SPACE SECURITY INDEX 2015

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SPACE SECURITY INDEX 2015 | EXECUTIVE SUMMARY

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Space Security Index 2015: Executive Summary

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Cover image: From the International Space Station, Expedition 42 Flight Engineer Terry W. Virts took this photograph of the Gulf of Mexico and U.S. Gulf Coast at sunset and posted it to social media on Dec. 14, 2014. Credit: NASA/Terry Virts.

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INTRODUCTION

Space Security Index 2015 is the twelfth annual report on developments related to safety, sustainability, and security in outer space, covering the period January-December 2014. It is part of the broader Space Security Index (SSI) project, which aims to improve transparency on space activities and provide a common, comprehensive, objective knowledge base to support the development of national and international policies that contribute to the security and sustainability of outer space.

The definition of space security guiding this report reflects the intent of the 1967 Outer Space Treaty that outer space should remain open for all to use for peaceful purposes now and in the future:

The secure and sustainable access to, and use of,
space and freedom from space-based threats.

The key consideration in this SSI definition of space security is not the interests of particular national or commercial entities, but the security and sustainability of outer space as an environment that can be used safely and responsibly by all. This broad definition encompasses the security of the unique outer space environment, which includes the physical and operational integrity of manmade objects in space and their ground stations, as well as security on Earth from threats originating in space.

From communications to financial operations, farming to weather forecasting and environmental monitoring to navigation, surveillance and treaty monitoring, outer space resources play a key role in the activities of all nations. In this context, issues such as the threat posed by space debris, the priorities of national civil space programs, the growing importance of the commercial space industry, efforts to develop a robust normative regime for outer space activities, and concerns about the militarization and potential weaponization of space are critical to consider as factors influencing overall space security.

The information in the report is organized under four broad Themes, with each divided into various indicators of space security. This arrangement is intended to reflect the increasing interdependence, mutual vulnerabilities, and synergies of outer space activities.

The structure of the 2015 report is as follows:

» **Theme 1:** Condition of the space environment
Indicator 1.1: *Orbital debris*
Indicator 1.2: *Radio frequency (RF) spectrum and orbital positions*

Indicator 1.3: *Natural hazards originating from space*
Indicator 1.4: *Space situational awareness (SSA)*

» **Theme 2: Access to and use of space by various actors**
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Indicator 2.3: *International cooperation in space activities*
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Indicator 3.1: *Vulnerability of satellite communications, broadcast links, and ground stations*
Indicator 3.2: *Capacity to rebuild space systems and integrate smaller satellites into space operations*
Indicator 3.3: *Earth-based capabilities to attack satellites*
Indicator 3.4: *Space-based negation enabling capabilities*

» **Theme 4: Outer space governance**
Indicator 4.1: *National space policies*
Indicator 4.2: *Multilateral forums for space governance*
Indicator 4.3: *Other initiatives*

The most critical challenge to the security and sustainability of outer space continues to be the threat posed by space debris to spacecraft of all nations. The total amount of manmade space debris in orbit is growing each year, concentrated in the orbits where human activities take place.

Today the U.S. Department of Defense (DoD) is using the Space Surveillance Network to track some 23,000 pieces of debris 10 centimeters (cm) in diameter or larger. Experts estimate that there are more than 500,000 objects with a diameter larger than one centimeter and several million that are smaller.

There is a growing risk that space assets may collide with one another or with a piece of orbital debris. As outer space becomes more congested, the likelihood of such events increases, making all spacecraft vulnerable, regardless of the nation or entity to which they belong.

In recent years, awareness of the space debris problem has grown considerably and some important efforts have been made to mitigate the production of new debris through compliance with national and international guidelines. The future development and deployment of technology to remove debris promises to ensure the sustainability of outer space if and when it becomes operational. It is incumbent

upon the international community to proactively address the myriad technical, political, and financial challenges that will inevitably be associated with active debris removal.

Similarly, the development of space situational awareness (SSA) capabilities to track space debris provides significant space security advantages—for example, when used to avoid collisions. The sensitive nature of some information and the small number of space actors with advanced tools for surveillance have traditionally kept significant data on space activities shrouded in secrecy. But recent developments followed by the Space Security Index suggest that there is a greater willingness to share SSA data through international partnerships—a most welcome trend. In addition, commercial providers of SSA information are also emerging.

As barriers to entry go down, more nations and their private entities will enter space. However, the limitations of some space resources will challenge the ability of newcomers to gain equitable access.

The growing number of spacefaring nations and satellite applications is driving the demand for access to radio frequencies and orbital slots. Issues of interference and competition for slots and frequencies are growing concerns for satellite operators, particularly in crowded space segments.

The use of space-based global utilities has grown substantially over the last decade. Millions of individuals rely on space applications on a daily basis for functions as diverse as weather forecasting, navigation, and search-and-rescue operations.

International cooperation remains key to both civil space programs and global utilities. Collaboration in civil space programs can assist in the transfer of expertise and technology for the access to, and use of, space by emerging space actors. Projects that involve complex technical challenges and mammoth expense, such as the International Space Station, require nations to work together. The degree of cooperation in space, however, may be affected by geopolitical tensions on Earth.

The role that the commercial space sector plays in the provision of launch, communications, imagery, and manufacturing services and its relationship with civil and military programs make this sector an important determinant of space security. A healthy space industry can lead to decreasing costs for space access and use, may increase the accessibility of space technology for a wider range of space actors, and possibly enhance space security.

The military space sector is an important driver in the advancement of capabilities to access and use space. Many of today's common space applications, such as satellite-based navigation, were first developed for military use. Space systems have augmented the military capabilities of a number of states by enhancing battlefield

awareness, offering precise navigation and targeting support, providing early warning of missile launch, and supporting real-time communications. Furthermore, remote sensing satellites have served as a technical means for nations to verify compliance with international nonproliferation, arms control, and disarmament regimes.

However, the use of space systems to support terrestrial military operations could be detrimental to space security if adversaries, viewing space as a new source of military threat or as critical military infrastructure, develop negation capabilities to neutralize the space systems of other nations.

The security dynamics of space systems protection and negation are closely related and space security cannot be divorced from terrestrial security. In this context, it is important to highlight that offensive and defensive space capabilities are not only related to systems that are physically in orbit, but include orbiting satellites, ground stations, and data and communications links.

No known hostile kinetic anti-satellite (ASAT) attacks have been carried out against an adversary; however, recent incidents testify to the availability and effectiveness of missiles to destroy an adversary's satellite. The ability to rapidly rebuild space systems after an attack could reduce vulnerabilities in space. The capabilities to refit space systems by launching new satellites into orbit in a timely manner to replace satellites damaged or destroyed by an attack are critical resilience measures. Smaller spacecraft that may be fractionated or distributed on hosts can improve continuity of capability and enhance security through redundancy and rapid replacement of assets. While these characteristics may make attacks against space assets less attractive, they can also make assets more difficult to track, could potentially hinder transparency in space activities, and even increase pressures for a space arms race. In addition, capabilities required to repair or service satellites in orbit could also enable space-based negation activities.

International instruments that regulate space activities have a direct effect on space security because they establish key parameters for acceptable and expected behavior in space. These include the right of all countries to access space, prohibitions against the national appropriation of space and celestial bodies, and the obligation to ensure that space is used with due regard to the interests of others and for peaceful purposes. International space law, as well as valuable unilateral, bilateral, and multilateral transparency and confidence-building measures (TCBMs) can make space more secure by regulating activities that may infringe upon the ability of actors to access and use space safely and sustainably, and by limiting space-based threats to national assets in space or on Earth.

While there is widespread international recognition that the existing regulatory framework is insufficient to meet current and future challenges facing the outer space domain, the development of an overarching normative regime has been slow. Space actors have been unable to reach consensus on the exact nature of a space security governance regime, although specific alternatives have been presented.

Proposals include both legally binding treaties, such as the proposed Treaty on the Prevention of the Placement of Weapons in Outer Space, the Threat or Use of Force against Outer Space Objects (known as the PPWT), and politically binding measures, such as the proposed International Code of Conduct for Outer Space Activities (ICoC). The latest revised versions of each of these proposals were made public during 2014.

As in the 2014 edition, *Space Security Index 2015* includes a brief Global Assessment analysis, which is intended to provide a broad assessment of the trends, priorities, highlights, breaking points, and dynamics that are shaping current space security discussions.

The Global Assessment will be assigned to a different space security expert every year to encourage a range of perspectives. The author of the current assessment is Theresa Hitchens, Senior Research Scholar at the Center for International and Security Studies at Maryland (CISSM), University of Maryland School of Public Policy. Prior to joining CISSM, Hitchens was the director of the United Nations Institute for Disarmament Research (UNIDIR) in Geneva from 2009 through 2014.

The information in *Space Security Index 2015* is from open sources. Great effort is made to ensure a complete and factually accurate description of events. Project partners and sponsors trust that this publication will continue to serve as both a reference source and a tool for policymaking, with the ultimate goal of enhancing the sustainability of outer space for all users.

Expert participation in the Space Security Index is a key component of the project. The primary research is peer-reviewed prior to publication at the Space Security Working Group in-person consultation, which is held each spring for two days to review the draft text for factual errors, misinterpretations, gaps, and misstatements. This meeting also provides an important forum for related policy dialogue on recent developments in outer space.

For further information about the Space Security Index, its methodology, project partners, and sponsors, please visit the website **www.spacesecurityindex.org**. The full report, *Space Security Index 2015*, will be available for purchase on the website in Autumn 2015. Comments and suggestions are welcome.

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EXECUTIVE SUMMARY

Theme 1:
Condition of the space environment

INDICATOR 1.1: Orbital debris — Space debris poses a significant, constant, and indiscriminate threat to all spacecraft. Most space missions create some space debris, mainly rocket booster stages that are expended and released to drift in space along with bits of hardware. Serious fragmentations are usually caused by energetic events such as explosions. These can be both unintentional, as in the case of unused fuel exploding, or intentional, as in the testing of weapons in space that utilize kinetic energy interceptors. Traveling at speeds of up to 7.8 kilometers (km) per second, even small pieces of space debris can destroy or severely disable a satellite upon impact. The number of objects in Earth orbit has increased steadily.

Today the U.S. Department of Defense (DoD) is using the Space Surveillance Network to catalog more than 16,000 objects approximately 10 centimeters (cm) in diameter or larger. Roughly 23,000 pieces of debris of this size are being tracked, but not cataloged; the U.S. military only catalogs objects with known owners. Experts estimate that there are more than 500,000 objects with a diameter larger than one centimeter and several million that are smaller. The annual rate of new tracked debris began to decrease in the 1990s, largely because of national debris mitigation efforts, but accelerated in recent years as a result of events such as the Chinese intentional destruction of one of its satellites in 2007 and the accidental 2009 collision of a U.S. Iridium active satellite and a defunct Russian Cosmos satellite.

The total amount of manmade space debris in orbit is growing each year, concentrated in the orbits where human activities take place. Low Earth Orbit (LEO) is the most highly congested area, especially the Sun-synchronous region. Some debris in LEO will reenter the Earth's atmosphere and disintegrate quite quickly due to atmospheric drag, but debris in orbits above 600 km will remain a threat for decades and even centuries. There have already been a number of collisions between civil, commercial, and military spacecraft and pieces of space debris. Although a rare occurrence, the reentry of very large debris could also potentially pose a threat on Earth.

2014 Developments

Space object population

- Debris and active object populations continue to grow
- U.S. Space Surveillance Network maintains a catalog of space objects

Debris-related risks and incidents
- Orbital debris still poses a risk to active satellites and human spaceflight operations
- Debris reentry continues to pose a risk in 2014

International awareness of debris problem increases as progress toward solutions continues
- Compliance with Debris Mitigation Guidelines is better in Geosynchronous Earth Orbit (GEO) than LEO
- International dialogues on debris problems, active debris removal, and other solutions continue in 2014
- Research and development in active debris removal continue in 2014
- Increasing number of nanosat launches raises concern about debris

INDICATOR 1.2: Radio frequency (RF) spectrum and orbital positions — The growing number of spacefaring nations and satellite applications is driving the demand for access to radio frequencies and orbital slots. Issues of interference arise primarily when two spacecraft use the same frequencies at the same time and their fields of view overlap or they are transmitting in close proximity to each other. While interference is not epidemic it is a growing concern for satellite operators, particularly in crowded space segments. More satellites are locating in GEO, using frequency bands in common and increasing the likelihood of frequency interference.

While crowded orbits can result in signal interference, new technologies are being developed to manage the need for greater frequency usage, allowing more satellites to operate in closer proximity without interference. For example, frequency hopping, lower power output, digital signal processing, frequency-agile transceivers, and a software-managed spectrum have the potential to significantly improve bandwidth use and alleviate conflicts over bandwidth allocation.

Research has also been conducted on the use of lasers for communications, particularly by the military. Lasers transmit information at very high bit rates and have very tight beams, which could allow for tighter placement of satellites, thus alleviating some of the current congestion and concern about interference. Newer receivers have a higher tolerance for interference than those created decades ago.

The increased competition for orbital slots, particularly in GEO, where most communications satellites operate, has caused occasional disputes between satellite operators. The International Telecommunication Union (ITU) has been pursuing reforms to address intentional signal jamming, slot allocation backlogs, and other related challenges.

2014 Developments
- Support growing to allow the ITU to track sources of interference
- Continuing efforts to counter intentional satellite jamming
- Ongoing development of technical solutions to spectrum crowding
- Terrestrial wireless operators seek to share C-band spectrum

- Disappearance of Malaysia Airlines Flight 370 prompts calls for satellite tracking of aircraft
- Regulatory concerns about trend to large constellations of satellites
- Coordination of orbital slots in crowded GEO remains a challenge

INDICATOR 1.3: Natural hazards originating from space — Natural hazards originating from space fall into two categories, Near-Earth Objects (NEOs) and space weather. NEOs are asteroids and comets in orbits that bring them into close proximity to the Earth. Within both groupings are Potentially Hazardous Objects (PHOs), those NEOs whose orbits intersect that of Earth and have a relatively high chance of impacting the Earth itself. As comets represent a very small portion of the overall collision threat in terms of probability, most NEO researchers commonly focus on Potentially Hazardous Asteroids (PHAs). A PHA is defined as an asteroid whose orbit comes within 0.05 astronomical units of the Earth's orbit and has a brightness magnitude greater than 22 (approximately 150 meters in diameter). By the end of 2014 there were 12,056 known Near-Earth Asteroids, 152 of which were identified as PHAs.

Over the past decade a growing amount of research has identified objects that pose threats to Earth and developed potential mitigation and deflection strategies. Increasing international awareness of the potential threat posed by NEOs has prompted discussions at various multilateral forums on the technical and policy challenges related to mitigation. Ongoing technical research is exploring how to mitigate a NEO collision with Earth. The challenge is considerable due to the extreme mass, velocity, and distance of any impacting NEO. Kinetic deflection methods include ramming the NEO with a series of kinetic projectiles. Some experts have advocated using nearby explosions of nuclear devices, which could create additional threats to the environment and stability of outer space and would have complex legal and policy implications. The effectiveness of deflection depends on the amount of warning time.

Space weather is a term that over the past few years has come to refer to a collection of physical processes, beginning at the Sun and ultimately affecting human activities on Earth and in space. The Sun emits energy as flares of electromagnetic radiation and as electrically charged particles through coronal mass ejections (CME) and plasma streams. Powerful solar flares can cause radio blackouts and slow down satellites, causing them to move to lower orbits. Increases in the number and energy of charged particles can induce power surges in transmission lines and pipelines, disruptions to high-frequency radio communication and Global Navigation Satellite System (GNSS) operations, and failure or incorrect operation of satellites. The U.S. National Oceanic and Atmospheric Administration (NOAA) and the U.S. Air Force jointly operate the Space Weather Prediction Center (SWPC), the national

and world warning center for disturbances that can affect people and equipment working on earth and in the space environment. Information for SWPC predictions comes from a variety of sources, ranging from solar imaging satellites to ground magnetometer stations.

2014 Developments

Near-Earth Objects (NEOs)

- Continued observation and assessment of Potentially Hazardous Objects
- More progress made on international cooperation on NEO threats
- NASA seeks technology for planetary defense with Asteroid Redirect Mission

Space Weather

- Increasing awareness of threats from space weather
- Greater coordination of activities related to space weather

INDICATOR 1.4: Space situational awareness (SSA) — SSA refers to the ability to detect, track, identify, and catalog objects in outer space, such as space debris and active or defunct satellites, as well as observe space weather and monitor spacecraft and payloads for maneuvers and other events. SSA enhances the ability to distinguish space negation attacks from technical failures or environmental disruptions and can thus contribute to stability in space by preventing misunderstandings and false accusations of hostile actions. Increasing the amount of SSA data available to all states can help to increase the transparency and confidence of space activities, which can reinforce the overall stability of the outer space regime.

The United States operates the Space Surveillance Network (SSN) that delivers the most advanced SSA capabilities. It also shares conjunction analysis—the ability to accurately predict high-speed collisions between two orbiting objects—with satellite owners and operators worldwide to enhance spaceflight safety and makes most SSA information available publically at the website space-track.org. Russia has relatively extensive capabilities in this area; it maintains a Space Surveillance System using early-warning radars and monitors objects (mostly in LEO), although it does not widely disseminate data. China and India have significant satellite tracking, telemetry, and control assets essential to their civil space programs. The European Union, Canada, France, Germany, and Japan are all developing space surveillance capabilities for various purposes, although none of these actors plan to develop a global system.

Wider sharing of SSA data could benefit all space actors, allowing them to supplement their own information at little if any additional cost. But there is currently no operational global system for space surveillance, in part because of the sensitive nature of surveillance data. Since the 2009 Cosmos-Iridium satellite

collision there has been an increased push in the United States to boost conjunction analysis and to undertake collaborative agreements with international partners that will allow for an increase in data sharing. As the importance of space situational awareness is acknowledged, more states are pursuing national space surveillance systems and engaging in discussions about international SSA data sharing.

2014 Developments

- United States enhances SSA capabilities and sharing agreements
- Other states continue to develop SSA capabilities
- Commercial space surveillance systems emerge
- United States launches two Geosynchronous Space Situational Awareness Program (GSSAP) satellites

Theme 2:
Access to and use of space by various actors

INDICATOR 2.1: Space-based global utilities — These global utilities are space assets that can be used by any actor equipped to receive the data they provide. The use of space-based global utilities has grown substantially over the last decade. Millions of individuals rely on space applications on a daily basis for functions as diverse as weather forecasting, navigation, and search-and-rescue operations. Global utilities are important for space security because they broaden the community of actors that have a direct interest in maintaining space for peaceful uses.

While key global utilities such as the Global Positioning System (GPS) and weather satellites were initially developed by military actors, these systems have grown into applications that are almost indispensable to the civil and commercial sectors. Advanced and developing economies alike depend on these space-based systems. Currently Russia, the United States, the EU, Japan, China, and India have or are developing satellite-based navigation capabilities.

Remote sensing satellites are used extensively for a variety of Earth observation functions, including weather forecasting; surveillance of borders and coastal waters; monitoring of crops, fisheries, and forests; and monitoring of natural disasters such as hurricanes, droughts, floods, volcanic eruptions, earthquakes, tsunamis, and avalanches. Space has also become critical for disaster relief. COSPAS-SARSAT, the International Satellite System for Search and Rescue, was founded by Canada, France, the USSR, and the United States to coordinate satellite-based search-and-rescue. COSPAS-SARSAT is basically a distress alert detection and information distribution system that provides alert and location data to national search-and-rescue authorities worldwide, with no discrimination, independent of country

participation in the management of the program. The UN Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER) ensures that all countries and international and regional organizations have access to and develop the capacity to use all types of space-based information to support disaster management.

2014 Developments

- Navigation systems improve
- Remote sensing capabilities advance
- Electro-optical (EO) imagery remains a priority for many nations
- Constellations of small satellites allow more frequent data collection than traditional EO satellites systems
- Advances made in global maritime ship location
- Initiatives for space-based disaster monitoring and relief continue

INDICATOR 2.2: Priorities and funding levels in civil space programs — Civil space programs can have a positive impact on the security of outer space because they constitute key drivers behind the development of technical capabilities to access and use space, such as those related to the development of space launch vehicles. As the number of space actors able to access space increases, more parties have a direct stake in space sustainability and preservation for peaceful purposes. As well, civil space programs and their technological spinoffs on Earth underscore the vast scientific, commercial, and social benefits of space exploration, thereby increasing global awareness of its importance.

As the social and economic benefits derived from space activities have become more apparent, civil expenditures on space activities have continued to increase in several countries. Virtually all new spacefaring states explicitly place a priority on space-based applications to support social and economic development. Such space applications as satellite navigation and Earth imaging are core elements of almost every existing civil space program. Moon exploration continues to be a priority for such established spacefaring states as China, Russia, India, and Japan.

New launch vehicles continue to be developed. Since the cancellation of the Constellation program, the United States has focused on encouraging development of new launchers by the private sector rather than the National Aeronautics and Space Administration (NASA). The China Academy of Launch Vehicle Technology (CALT) is proceeding with development of the Long March-5, the next generation of launch vehicles. Russia continues to develop the new Angara family of space launchers, which will replace, *inter alia*, the Proton rocket.

2014 Developments

- NASA budget still dwarfs those of other space agencies
- Space agencies fund development of new launch vehicles
- Russian budget focuses on improved launch facilities
- China and India continue to fund ambitious programs with modest budgets
- Syria and United Arab Emirates create new space agencies

INDICATOR 2.3: International cooperation in space activities — Due to the huge costs and technical challenges associated with access to and use of space, international cooperation has been a defining feature of civil space programs throughout the space age. Scientific satellites, in particular, have been cooperative ventures. International cooperation remains a key feature of both civil and global utilities space programs. In particular, cooperation enhances the transparency of certain civil programs that could potentially have military purposes.

The most prominent example of international cooperation continues to be the International Space Station (ISS), a collaborative project of NASA, the Russian space agency (Roscosmos), the European Space Agency (ESA), the Japan Aerospace Exploration Agency (JAXA), and the Canadian Space Agency (CSA). A multinational effort with a focus on scientific research and an estimated cost of over $100-billion to date, the ISS is the largest, most expensive international engineering project ever undertaken.

By allowing states to pool resources and expertise, international civil space cooperation has played a key role in the proliferation of the technical capabilities needed by states to access space. Cooperation agreements on space activities have proven to be especially helpful for emerging spacefaring states that currently lack the technological means for independent space access.

Cooperation agreements also enable established spacefaring countries to tackle high-cost, complex missions as collaborative endeavors with international partners. The high costs and remarkable technical challenges associated with human spaceflight are likely to make collaborative efforts in this area increasingly common.

2014 Developments

- Geopolitical tension between the United States and Russia adversely affects cooperative agreements
- NASA signs cooperative agreements with Japan, France, and India
- ESA cooperation with Russia continues, reaches agreement with China on manned spaceflight
- Russia, China seek new cooperative agreements
- International cooperation in the development of commercial space transportation

INDICATOR 2.4: Growth in commercial space industry — The role that the commercial space sector plays in the provision of launch, communications, imagery, and manufacturing services, as well as its relationship with civil and military programs, make this sector an important determinant of space security. A healthy space industry can lead to decreasing costs for space access and use, and may increase the accessibility of space technology for a wider range of space actors. Increased commercial competition in the research and development of new applications can also lead to the further diversification of capabilities to access and use space.

The global commercial satellite industry is comprised of satellite service providers, satellite manufacturers, the launch industry, and providers of ground equipment. Revenues from the global satellite industry nearly tripled from 2004 to 2013 to approach an annual revenue of $200-billion. While the annual growth rate over that period was 11% on average, growth of the global satellite industry has slowed since 2010. Services provided directly to consumers—in particular satellite TV—are driving overall growth of the industry.

2014 Developments

- Commercial launch revenues increase
- U.S. Export-Import Bank supports satellite industry
- National satellites provide low-cost services for Latin American nations
- Commercial entities provide satellite services for the developing world
- The association between commercial satellites and specific states becomes less clear
- U.S. Federal Aviation Administration releases report on commercial human spaceflight safety
- Suborbital spaceplane designed for space tourism crashes in test flight
- Various commercial spaceports are under consideration

INDICATOR 2.5: Public-private collaboration on space activities — The commercial space sector is significantly shaped by the particular security concerns of national governments. There is an increasingly close relationship between governments and the commercial space sector. Various national space policies place great emphasis on maintaining a robust and competitive industrial base and encourage partnerships with the private sector. The space launch and manufacturing sectors rely heavily on government contracts. The retirement of the space shuttle in the United States, for instance, opened up new opportunities for the commercial sector to develop launch services for human spaceflight.

Governments function as partners and regulators, while national militaries are increasingly reliant on commercial services. Governments play a central role in commercial space activities by supporting research and development, subsidizing certain space industries, and adopting enabling policies and regulations. Conversely, because space technology is often dual-use, governments have sometimes taken

actions, such as the imposition of export controls, which hinder the growth of the commercial market.

There is evidence of increased dialogue between commercial actors and governments on such issues as space traffic management and SSA. National export regulations can be influenced by the growing number of international partnerships formed by the commercial sector.

There are challenges with public-private collaboration on space activities. The growing dependence of certain segments of the commercial space industry on military clients could have an adverse impact on space security by making commercial space assets the potential target of military attacks.

2014 Developments

- NASA maintains partnerships with the commercial space industry for essential capabilities
- NASA seeks commercial uses for ISS
- Ongoing debate over the cost and performance of Military Satellite Communications (SATCOM)
- Slowdown in U.S. acquisition of military space systems expected
- U.S. military continues to explore viability of commercially hosted payloads and other services
- High-resolution commercial satellite imagery presents new opportunities
- ESA agrees to develop Ariane 6 launch vehicle
- UK invests 200-million pounds in space industry
- Russia's deputy prime minister recommends developing Public-Private Partnership for space exploration
- Japanese government funds development of new launch vehicle

INDICATOR 2.6: Space-based military systems — The United States has dominated the military space arena since the end of the Cold War and continues to give priority to its military and intelligence programs. Building upon the capabilities of its GPS, the United States began to expand the role of military space systems. They are now integrated into virtually all aspects of military operations, providing indirect strategic support to military forces and enabling the application of military force in near-real-time tactical operations through precision weapons guidance.

Russia maintains the second largest fleet of military satellites. Its early warning, imaging intelligence, communications, and navigation systems were developed during the Cold War. The Chinese government's space program does not maintain a strong separation between civil and military applications. Officially, its space program is dedicated to science and exploration, but like the programs of many other actors, it is widely believed to provide support to the military.

India's National Satellite System is one of the most extensive domestic satellite communications networks in Asia. To enhance its use of GPS, India has been developing GAGAN, a satellite-based augmentation system. This will be followed

by the Indian Regional Navigation Satellite System (IRNSS), which is to provide an independent satellite navigation capability. Although these are civilian-developed and -controlled technologies, they are used by the Indian military for its applications.

States such as Australia, Canada, France, Germany, Israel, Italy, Japan, and Spain have recently been developing multiuse satellites with a wider range of functions. As security becomes a key driver of these space programs, expenditures on multiuse space applications go up. In the absence of dedicated military satellites, many actors use their civilian satellites for military purposes or purchase data and services from civilian satellite operators.

2014 Developments

- Major spacefaring nations continue to update space-based military capabilities
- Cooperation in space-based military activities increases

Theme 3: Security of space systems

INDICATOR 3.1: Vulnerability of satellite communications, broadcast links, and ground stations — Satellite ground stations and communications links constitute likely targets for space negation efforts, since they are vulnerable to a range of widely available conventional and electronic weapons. While military satellite ground stations and communications links are generally well protected, civil and commercial assets tend to have fewer protective features. Many commercial space systems have only one operations center and one ground station, making them particularly vulnerable to negation efforts.

The vulnerability of satellite communications, broadcast links, and ground stations raises security concerns since a number of military space actors are becoming increasingly dependent on space assets for a variety of applications. Satellite communications links require specific electronic protective measures to safeguard their utility. Although unclassified information on these capabilities is difficult to obtain, it can be assumed that most space actors are able to take advantage of simple but reasonably robust electronic protective measures. While many actors employ passive electronic protection capabilities, such as shielding and directional antennas, more advanced measures, such as burst transmissions, are generally confined to military systems and the capabilities of more technically advanced states.

Because the vast majority of space assets depend on cyber networks, the link between cyberspace and outer space constitutes a critical vulnerability.

2014 Developments

- Vulnerability to cyberattacks remains
- Military systems continue to employ protective measures to counter jamming
- UAE claims U.S.-supplied components on intelligence satellites are intended to intercept data

INDICATOR 3.2: Capacity to rebuild space systems and integrate smaller satellites into space operations — The ability to rapidly rebuild space systems after an attack could reduce vulnerabilities in space. The capabilities to refit space systems by launching new satellites into orbit in a timely manner to replace satellites damaged or destroyed by an attack are critical resilience measures. Multiple programs show the prioritization of, and progress in, new technologies that can be integrated quickly into space operations. Smaller, less expensive spacecraft that may be fractionated or distributed on hosts can improve continuity of capability and enhance security through redundancy and rapid replacement of assets. While these characteristics may make attack against space assets less attractive, they can also make assets more difficult to track, and so inhibit transparency. Although the United States and Russia are developing elements of responsive space systems, no state has perfected this capability.

Work continues in the U.S. Department of Defense Operationally Responsive Space (ORS) Office to develop the ability to address emerging, persistent, and/or unanticipated needs through timely augmentation; reconstitution; and exploitation of space force enhancement, space control, and space support capabilities.

2014 Developments

- Development of satellite servicing capability continues
- U.S. Air Force faces opposition to disaggregation efforts
- Commercial microsatellite constellations see first on-orbit operations
- Continued development of various responsive launch capabilities
- Alternative capabilities for GPS sought

INDICATOR 3.3: Earth-based capabilities to attack satellites — Launching a payload to coincide with the passage of a satellite in orbit is the fundamental requirement for anti-satellite (ASAT) capability. Ground-based anti-satellite weapons employing conventional, nuclear, and directed energy capabilities date back to the Cold War, but no hostile use of them has been recorded. Conventional ASAT weapons include precision-guided kinetic-intercept vehicles, conventional explosives, and specialized systems designed to spread lethal clouds of metal pellets in the orbital path of a targeted satellite.

A space launch vehicle with a nuclear weapon would be capable of producing a High Altitude Nuclear Detonation (HAND), causing widespread and immediate

electronic damage to satellites, combined with the long-term effects of pumped radiation belts, which would have an adverse impact on many satellites. Detonation of a nuclear weapon in space would violate the Outer Space and Comprehensive Test Ban Treaties. The application of some destructive space negation capabilities, such as kinetic-intercept vehicles, would also generate space debris that could potentially inflict widespread damage on other space systems and undermine the sustainability of outer space.

Security concerns about the development of negation capabilities are compounded by the fact that many key space capabilities are dual-use. For example, space launchers are required for many anti-satellite systems; microsatellites offer great advantages as space-based kinetic-intercept vehicles; and SSA capabilities can support both space debris collision avoidance strategies and targeting for weapons.

The United States, China, and Russia lead in the development of more advanced ground-based kinetic-kill systems that are able to directly attack satellites. Incidents involving the use of kinetic interceptors against their own satellites (China in 2007 and the United States in 2008) underscore the detrimental effect that such systems have for space security. Such use not only aggravates the space debris problem, but contributes to a climate of mistrust among spacefaring nations.

2014 Developments

- Further development and testing of missile defense systems
- Further development of laser technology

INDICATOR 3.4: Space-based negation enabling capabilities — Deploying space-based ASATs—using kinetic-kill, directed energy, or conventional explosive techniques—would require enabling technologies somewhat more advanced than the fundamental requirements for orbital launch. Space-based negation efforts require sophisticated capabilities, such as precision on-orbit maneuverability and space tracking.

While microsatellites, maneuverability, and other autonomous proximity operations are essential building blocks for a space-based negation system, they have dual-use potential and are also advantageous for a variety of civil, commercial, and non-negation military programs. For example, microsatellites provide an inexpensive option for many space applications, but could be modified to serve as kinetic-kill vehicles or offer targeting assistance for other kinetic-kill vehicles. Space-based weapons targeting satellites with conventional explosives could potentially employ microsatellites to maneuver near a satellite and explode within close range. Microsatellites are relatively inexpensive to develop and launch and have a long lifespan; their intended purpose is difficult to determine until detonation.

On-orbit servicing is also a key research priority for several civil space programs and supporting commercial companies. While some nations have developed these technologies, there is no evidence that they have integrated on-orbit servicing into a dedicated space-based negation system.

2014 Developments

- United States and Russia launch satellites capable of Rendezvous and Proximity Operations (RPO)
- Active debris removal programs involve dual-use capabilities

Theme 4: Outer space governance

INDICATOR 4.1: National space policies — The development of national space policies that delineate the principles and objectives of space actors with respect to access to and use of space has been conducive to greater transparency and predictability of space activities. National civil, commercial, and military space actors all operate according to these policies. Most spacefaring states explicitly support the principles of peaceful and equitable use of space, and emphasize space activities that promote national socioeconomic, scientific, and technological goals. Virtually all space actors underscore the importance of international cooperation in their space policies; several developing nations have been able to access space because of such cooperation.

However, the military doctrines of a growing number of states emphasize the use of space systems to support national security. Major space powers and emerging spacefaring nations increasingly view space assets such as multiuse space systems as integral elements of their national security infrastructure.

As well, more states have come to view their national space industries as fundamental drivers and components of their space policies. A number of nations, including the United Kingdom, Germany, Australia, and the United States, have made innovation and development of industrial space sectors a key priority of their national space strategies.

2014 Developments

- Canada announces new Space Policy Framework
- Japan issues 10-year Basic Plan on Space Policy
- United Kingdom announces first National Space Security Policy
- U.S. National Defense Authorization Act increases emphasis on offensive space control
- The United States explores commercial rights to space resources

INDICATOR 4.2: Multilateral forums for space governance — A number of international institutions provide multilateral forums to address space security issues. Within the United Nations, these include the UNGA First and Fourth Committees, UN Space, the UN Committee on the Peaceful Uses of Outer Space (COPUOS), the International Telecommunication Union, the Conference on Disarmament (CD), and the International Committee on Global Navigation Satellite Systems (ICG). Outside the UN, there is also an important European-led initiative to develop an International Code of Conduct for Outer Space.

UN General Assembly

Every year the UN General Assembly examines outer space issues, primarily through the work of the first and fourth committees. Recurring resolutions include the Prevention of an Arms Race in Outer Space (PAROS), Transparency and Confidence-building Measures in Outer Space Activities, and International Cooperation in the Peaceful Uses of Outer Space.

The influential 2013 report of a Group of Governmental Experts on Transparency and Confidence-building Measures (TCBMs) in Outer Space Activities concluded that the world's growing reliance on space-based technologies meant that collaborative efforts in the form of TCBMs were needed to enhance the sustainability and security of outer space activities. There is broad international consensus on the value and importance of increased confidence and mutual trust between space actors in encouraging security, safety, and sustainability in space.

UN Space

The UN Inter-Agency Committee on Outer Space meets annually to coordinate future space-related plans and programs among UN agencies.

UN COPUOS

Reporting to the UN General Assembly through the fourth committee, COPUOS (established in 1958) reviews the scope of international cooperation in the peaceful uses of outer space, develops relevant UN programs, encourages research and information exchanges on outer space matters, and studies legal problems arising from the exploration of outer space. Supported by secretariat services provided by the United Nations Office for Outer Space Affairs (UNOOSA), COPUOS and its two standing subcommittees—the Scientific and Technical Subcommittee (STSC) and the Legal Subcommittee (LSC)—meet annually to develop recommendations based on questions and issues put before them by UNGA and Member States.

An ongoing priority initiative within COPUOS since 2010 falls under the Working Group on the Long-Term Sustainability of Outer Space Activities. This working group has the objective to examine and propose practical measures to ensure the

safe and sustainable use of outer space for peaceful purposes, for the benefit of all countries. It will deliver a report of the working group and a set of voluntary guidelines to promote the long-term sustainability of outer space activities.

ITU

The ITU coordinates the shared global use of the radio spectrum, promotes international cooperation in assigning satellite orbits, works to improve telecommunication infrastructure in the developing world, and assists in the development and coordination of worldwide technical standards.

CD

The Conference on Disarmament is the multilateral forum established by the United Nations to negotiate multilateral arms control and disarmament agreements. While at the end of 2013 the adoption of a Program of Work remained an elusive pursuit for the Conference on Disarmament, overwhelming support for the resolution on the Prevention of an Arms Race in Outer Space at UNGA indicates broad international consensus in support of consolidating and reinforcing the normative regime for space governance to enhance its effectiveness.

2014 Developments

- UNGA passes resolution on No First Placement of Weapons in Outer Space
- UNGA calls for unprecedented meeting of First and Fourth Committees in 2015 to address possible challenges to space security and sustainability
- In COPUOS, member States continue discussions and extend the work plan to complete the draft Guidelines for Long Term Sustainability of Outer Space for referral to the UNGA in 2016.
- Latest draft International Code of Conduct for Outer Space Activities released
- Russia and China submit updated draft Treaty on Prevention of Placement of Weapons in Outer Space to the CD
- New international networks formally established
- UN-Space discusses post-2015 Development Agenda

INDICATOR 4.3: Other initiatives — Historically, primary governance challenges related to outer space activities have been discussed at multilateral bodies related to, or under the auspices of, the United Nations, such as COPUOS, the UNGA First Committee, or the CD. However, diplomatic efforts outside these forums have been undertaken.

A growing number of diplomatic initiatives relate to bilateral or regional collaborations in space activities. Examples of this include the work of the Asia-Pacific Regional Space Agency Forum and discussions within the African Union to develop an African space agency. The UN Institute for Disarmament Research

(UNIDIR)—an autonomous institute within the UN system—has also played a key role to facilitate dialogue among key space stakeholders. Every year UNIDIR partners with civil society actors and some governments to bring together space security experts and government representatives at a conference on emerging security threats to outer space.

2014 Developments

- UNIDIR Space Security Conference held 19-20 March with the theme "The Evolving Space Security Regime: Implementation, Compliance, and New Initiatives"
- ESA Council at Ministerial Level emphasizes independent European access to space
- International Space Exploration Forum welcomes developing nations

2015

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