look ..." General John Chain, Strategic Air Command commander, quoted in Edgar Ulsamer, "Strategic Connections in Space," *Air Force Magazine* (August 1987): 79.

7. See, for example, Colin S. Gray, "Space and Arms Control: A Skeptical View," in *American Plans for Space: A Reader Based on the National Defense University Space Symposium* (Washington, D.C.: NDU Press, 1986), pp. 133–56.

8. According to Presidential arms control adviser Paul Nitze, U.S. policy toward the Soviet Union, including its arms control policy, is based on the following strategic concept: "During the next 10 years, the United States objective is a radical reduction in the power of existing and planned offensive nuclear arms, as well as a stabilization of the relationship between offensive and defensive nuclear arms, whether on earth or in space. We are even now looking forward to a period of transition to a more stable world, with greatly reduced levels of nuclear arms and an enhanced ability to deter war based on

an increasing contribution of non-nuclear defenses against offensive nuclear arms. This period of transition could lead to the eventual elimination of all nuclear arms, both offensive and defensive. A world free of nuclear arms is an ultimate objective to which we, the Soviet Union, and all other nations can agree." According to Nitze, this strategic concept, to be realized in part through arms control, entails three time phases: "the near-term, a transition phase, and an ultimate phase." Paul Nitze, "On the Road to a More Stable Peace," Address before the Philadelphia World Affairs Council, Current Policy No. 657 (Washington, D.C.: U.S. Department of State, Bureau of Public Affairs, February 20, 1985), p. 1.

9. The Soviet draft U.N. Treaties are analyzed in Malcolm Russell, "Soviet Legal Views on Military Space Activities," in William J. Durch, ed., *National Interests and the Military Uses of Space* (Cambridge, MA: Ballinger, 1984), pp. 218–23; Harry H. Almond, Jr., "Arms Control, International Law, and Outer Space," in Uri Ra'anan and Robert Pfaltzgraff, Jr., eds., *International Security Dimensions of Space* (Hamden, Connecticut: Archon Books, 1984), pp. 234–40; and the comments of Rebecca V. Strode in Colin S. Gray, *American Military Space Policy* (Cambridge, MA: Abt Books, 1982), Annex to Chapter 4, pp. 85–92.

10. Some U.S. critics of administration policy, on the other hand, contend that this broad Soviet approach to space is not simply a propaganda exercise, but represents a meaningful attempt to preserve space as a sanctuary from military operations. See Paul Stares, *The Militarization of Space,* pp. 229–35.

11. The Moscow ABM system, which is allowed under the 1972 ABM Treaty, consists of "a two-layer defense composed of silo-based, long-range, modified GALOSH interceptors; silo-based, probably nuclear armed GAZELLE high-acceleration endoatmospheric interceptors (designed to engage reentry vehicles inside the atmosphere); and associated engagement, guidance, and battle management radar systems, including the new PILL BOX large, four-sided, phased-array radar at Pushkino north of Moscow." Department of Defense, *Soviet Military Power 1987,* 6th ed. (Washington, D.C: USGPO, 1987).

12. The Soviet ASAT system is launched from a modified SS-9 (SL-11) missile, uses radar to acquire and track the target in a co-orbital approach, and destroys the target with a conventional explosive kill mechanism. The USSR last tested its ASAT system in 1982; despite this six-year hiatus, the Reagan administration contends that the operational proficiency of the Soviet ASAT has not eroded, and that the Soviets would not face any significant delay in further testing or actually employing the weapon. DoD, *Soviet Military Power 1987,* p. 52; see also Department of Defense, *The Soviet Space Challenge* (Washington, D.C.: DoD, November 1987), p. 11. Some non-governmental experts question the operational effectiveness of the Soviet ASAT. See, for example, Stephen M. Meyer, "Space and Soviet Military Planning," in Durch, ed., *National Interests and the Military Uses of Space,* pp. 78–80.

13. The U.S. ASAT system currently under development consists of a miniature, non-nuclear homing vehicle (MV) warhead mounted on a short-range attack missile (SRAM) booster with a modified Altair rocket motor as the upper stage. The ASAT would be launched in the air from a specially configured F-15 aircraft; after the upper stage burned out, the MV would separate from the carrier rocket and be guided into a collision with the target by an on-board sensor. The F-15 MV system has been tested against

objects and points in space, but Congressional funding restrictions have place the entire program in jeopardy. See Paul Stares, *Space and National Security* (Washington, D.C.: Brookings Institution, 1987), pp. 99–110.

14. The Reagan administration has expressed repeated concern over the Soviet Union's ocean reconnaissance satellites (RORSAT and EORSAT), "which use radar and electronic intelligence to provide real-time targeting data to Soviet weapons platforms which can quickly attack U.S. and Allied surface fleets." This Soviet threat serves as one of the principal justifications for a U.S. ASAT capability. See *The U.S. Anti-Satellite (ASAT) Program: A Key Element in the National Strategy of Deterrence* (Washington, D.C.: The White House, May 1987), p. 3. Hereinafter referred to as *The U.S. ASAT Program.*

15. Canavan, "Technical Issues Associated with Controls," pp. 6–7.

16. Of particular concern for the United States in the near-term would be an agreement that expanded ground-based ASAT and BMD. Not only do the Soviets have a lead on this area, but such systems appear better to serve Soviet than U.S. interests.

17. See Reynaldo Morales and Robert E. Pendley, *The ABM Treaty Controversy,* CNSS Briefs (Los Alamos, NM: Center for National Security Studies, Los Alamos National Laboratory, May 1987).

18. See, for example, Charles W. Coddry and Frank Starr, "Soviets Offered U.S. Outlines of SDI Compromise," *Baltimore Sun* (23 September 1987): 1; Don Cook, "Kremlin Shift on 'Star Wars' Tests Indicated," *Los Angeles Times* (28 September 1987): 1. Paul Nitze, an arms advisor to the President and the Secretary of State, reportedly favors negotiations with the Soviets over such testing restrictions. See Warren Strobel, "Pentagon Scorns Soviet ABM Offer," *Washington Times* (2 October 1987): 1; Michael R. Gordon, "U.S. Aides Divided on Talks to Limit 'Star Wars' Tests," *New York Times* (27 September 1987): 1. Senator Sam Nunn, chairman of the Senate Armed Services Committee, has publicly advocated such negotiations. Nunn, Speech Before the Arms Control Association, January 19, 1988 (mimeographed), p. 12.

19. Ambassador Henry F. Cooper, head of the American delegation at the Defense and Space negotiations, has said that the U.S. proposal contains "predictability measures" intended to ensure full consultation before either side deploys missile defenses. These could include exchanges of data, scientific visits, and observers to witness tests of defensive systems. Robert C. Toth, "U.S. Shifts Stand on a Space Defense Accord," *Los Angeles Times* (23 January 1988): 13.

20. "The current political reality is that some in this Administration have been ardently searching for near-term SDI tests in space that could only be conducted under the broad interpretation and which, if conducted, could trigger a Soviet reaction which could destroy the ABM Treaty. In my view, the motivation for such tests has been driven by ideology, not by scientific judgments." Nunn, Speech Before the Arms Control Association, p. 5.

21. For an account and analysis of the 1978–1979 ASAT talks, see John Wertheimer, "The Anti-Satellite Negotiations," in Albert Carnesale and Richard N. Haass, eds., *Superpower Arms Control: Setting the Record Straight* (Cambridge, MA: Ballinger, 1987), pp. 139-64; Stares, *The Militarization of Space,* pp. 192–200.

22. *The U.S. ASAT Program,* p. 5.

23. Examples of proposals for limited ASAT agreements are contained in Ashton B. Carter, "Satellites and Anti-Satellites: The Limits of the Possible," *International Security* 10 (Spring 1986): 94–98; Donald L. Hafner, "Approaches to the Control of Anti-Satellite Weapons," in Durch, ed., *National Interests and the Military Uses of Space,* pp. 239–70; Kurt Gottfried and Richard Ned Lebow, "Anti-Satellite Weapons: Weighing the Risks," *Daedalus* 114 (Spring 1985): 163–70; U.S. Congress, Office of Technology Assessment, *Anti-Satellite Weapons, Countermeasures, and Arms Control,* OTA ISC-281 (Washington, D.C.: USGPO, September 1985), pp. 105–22.

24. The U.S. interest in developing a higher-altitude ASAT capability is stated in *The U.S. ASAT Program,* p. 5, which also notes that the Department of Defense "is investigating the feasibility of ground-based laser technologies for ASAT application."

25. The ASAT "loophole" in the ABM Treaty is discussed in Gottfried and Lebow, "Anti-Satellite Weapons: Weighing the Risks," pp. 166–67. See also Ashton B. Carter, "The Relationship of ASAT and BMD Systems," *Daedalus* 114 (Spring 1985): 171–89.

26. The case for a U.S. ASAT capability as a deterrent-in-kind to Soviet ASAT use is made in *The U.S. ASAT Program,* pp. 3–4.

27. FOBS refers to operational method in which a nuclear payload would be placed in very low earth orbit and called down to strike its target before completing a single revolution. According to Nicholas Johnson, the USSR conducted approximately 18 FOBS tests between 1966 or 1967 and 1971. For details, see Johnson, *Soviet Military Strategy in Space* (London: Jane's Publishing Company, 1987), pp. 125–36.

28. During the late 1960s and early 1970s, the planned U.S. ABM system relied on a nuclear-armed exoatmospheric interceptor (Spartan) and a nuclear-armed endoatmospheric interceptor (Sprint). Although the United States is now exploring non-nuclear kill mechanisms for the equivalent ABM systems under SDI (ERIS and HEDI), ground-based nuclear interceptors might still be an attractive short-term military option in the event of a Soviet ABM breakout. For a discussion of the technology and history of the earlier ABM systems, see Stephen M. Weiner, "Systems and Technology," and David N. Schwartz, "Past and Present: The Historical Legacy," in Ashton B. Carter and David N. Schwartz, ed., *Ballistic Missile Defense* (Washington, D.C.: Brookings Institution, 1984), pp. 49–97 and 330–349.

29. Possible CBMs for space systems are described in Albert Wohlstetter and Brian G. Chow, *Self-Defense Zones in Space,* Report MDA 903-84-C-0325 (Marina del Rey, CA: Pan Heuristics, 1986); *Arms Control in Space: Workshop Proceedings* (Washington, D.C.: U.S. Congress, Office of Technology Assessment, OTA-BP-ISC-28, May 1984), pp. 20–22; OTA, *Anti-Satellite Weapons, Countermeasures, and Arms Control,* pp. 116–9; Stares, *Space and National Security,* pp. 142–73.

30. The potential drawbacks of CBMs in general during certain types of crises are discussed in Kevin N. Lewis and Mark A. Lorell, "Confidence Building Measures and Crisis Resolution: Historical Perspectives," *ORBIS* 28 (Summer 1984): 281–306.

APPENDIX
SOME OBSERVABLES FOR THE TESTING AND DEPLOYMENT OF CERTAIN SPACE WEAPONS CONCEPTS

INTRODUCTION

The following Appendix of observables associated with the testing and deployment of space weapons was developed through discussions with scientists and engineers researching and developing the technologies related to the weapons listed. Obtained in this manner, the list is not, nor was it intended to be, complete or uniform in the observables identified (i.e., items range from major events, such as missile launch, to detection of nuclear particles; with technologies even mentioned some places). Thus, this Appendix emphasizes the diversity and unknown nature of many of the observables or signatures that may be associated with the functioning of space weapons. This conglomeration serves to highlight the need for research in this area.

GROUND TO SPACE

System: Nuclear Explosives

Testing Observables

- Missile launch resulting in explosion of a nuclear device in proximity of space target(s)
- Missile launch resulting in detonation of a conventional explosive device in proximity of space target(s), but outside conventional explosive kill range
- Plasmas, neutrons, x-rays, gamma rays, optical signals, electromagnetic pulse (EMP), and other debris from nuclear explosions in space
- Missile flight test profiles which indicate intended use against space targets but with accuracy good enough for nuclear kill only

Deployment Observables

- Deployment of missiles previously tested against space targets, and armed with nuclear explosives
- Deployment of single-warhead, small-yield devices on missiles capable of attacking space targets

- Numerous dispersed ground radars to avoid clutter and blackout problems

System: Nuclear Driven (Optical or RF)

Testing Observables

- Underground nuclear test simultaneous with optical or RF emissions from source region
- Optical emissions from RF-excited atmosphere associates with underground nuclear test
- RF and other emissions from beam/target interaction following a nuclear test
- Tunneling activities—DEW systems tests may have to be line-of-sight; and DEW detection systems will require line-of-sight to the beam
- Nuclear weapons effects testing of an unusual nature

Deployment Observables

- (Multiple) underground or tunnel nuclear device emplacements, coupled with RF antennas or optical components, distant from known nuclear test sites
- Location of such facilities at higher elevations to assist propagation

System: Kinetic Energy Weapons

Testing Observables

- Direct launch (or ballistic reentry) and satellite or RV intercept using ground-based missiles
- Launch and satellite intercept using "space junk," e.g., many little pellets
- Rail-gun test against orbiting target
- Simultaneous launch of many little rockets (á la High Frontier)
- Moderately dispersed reentry debris
- Missile tests similar to those used in the homing overlay experiment (HOE) or in nuclear-kill ground to space tests

Deployment Observables

- Things built out of tested hardware—rail guns, clusters of launchers, missiles
- Radars for target acquisition and control
- Boosters tested previously in space-attack exercises

System: Directed Energy Weapons (Lasers)
Testing Observables

- Rayleigh scattering from optical transmission through the atmosphere
- RF emissions from particle accelerators
- Characteristic exhaust chemicals in spent fuel from chemical lasers
- Return optical signals from space targets

Deployment Observables

- Very large optical systems
- Radars deployed with each laser
- Large pointing and tracking mirrors
- Beam deflector and battle management mirrors deployed in space
- Accelerator facilities
- Laser facilities located in atmospherically clear regions, at high altitudes, or in low latitudes

SPACE TO SPACE

System: Nuclear Explosives
Testing Observables

- Direct detection of an explosion of a nuclear device in an orbiting platform
- Indirect detection of a nuclear explosion in space—increase in trapped particle fluxes along earth magnetic lines
- Simulating nuclear weapons effects from an orbiting platform

Deployment Observables

- Intrinsic radiation from warheads in orbit
- Stimulated radiation from active interrogation of satellites containing warheads (if possible without high probability of damaging satellites)
- Radiographic images of satellite packages

- Satellites newly launched with no apparent mission or emissions, in an apparent quiescent state
- Disposition of the orbits of such satellites—proximity to space assets

System: Nuclear Driven (Optical or RF)

Testing Observables

- X-rays, gamma-rays, and optical pulses from nuclear explosion
- EMP emissions from test system
- X-ray and optical signals from target(s)
- Mirror deployments
- Increased flux of trapped particles along gravitational field lines

Deployment Observables

- Launch and assembly in space of very large systems of unknown purpose
- Intrinsic radiation from a nuclear device
- Stimulated radiation from active interrogation
- Radiographic images
- Optical signature—size and shape

System: Kinetic Energy Weapons

Testing Observables

- Infrared signals in space from rocket propulsion
- Electromagnetic signal from railgun drive
- Operation of maneuvering satellites
- Effects on target(s)

Deployment Observables

- Large orbiting systems with prime power sources
- Radiographic images
- Deployments in proximity to targets—must be 10s to 100s of meters from target(s)

System: Directed Energy Weapons (Particle beams)

Testing Observables

- X-ray, gamma-ray, and optical emissions from stripper cell of neutral particle beam accelerator
- RF emissions from accelerators for charged-particle beams
- Nuclear and infrared signals from operation of nuclear power reactor(s) for space power
- Giant solar panels and batteries for solar space power
- Platform charging rates and levels
- Emissions from target(s)
- Infrared signal from operating power supplies
- Flux of monoenergetic particles
- Space testing of large, characteristic systems

Deployment Observables

- Optical signatures of accelerators (size, shape, etc.)
- Nature of orbit and the coverage of the threat tube; the number of platforms involved
- Radiation from quiescent nuclear reactor(s)
- Configuration of solar power gear
- Radiographic images
- Very large space vehicles and power sources

System: Directed Energy Weapons (Lasers)

Testing Observables

- Infrared signal from spent fuel from chemical laser
- RF emissions from free-electron laser accelerator
- X-ray and gamma-ray emissions from lasers
- Infrared signals from operating power supplies
- Emissions from target(s)

- Space tests of large optical and power supply systems

Deployment Observables

- Mirror deployments
- Optical signature: very large space vehicles with large power supplies
- Chemical storage tanks
- Radiographic images

System: Directed Energy Weapons (Microwave)
Testing Observables

- RF and EMP signals from source platform
- Infrared heat signal and EMP from target(s)
- Infrared heat signals from operating space reactors or solar power systems for power supplies
- Focussing antennas different than those for communications—not earth-directed

Deployment Observables

- Optical signature: very large systems with large power supplies
- Radiographic image
- New nuclear or solar power supplies
- Focussing antennas

SPACE TO GROUND

System: Nuclear Explosive
Testing Observables

- Simulating launch of weapon(s) against ground target(s)
- Orbits providing coverage of land-based military sites, or patrol areas at sea
- (—same as "SPACE TO SPACE"—)

Deployment Observables

- (—same as "SPACE TO SPACE"—)

System: Nuclear Driven (Optical or RF)
Testing Observables

- Scattering from atmospheric propagation of light pulses
- (—same as "SPACE TO SPACE"—)

Deployment Observables

- (—same as "SPACE TO SPACE"—)

System: Directed Energy Weapons (Lasers)
Testing Observables

- Optical scattering from atmospheric propagation of lasers
- Tests with coorbiters or Soviet space lab
- (—same as "SPACE TO SPACE"—)

Deployment Observables

- (—same as "SPACE TO SPACE"—)

System: Directed Energy Weapons (Microwave)
Testing Observables

- RF and EMP signals from source platform
- Infrared heat signal and RF signals from target(s)
- Optical and RF emissions caused by excitation and neutral breakdown of the atmosphere
- Infrared signals from operating large power supplies

Deployment Observables

- (—same as "SPACE TO SPACE"—)

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