CHAPTER 10

INCENTIVES FOR SPACE SECURITY: TECHNOLOGY, TRANSPARENCY AND COMPLIANCE

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As commonly understood, “security” denotes the absence of threats. Today, security is a core value of modern state behaviour.[1] As humankind explores outer space, the concept of security will also be increasingly applied to the space environment. Until now, the only threats to manned spacecraft such as the International Space Station or unmanned satellites were meteoroids or man-made space debris. This situation might change significantly if a country decides to deploy weapons in orbit. An arms race in space, which will always start on Earth, is a likely outcome. The deployment of space weapons could complicate using space for other commercial and military purposes and might promote a false sense of security for objects in space and the Earth itself. Such a move also might stimulate military reactions by adversaries that currently do not possess space weapons. A space arms race would use enormous resources and would also project currently Earth-bound rivalries into space. The climate of mistrust in world politics would once again increase. Thus, the international community has a vested interest in keeping space free of weapons.

Outer space has commercial applications such as surveillance, meteorology, navigation, communication and early warning. Remote sensing satellites play an important role in urban planning, fire prevention and pollution management. Global positioning system (GPS) satellite navigation is used for many traffic, rescue and mapping applications. Satellites are creating a space-based infrastructure by extending and complementing terrestrial networks, providing global and universal connectivity in areas such as communication and the broadcast industry.

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The United States is certainly the biggest space power in terms of expenditures, launches and space assets, followed by the Russian Federation, the European Union and China. Independent access to space, a global infrastructure and research and development in the field of astronautics are necessary preconditions for civilian and military space flight. In addition to the classical space-faring nations, new actors such as Brazil, India, Israel, Japan and Ukraine also have the capabilities to launch payloads into space. Until now, the number of space-faring nations has been limited, but the implications of a disruption of space applications would be global.

Most of the technology for launching and operating satellites is dual-use. Many of the early programmes of the United States and the Soviet Union were military-related such as launchers—for example, Atlas, Jupiter, Titan or R-7/SS-6, SS-18. Intercontinental ballistic missiles (ICBMs) are still used to boost some commercial payloads into orbit. Part of the ground infrastructure is military related. The civilian space industries in the United States and in Europe have strong defence branches. Many results from astronautical engineering could be used for civilian as well as for military purposes thus blurring the distinction between civilian and military technologies.

Using space assets such as communication satellites (ComSats), GPS or surveillance satellites are becoming a prerequisite for the "revolution in military affairs" and the conduct of modern warfare. In the coming years, more countries will try to obtain these capabilities by developing space capabilities in pursuit of their national interests. Outer space is an important medium for warfare on Earth, but no "weaponized" satellites—for example, collision devices, shooters or lasers—exist in orbit. It is important to preserve this situation and to avoid a costly arms race in space.

THE TECHNOLOGY OF SPACE WEAPONS

Generally, it is important to differentiate between weapons deployed in space and weapons directed against objects in space. Space-based weapons can hit targets in space (space-to-space weapons, or they can be directed against objects on the ground (space-to-Earth weapons). Earth-based weapons can hit objects in space (Earth-to-space). Earth-based weapons such as ICBMs directed against Earth-based targets might temporarily use or transit space or enter the space plane (Earth-to-Earth).

Technically, several “principles” exist to hit, blind or destroy objects in space, including nuclear explosions in orbit, directed energy weapons and kinetic energy weapons.

NUCLEAR EXPLOSIONS IN ORBIT

Civilian and military satellites can be disabled by a low-yield (10–20kt), high-altitude (125–300km) nuclear detonation. The US project HALEOS came to the conclusion that a nuclear detonation against low-Earth orbit (LEO) satellites could “disable all LEO satellites not specifically hardened to withstand radiation generated by that explosion”.[2] In addition, the lifetime of a satellite might decrease as a result of increased ambient radiation in LEO; however hardening or replacement of satellites might be effective countermeasures.

A simple nuclear warhead could be delivered to space by a medium-range ballistic missile in a very short time, causing much harm to civilian as well as to military satellites. However, the Outer Space Treaty and the (yet to enter into force) Comprehensive Test Ban Treaty prohibit the deployment of a nuclear device in outer space. Such an event could easily be traced to the culprit. A country that decides to use nuclear weapons in orbit would face severe international consequences.

There are various ways to limit such scenarios. The most obvious are to restrict missile proliferation and to strengthen the nuclear non-proliferation regime. Another possibility is to introduce regional zones that are free from ballistic missiles. Strengthening the Outer Space Treaty by explicitly prohibiting explosions in space or the Comprehensive Test Ban Treaty entering into force are two additional options.

DIRECTED ENERGY WEAPONS

Directed energy weapons (for example, laser or particle beams) might seem like an exotic technology, but the high-energy laser research and development currently underway within the US Ballistic Missile Defense (BMD) programme has an inherent anti-satellite (ASAT) capability.[3] The reason is simple: a missile air-frame body is in principle less vulnerable than a satellite. The Airborne Laser (ABL) is designed to use a high-energy laser to intercept a missile in its boost phase. It is a megawatt chemical laser (mounted on a modified 747 aircraft) that aims at a ballistic missile body, causing structural damage. Certainly such a system, if it works one day, also has an inherent ASAT capability against LEO satellites. Even if the ABL does not use its full power, it can still blind satellite sensors. Another high-energy laser was chosen for the space-based laser being developed for BMD purposes. In December 2002, the Missile Defense Agency announced the start of a "test bed" for space-based weapons. The first space-based laser tests are planned by the US for 2008–2010.

The technology is far from operational, but a space-based laser could have the capability to reach satellites in a geosynchronous orbit (GEO). There is a fear that other nations could use ground-based lasers to blind satellites. A future challenge is to create a regime to preventively prohibit "new weapons principles" such as lasers or microwaves. Methods to detect and verify such weapons near the source have already been developed.

KINETIC ENERGY WEAPONS

Satellites circulate on predictable orbits around the Earth and are much more vulnerable to kinetic attacks than warheads from ballistic missiles, which are hardened for re-entry. The hit-to-kill technology of the planned US BMD programme can also be effective against satellites. The ground-based interceptors could lift the "kill vehicle" to a height of 6,000km and can reach satellites in LEO. The US Ground Midcourse system also includes ground-based radars (X-Band) and space-based sensors (for example, Space-Based Infrared System satellites), which are, together with the deep space surveillance network and the NORAD radars, capable of precisely tracking satellites in outer space. Previous space-based missile defence systems (such as Brilliant Pebbles) were planned under the Global Protection Against Limited Strikes Programme. In Brilliant Pebbles, several hundred autonomous manoeuvring small satellites were intended to intercept missiles in the midcourse phase of a ballistic missile. The current Bush Administration's missile defence programme is dedicated to boost-phase intercept, but could have also the capability to lift to higher orbits to attack satellites.

Another possibility is lightweight satellites, so called micro-satellites.[4] The 2001 *Report of the Commission to Assess United States National Security Space Management and Organization (The Rumsfeld Space Commission)* stated that "micro-satellites can perform satellite inspection, imaging and other function and could be adapted as weapons".[5] Because these systems are small, light, inexpensive (in terms of launch and development costs) and accessible to many states, there is concern that these satellites could also be used as space weapons. But it is important to remember that even a micro-satellite must have sufficient propulsion to manoeuvre or to move to the target satellite. It also needs sensors for detection and discrimination and a guidance system for homing in on the target. Existing satellites lack many of these capabilities. Another counterargument is that even small satellites can be detected and tracked after launch.

The efficiency of a potential space weapon depends on several important factors:

- the vulnerability of the target (for example, solar panels, sensors, energy supply);
- the characteristics of orbit (for example, altitude and motion in LEO or GEO);
- the deployment and manoeuvrability of the space-based weapon and the target;
- access to space and space technologies to launch space-based weapons (for example, launch capabilities, space launch vehicles or ballistic missiles); and
- ground stations and radar components.

These parameters have to be more or less defined and restricted if a "space arms control regime" is established. One key problem is the definition of a space weapon. This is complex because the characterization of a space weapon can vary due to technical, geographical and political perspectives. Furthermore, the deployment region or the target area (for example, space or Earth) of such weapons is decisive. Definitions could be based on specific parameters, technical lists, legal agreements and functional or purpose-oriented measures, among others.

However, a simpler solution might be to first define "outer space", for example in relation to the legal airspace of a country or by a specific altitude threshold. Once there was an agreed definition of “outer space”, the definition of a space weapon could be based on it—for example, “deployed in” or “the use of outer space”. Another option is to use concrete parameters such as “deployment altitude” or that the “object must be in orbit”.

Whereas strict measures like a technical list can provide short-term solutions by banning specific equipment, functional- or purpose-oriented definitions might be preferable for long-term solutions. For example, ballistic missiles pass through space at high altitudes—but generally are not considered as space assets.

VULNERABILITY OF CIVILIAN SATELLITES AND INFRASTRUCTURES

Destroying or deactivating a space system does not necessarily mean shooting down a satellite in orbit. A space system consists of several elements: ground stations with an uplink and a downlink connection and a space segment. Uplink jamming requires very high power from fixed sites and downlink jamming is not a significant threat because close proximity to the user is necessary. There is concern about terrorist attacks on ground stations, but the best protection for ground stations is sufficient security at key facilities. ComSats are often in geostationary orbits and are safe given today’s technologies. With regard to space launchers that are capable of hitting satellites in space, only a threat from major space-faring nations seems plausible. Conventional ASATs against GEO satellites are not easy to handle and need a lot of time for manoeuvring and testing. Directed energy weapon threats are unlikely for many years to come. Satellites will operate increasingly within networks, which imply some form of redundancy. This means that inactive ground stations can be replaced or other satellites can be used.

SPACE DEBRIS

A decision to test and deploy weapons in space might not only make space weapons more attractive to other nations, it also affects the common use of space in general. Space is not “empty”—natural (meteoroids or comets) and artificial (man-made) objects can be found in the space environment. They travel through Earth orbital space at high velocities and pose a risk to orbiting objects. Orbital debris is not of natural origin, rather it is the result of about 45 years of space exploration—parts of spacecraft, remains of intentional and unintentional explosions as well as mission-related objects. Each of these objects can be classified by its source (debris type) or its size. With particle size, a distinction is made between small objects (less than 1mm), medium-sized objects (from 1mm to 1cm) and large objects (more than 10cm). The number of objects varies with orbit parameters and size. Small-sized objects are more prevalent than larger objects, resulting in different mean times of debris impacts on target objects (for example, spacecraft). Mean times of impacts can vary from days to several thousand years. Although the probability of a spacecraft colliding with a large fragment is low, such an impact could have catastrophic results. Collision with medium fragments would cause significant damage to a spacecraft and possibly result in mission failure. Small fragments can cause component damage, spallation or degradation of spacecraft surfaces.

A spacecraft can be protected against space debris by shielding the craft or by manoeuvring to avoid a collision. Shields can protect against fragment sizes up to approximately 1cm, depending on the shield type. Despite the progress in shield development, spacecrafts in near-Earth orbits are at increasing risk of being damaged. Small fragments less than approximately 1cm are particularly dangerous because they are not trackable—or only barely so. In this case, manoeuvring is not applicable. The chance of failure as a result of collision with small fragments is about 1% per year for an average small satellite in an 800km orbit.[6] Scientists expect there will be an increasing number of collisions until at least 2025, which will also increase the number of fragments in orbit. Depending on the their specific characteristics (for example, specific orbit, fragment mass, fragment cross sectional area, radiation pressure) fragments can remain in Earth orbit up to several thousand years. To paraphrase one analyst, if humankind continues its use of space in the way that it has until now, space will be overflow with debris to the point that it will be no longer utilizable. While we don't know if this will take 70 or 130 years, that it appears is assured.[7]

Space weapons might aggravate the danger of space debris. Although there are now no weapons deployed in space, several weapons to attack satellites have been developed[8] and various scenarios highlighting the benefit of space weapons have been considered. The successful tests of the

Russian co-orbital ASAT programme and the destruction of the Solwind satellite by the US military created hundreds of fragments of trackable debris. Remaining fragments can still be found in orbit. Since the increasing amount of debris raises the possibility of damaging spacecraft, it must be recognized that every launch to deploy space assets also creates more potentially dangerous debris. Kinetic ASAT systems like Brilliant Pebbles are based on hundreds of satellites and will create a significant amount of debris simply through their deployment. In addition to the generation of space debris there is also an economic impact. An American Physical Society study[9] reports that about 1,600 interceptor satellites are needed for a boost-phase intercept using space-based interceptors. The mass of the constellation was found to be approximately 2,000t, requiring a 5–10 times increase in the current launch capacity of the United States to deploy such a system.

An effective and cheap space weapon might release a larger debris cloud—for example, pellets made of steel balls—to destroy a satellite or a weapon system in LEO. In a worst-case scenario the balls and the remaining fragments of the asset, in conjunction with the existing space debris, would further increase the fragmentation of the approximately 3,000 tons of existing debris. The emerging debris would then endanger all existing satellites in LEO and might make it unusable for a limited time. The increasing dangers caused by space debris will be a growing problem for both civilian and military satellites. Hence, the "vulnerability problem" of space infrastructure by space debris and by military attacks can be a common basis to link the civilian space industry interests and the concerns of the security community for a future control regime.

ACTIVE AND PASSIVE MEASURES TO IMPROVE SPACE SECURITY

A unilateral but costly answer to the problem of space debris or direct threats to satellites is the hardening of space systems. The following "passive countermeasures" are possible but will certainly raise the costs of spacecraft:

- hardening of satellites against heat, shock, radiation and jamming;
- evasive action of satellites by manoeuvres, hiding and decoys;
- redundancy and repair;
- deployment in less threatened orbits; and

- substituting destroyed satellites.

Another possibility would be to include "active countermeasures" such as the deployment of new ASATs—defensive satellites, bodyguard satellites—or the integration of active defence systems. But these measures might fuel an arms race in space where space-faring nations feel under pressure to introduce orbital weapons to protect their own space assets. In the end, treaties to prevent testing and use of ASATs would be more effective than costly investments in hardening satellites or deploying space weapons, which might not work effectively anyway.

STRENGTHENING EXISTING ARMS CONTROL TREATIES

The 1967 Outer Space Treaty is a key document for arms control in space.[10] The preamble recognizes "the common interest of all mankind in the progress of the exploration and use of outer space for peaceful purposes". It extends international law, including the United Nations Charter, to outer space (Article III), prohibits orbiting around the Earth and the stationing of weapons of mass destruction, especially nuclear weapons in outer space (Article IV.1) and demilitarizes the Moon and other celestial bodies (Article IV.2). The treaty does not ban the transit of ballistic missiles equipped with nuclear weapons through space nor the use of nuclear equipped interceptors for missile defence purposes.

The Outer Space Treaty provides the cornerstone for peaceful space activities. It does not include provisions for verification, but it foresees consultations in the case of one member believing that the activity of another member could cause "potentially harmful interference" with peaceful activities.[11] Additional agreements regulate other space activities through launch notification or liability regulations.[12] The members are obligated to provide information about the date, location of the launch site and purpose of the space object. The discipline of the notifying states as well as the details of the registered information is generally quite low. There are delays in announcing launches or in describing the mission in detail. Transparency in outer space can be drastically improved by providing precise orbital data and the size and detailed characteristics of the satellite, such as energy sources, manoeuvring capabilities, payload, luminance and fuel availability. An agency that has the capability to monitor or to check the compliance of the extended convention should be established.

Other instruments also regulate military operations in space. Article I of the 1963 Partial Test Ban Treaty (or Limited Test Ban Treaty) prohibits nuclear weapon tests "or any other nuclear explosions in … outer space". Articles I and II of the 1977 Environmental Modification Convention prohibit the military use of environmental modification techniques affecting outer space. Article V of the defunct 1972 Anti-Ballistic Missile (ABM) Treaty prohibits "the developing, testing or deployment of ABM systems which are … space-based".[13] The ABM Treaty as well as other arms control treaties—for example, the 1987 Intermediate-range Nuclear Forces Treaty (INF), the 1990 Conventional Armed Forces in Europe (CFE) Treaty and the 1991 Strategic Arms Reduction Treaty (START I)—include provisions not to interfere with national technical means (NTM) such as satellites that are operated for verification purposes. These agreements are a good foundation for strengthening legal regimes, but it should be understood that the legal obligations and norms for prohibiting the use of new "conventional technologies" for space weapons are rather weak.

PROPOSALS FOR BANNING SPACE WEAPONS

Resolutions to ban space weapons have been proposed by the international community at the United Nations for many decades. The United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) deals with civilian space traffic issues but excludes arms control problems. The United States and other countries insist that military-related problems in outer space must be addressed in the Prevention of an Arms Race in Outer Space (PAROS) talks at the Conference on Disarmament (CD) in Geneva. Unfortunately, any progress on the issue is blocked at the CD by some space-faring nations, especially the United States. On 27 June 2002, China and the Russian Federation introduced a working paper, which banned the deployment of weapons in outer space, though testing of space weapons and missile defence interceptors would be allowed. Verification is not mentioned in this proposal because verification is seen as "rather complicated and the ideas are diversified".[14]

However verification of any future agreement limiting or banning space weapons is a key subject.[15] Adequate verification is important because it helps to identify launches from Earth to space and it monitors the behaviour of space objects in both the short and long term. In particular, verification helps to discriminate between permitted civilian satellites and banned space weapons. As was learned from the development of verification throughout arms control history, the efficiency of an arms control treaty is highly dependent on the confidence in its verification system. There have been “robust verification systems” such as the CFE Treaty and the Open Skies Treaty, as well as agreements without any verification provision such as the Outer Space Treaty or the Biological Weapon Convention. Agreements can have different degrees of intrusiveness and use different human (inspections) and technical verification instruments. Effective verification measures in space would be dependent upon the treaty’s scope (the application area, whether in space or on Earth), verification subject (for example, space launch vehicles, weapon principles, satellites) or the mission mode (for example, development, testing, manufacture, deployment, transfer, use, dismantlement). A space weapon treaty should ban all weapons in space, because a zero-weapon treaty “is easier to verify than a treaty that differentiates between different numbers and kinds of weapons in space”. Another important issue is whether the verification data would be available for all members of the treaty, an agency would be established to monitor compliance, or specific state parties would use NTM—for example, remote sensing satellites or space surveillance networks—to verify compliance.

Only the biggest space powers have space surveillance capabilities on the ground. Optical capabilities—such as the American DEEPSTAR or GEODSS—are inexpensive but are also highly weather dependent. Radar surveillance networks are already used by the United States to monitor space activities. Civilian capabilities are mainly used to coordinate satellite traffic and monitor debris in order to prevent collisions. In addition, the military is also interested in the rapid characterization of launches and the identification of mission modes. Early warning satellites and signals intelligence satellites for the interception of telemetry data can be used for remote observation. Besides long-term monitoring from the Earth’s surface, monitoring launch activities or outdoor testing can also be done from space. Routine or challenge inspections at the final assembly site, as permitted under the INF and CFE treaties, could complement these pre-launch verification efforts. Commercial satellite imagery could be used to locate preparations at fixed launch sites or testing areas. The Canadian PAXSAT satellite was an attempt to design a special monitoring tool for space verification purposes. Additional radio frequency or infrared sensors on board can help to detect the function of inspected satellites. Another way to help identify satellites is to include proximity sensors in operating satellites, which can alert ground stations if satellites are approaching at a specific distance.

The effectiveness and robustness of arms control treaties are often assessed on the basis of verification and compliance. Verification requires monitoring treaty-limited equipment and activities, as well as assessing compliance on the basis of observing and collecting other information. Transparency measures help to meet these objectives by openly presenting treaty-relevant information to demonstrate good will to other parties. These processes create different levels of confidence to achieve the objectives of an arms control accord. Depending on the scope and the subject of a treaty, verification has different functions: it can improve confidence building between different parties or it can have an early warning instrument to determine compliance or non-compliance with the treaty objectives.[16] Verification is also a key factor for the efficiency and the strictness of a compliance regime, because it determines the detectability of significant violations. Universality in geographic as well as political terms is important. A useful space weapon agreement needs an enforcement mechanism as well as barriers to withdraw from such a treaty.

Elements of a future comprehensive space control regime can be found in existing treaties—for example, the Outer Space Treaty—or in historical proposals.[17] Other proposals from academia emphasize banning attacks on the International Space Station or preventing all military activities beyond GEO.[18] Jonathan Dean, retired ambassador from the US State Department, proposed that the International Court of Justice could give an advisory opinion on whether testing or deployment of space weapons would be compatible with the key principle of the Outer Space Treaty: the peaceful uses of outer space. Coyle and Rhinelander proposed a caucus of states and parties to amend the Outer Space Treaty and a ban of shooters in space.[19] And other comprehensive proposals have been made since 2000.[20]

There are good arguments to start with confidence building and transparency measures to build-up trust by introducing procedures to improve space security in the areas of space debris, traffic in space or the expansion of launch notification. A code of conduct for not attacking military or commercial satellites might be in the interest of all space-faring nations. After the end of the Cold War, it is time not only to begin serious discussions on a future space accord, but also to establish a new space order to keep outer space free of weapons

Notes

[1] Graham Evans and Jeffrey Newnham, 1998, *The Penguin Dictionary of International Relations*, London, Penguin Books.

[2] High Altitude Nuclear Detonations (HAND) Against Low Earth Orbit Satellites ("HALEOS"), Defense Threat Reduction Agency (DTRA), Advanced Systems and Concepts Office, April 2001, at <http://www.fas.org/spp/military/program/asat/haleos.pdf (13.11.02)>.

[3] For details see, David Wright and Laura Grego, Anti-Satellite Capabilities of Planned US Missile Defense System, *Disarmament Diplomacy*, December 2002/January 2003, at <www.ucs.usa.org/global/space_weapons>.

[4] The mass of a micro-satellite ranges per definition from a few kilograms to 500kg. Several hundred satellites have been launched over the last 25 years.

[5] United States, 2001, *Report of the Commission to Assess United States National Security Space Management and Organization*, Washington, DC, Government Printing Office.

[6] A presentation by Joel R. Primack, *Debris and Future Space Activities*, at a conference on future security in space, Southampton, England, 28–29 May 2002, at <physics.ucsc.edu/cosmo/mountbatten.pdf>.

[7] Paraphrase of Dietrich Rex, 1996, *Wird es eng im Weltraum? Die mögliche Überfüllung erdnaher Umlaufbahnen durch die Raumfahrt*, at <http://www.ilr.ing.tu-bs.de/forschung/raumfahrt/spacedebris/space/spacedebris.html>.

[8] For example, ASATs such as Gorgon (Russian) or Safeguard/Sentinel (US); an orbital ASAT system such as Istrebitelny Sputnik (Russian) or the Air Launched Miniature Vehicle (ALMV) (US). The orbital and the ALMV ASAT have been tested successfully. The status of the systems has not been disclosed.

[9] American Physical Society, 2003, *Report of the American Physical Society Study Group on Boost-Phase Intercept Systems for National Missile Defense: Scientific and Technical Issues,* Washington, DC, at <www.aps.org/public_affairs/popa/reports/nmdfull-report.pdf>.

[10] See J. Goldblat, 2003, Efforts to Control Arms in Outer Space, *Security Dialogue*, vol. 34, no. 1 (March), p.103–108.

[11] Op. cit., p. 104.

[12] For example, the Convention on International liability for Damage Caused by Space Objects (1972); the Convention on Registration of Objects Launched into Outer Space (1975), also see <www.islandone.org/Treaties/>.

[13] There are voices that argue that the real reason for withdrawing from the ABM Treaty was not the extended missile defence testing programme of the US Administration, but rather to remove this "barrier" to the testing and deployment of future space weapons.

[14] Fu Zhigang, 2002, The Joint Working Paper by China and the Russian Federation, *International Network of Engineers and Scientists Against Proliferation Information Bulletin*, no.20 (August).

[15] Regina Hagen and Jürgen Scheffran, 2003, Is a space weapon ban feasible? Thoughts on technology and verification of arms control in space, *Disarmament Forum,* no. 1, pp. 41–51.

[16] See Joseph Pilat, 2003, Verification and Transparency: Relics of Future Requirements?, in Jeffrey Larsen (ed.), *Arms Control: Cooperative Security in a Changing Environment*, Boulder, Lynne-Rienner Publishers, pp. 79–96.

[17] Reiner Labusch, Eckart Maus and Wolfgang Send, 1984, *Space-Based Missile Defense*, Report by the Union of Concerned Scientists, Cambridge.

[18] Clifford E. Singer and Amy Sands, 2002, *Keys to Unblocking Multilateral Nuclear Arms Control*, University of Illinois at Urbana-Champaign.

[19] Philip E. Coyle and John B. Rhinelander, 2002, Drawing the Line: the Path to Controlling Weapons in Space, *Disarmament Diplomacy,* no. 66 (September).

[20] See James Clay Moltz, 2002, Breaking the Deadlock on Space Arms Control, *Arms Control Today*, April, pp. 3–9; Rebecca Johnson, 2001, Multilateral Approaches to Preventing the Weaponization of Space, *Disarmament Diplomacy*, no. 56 (April).