CHAPTER 6

RISK REDUCTION AND MONITORING IN OUTER SPACE

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Space is increasingly used for a variety of purposes, which leads to a growing dependence on space objects. For the largest space power, the United States, this dependence translates into vulnerability that contains the threat of a space "Pearl Harbor". This paper discusses options to reduce this threat through a combination of risk reduction measures, arms control and monitoring.

RISKS AND RISK-REDUCTION FOR SPACE OBJECTS

Space objects are designed for a hostile space environment that is characterized by vacuum, radiation, temperature extremes and a limited energy supply. They also must survive the strains of launch and sometimes the stress of re-entry. Space systems can fail as a result of a variety of reasons: component failure and degradation; design, development, production, programming or mission errors; interruption of ground communication caused by accidents, jamming or ground attacks; collision with space debris; physical attack; blinding of sensors; hacking; deception; or hijacking.

In a concrete case, it might be difficult to trace a system failure back to a specific cause, which in many cases could be space debris. More than 8,000 man-made objects larger than 10cm orbit around the Earth, including operational satellites (approximately 7%), rocket bodies (approximately 15%) and space debris (fragmentation and defunct satellites 78%). It is difficult to track all space activities and distinguish between harmless and potentially threatening objects and activities.

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Vulnerabilities and threats would be considerably increased with advanced space weapons, such as manoeuvrable satellites, space mines, micro-satellites, kinetic kill vehicles, chemical and nuclear explosives, or particle, microwave and laser beams. They would contribute significantly to the complexity and instability of the strategic situation, which ultimately would not serve the security interests of any country, including the United States.

To some degree, the survivability of space objects against some of the potential attacks can be increased by passive or active protection measures including the following:

- autonomy from ground control to reduce the risk of communication failure or interruption;
- provisions for quick replacement of crucial satellites in case of a failure or attack;
- physical hardening against nuclear and laser radiation, or collision with small objects;
- attack warning sensors and sensor shutdown on-board of important spacecraft;
- redundancy and distribution of important functions to several satellites (clustering);
- evasion manoeuvres to escape a potential physical threat; and
- deception of attacking sensors and shoot back capabilities.

Some of these measures are costly and do not provide security against all kinds of attacks and technologies. For the most important satellites in the United States, some or all of these measures have already been implemented. Within the existing framework of international space law, confidence-building measures can contribute to stabilizing international security including:

- advanced notification and more detailed information about space launches and experiments (for example, with lasers);
- establishment of a crisis hotline between major missile and space powers;
- a code of conduct for responsible space behaviour, learning from the ongoing process of the Missile Technology Control Regime (MTCR);
- improved international monitoring system and information exchange; and

- strengthened international space cooperation that improves transparency and reduces incentives for indigenous space development.

In addition, rules of the road could be agreed for outer space:

- keep-out-zones, minimum flyby distances and speed limits around satellites to increase warning time against attack and reduce efficiency of attack;
- satellite immunity and non-interference with satellites; and
- reduction of space debris.

A combination of satellite hardening, confidence building and rules of the road might better protect satellites against existing residual (non-dedicated) space threats such as attacks with intercontinental ballistic missiles (ICBMs) and manoeuvrable satellites, with radio or laser beams not explicitly developed for weapon purposes. High-altitude nuclear explosions are a severe risk for all electronic components in space, not just from direct impact but even more so from captured radiation in the Van Allen radiation belt.

ARMS CONTROL MEASURES

If dedicated space weapons based on new technologies are developed, the existing regime would not be sufficient enough to substantially diminish the emerging threats. Additional risk reduction could be achieved by partial arms control measures, which by agreement would restrict or ban certain kinds of weapons or weapon uses. For example, these could include the following:

- A ban on testing, deployment and use of weapons above a specific altitude would relegate weaponization to low-Earth orbits and keep the remaining outer space a weapon-free zone. Possible altitudes range from 500 km to 5,000 km in order to protect space objects beyond that range. Protecting high-orbit navigation satellites and geostationary communication and early warning satellites is of greatest importance to military and commercial interests. However, allowing weapons development in low-Earth orbits could open the door to space weaponization, and it would not preclude the development of sophisticated low-Earth orbit weapon systems that could later be extended to higher orbits.

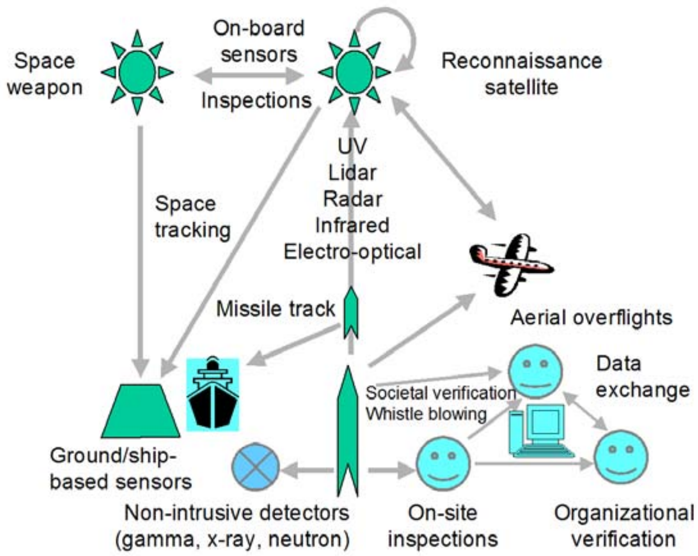
- The legal and physical protection of manned missions and the prohibition of manned military space operations could prevent people from being involved in space warfare. Most important, it would protect manned space stations by maintaining keep-out zones and shielding them against space debris and some forms of attack.
- Certain types or deployment modes of space weapon systems and technologies could be banned—in particular, ASAT or BMD systems, or weapons with a predominantly offensive role. Laser and other kinds of beam weapons could be excluded, whether ground-based or space-based. Small satellites below a specific size limit (for example, 10cm) or weight limit (for example, 10kg) could be restricted.
- States could restrict particular stages in the life cycle of a weapon such as research, development, testing, production, deployment or use. For example, an ASAT testing moratorium has been maintained since the mid-1980s between the United States and the Soviet Union (and now the Russian Federation). A ballistic missile flight test ban was also discussed.
- Specific limits on interception speeds and altitudes or the size of mirrors and power levels could be agreed.
- Partial arms control measures could be embedded into more comprehensive arms control regimes in space, including a global ban on weapons against objects in space and from objects in space against any target. Several proposals have been outlined in the last two decades.

MONITORING AND VERIFICATION

Any agreement would need some degree of verification, and even without agreement there is a need for improved monitoring of space activities. Although space is large, it is transparent and allows for remote tracking, surveillance and observation of suspicious activities on the Earth and in space with optical, infrared, radar, electronic, electromagnetic and other technology. Since all space objects are launched from the Earth, they are visible to space tracking systems, which can be complemented by inexpensive pre-launch verification measures—for example, on-site inspection of payloads or societal verification/whistle-blowing. A multitude of technologies and procedures could be employed to monitor space activities and verify space arms control, including the following (see Figure 1):

- For several decades, the United States has been maintaining a global Space Surveillance Network (SSN) under the control of the United States Space Command to detect, track, catalogue and identify all objects larger than 10cm in Earth orbit, with a primary interest in operational satellites. The SSN includes United States Army, Navy and Air Force operated ground-based phased-array and conventional radars and optical sensors (telescopes) at 25 sites worldwide. The Ground-Based Electro-Optical Deep-Space Surveillance System telescopes are upgraded to cover objects 5cm or larger. Russia operates a similar but less capable system. The European Space Agency maintains the European Space Research Organisation Tracking and Telemetry Network to track their own satellites and those of their industrial customers.
- Reconnaissance systems are suitable tools for verification purposes. These include early infrared warning satellites to detect space launches of missiles and rockets; reconnaissance satellites with optical cameras, infrared or microwave sensors to observe suspected ASAT facilities such as launchers, rockets or laser systems; and ground-, air- and space-based electronic and electromagnetic surveillance systems to intercept communication signals of suspicious facilities, which could with some probability also receive telemetry signals of prohibited weapons tests in space.
- On-board sensors on important satellites could collect pressure, acceleration, heat, and radiation data and notify ground control of any deviation from the expected status. In case of a satellite failure, the sensor data could help to determine the failure cause and exclude or confirm the likelihood of an attack.
- Inspectors could verify on-site production launch and infrastructure facilities on Earth; more permanent verification could be facilitated by observers as well as by on-site monitoring instruments and detectors. On-site inspections could be conducted in space by using dedicated remote control or manned verification spacecraft. Human intelligence and societal verification—including whistle-blowing—would add to the reliability of the verification results.
- Prohibiting interference, deliberate concealment measures and encryption that impede verification would minimize the likelihood that cheating of the treaty provisions would go unnoticed.

Figure 1. An integrated monitoring system for space arms control



Many of these systems could be integrated into an International Monitoring System, which would include a variety of global verification means and make relevant data available to all states that are part of an agreement. Each of the systems has its strength and the combination of the systems covers the diversity of activities to be monitored (see Table 1).

The highest monitoring priority would be the identification of any interference with or attack on early warning satellites since this would be a strong indicator of a forthcoming more extensive attack. As a result of the inherent dual-use potential of space objects, a particular challenge to verification is posed by the potential overlap of permitted capabilities of space objects with prohibited capabilities. Generally, the expenditures for verification should be assessed in relation to the expected security gains and the risk posed by an activity. The further the development and testing of relevant systems advances, the more the costs for eventual verification will increase and the reliability of verification will decrease. Thus, a test moratorium for space weapons would be important to stop development at an early stage, which would also facilitate verification.

Table 1: Comprehensive coverage of an integrated space monitoring system

Verification means / Activities	Remote sensing	On-site sensors	Data exchange	Over flights	Inspections	Space tracking	Institutional verification	Societal verification
NW use in space	■	■				■		
NW deployment in space	■				■	■		
Missile test	■		■			■		
Missile disarmament	■	■	■	■	■		■	■
Transformation of space launcher		■	■		■	■	■	■
ASAT test	■		■			■		
ASAT use	■					■		
BMD test	■		■			■		
BMD deployment	■	■		■	■	■		■
BMD capability	■			■	■			
Space weapon in orbit	■				■	■		
Space debris	■	■	■			■		

NW = nuclear weapon; BM = ballistic missile; ABM = anti-ballistic missile; ASAT = anti-satellite

FURTHER READING

R. Hagen and J. Scheffran, 2003, Is a space weapons ban feasible? Thoughts on technology and verification of arms control in space, *Disarmament Forum*, no. 1, pp. 42–51.

J. Scheffran, 1999, Options for Rules in Outer Space, *INESAP Bulletin*, no. 20 (August), pp. 9–14.