SPACE SECURITY INDEX 2014

www.spacesecurityindex.org

Featuring a global assessment of space security by James Clay Moltz

SPACE SECURITY INDEX

2014

SPACESECURITYINDEX.ORG

Library and Archives Canada Cataloguing in Publications Data
Space Security Index 2014

ISBN: 978-1-927802-07-6

Edited by Cesar Jaramillo

Design and layout by Creative Services, University of Waterloo, Waterloo, Ontario, Canada

Cover image: In this 25 April 1990 photograph taken with a handheld Hasselblad camera, most of the giant Hubble Space Telescope can be seen as it is suspended in space by Discovery's Remote Manipulator System (RMS) following the deployment of part of its solar panels and antennae. This was among the first photos NASA released on 30 April from the five-day STS-31 mission.

Printed in Canada

Printer: Pandora Print Shop, Kitchener, Ontario

First published October 2014

Please direct enquiries to:
Cesar Jaramillo
Project Ploughshares
140 Westmount Rd. N.
Waterloo, Ontario N2L 3G6
Canada
Telephone: 519-888-6541, ext. 24308
Fax: 519-888-0018
Email: cjaramillo@ploughshares.ca

Governance Group

Peter Hays
Eisenhower Center for Space and Defense Studies

Ram Jakhu
Institute of Air and Space Law, McGill University

Paul Meyer
The Simons Foundation

John Siebert
Project Ploughshares

Isabelle Sourbès-Verger
Centre National de la Recherche Scientifique

Project Manager

Cesar Jaramillo
Project Ploughshares

TABLE OF CONTENTS

ACRONYMS AND ABBREVIATIONS

ABM	Anti-Ballistic Missile
ADR	Active Debris Removal
ADS-B	Automatic Dependent Surveillance-Broadcast
AEHF	Advanced Extremely High Frequency system (U.S.)
AIDA	Asteroid Impact and Deflection Assessment
ALTB	Airborne Laser Test Bed
AMAZE	Additive Manufacturing Aiming Towards Zero Waste and Efficient Production of High-Tech Metal Products
ASAT	Anti-Satellite Weapon
ASBU	Arab States Broadcasting Union
ASI	Agenzia Spaziale Italiana
ASNARO	Advanced Satellite with New System Architecture for Observation (Japan)
ATLAS	Asteroid Terrestrial-Impact Last Alert System
BEAM	Bigelow Expandable Activity Module
BLITS	Ball Lens In The Space
CALT	China Academy of Launch Vehicle Technology
CD	Conference on Disarmament
CFE	Commercial and Foreign Entities program (U.S.)
CHEOS	China High-resolution Earth Observation System
CNES	Centre national d'études spatiales (France)
CNSA	China National Space Administration
COPUOS	Committee on the Peaceful Uses of Outer Space (UN)
COTS	Commercial Orbital Transportation Services (U.S.)
CSA	Canadian Space Agency
DAPA	Defense Acquisition Program Administration (South Korea)
DARPA	Defense Advanced Research Projects Agency (U.S.)
DLR	German Aerospace Center
DoD	Department of Defense (U.S.)
EDRS	European Data Relay System
EELV	Evolved Expendable Launch Vehicle (U.S.)
EKV	Exoatmospheric Kill Vehicle
EMP	Electromagnetic pulse (or HEMP for High Altitude EMP)
EO	Earth Observation
ESA	European Space Agency
EU	European Union
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
EXA	Ecuadorian Civilian Space Agency
FAA	Federal Aviation Administration (U.S.)
FCC	Federal Communications Commission (U.S.)
FMCT	Fissile Material Cut-off Treaty
GEO	Geostationary/geosynchronous Earth Orbit
GEOSS	Global Earth Observation System of Systems
GLONASS	Global Navigation Satellite System (Russia)
GMES	Global Monitoring for Environment and Security (Europe)

GNSS	Global Navigation Satellite System
GOCE	Gravity field and steady-state Ocean Circulation Explorer
GPS	Global Positioning System (U.S.)
GPS OCX	GPS Next Generation Operational Control System
GSAP	Geosynchronous Space Situational Awareness Program (U.S.)
GTO	Geosynchronous Transfer Orbit
HAND	High Altitude Nuclear Detonation
HEO	Highly Elliptical Orbit
IADC	Inter-Agency Space Debris Coordination Committee
IAWN	International Asteroid Warning Network
ICBM	Intercontinental Ballistic Missile
ICG	International Committee on GNSS (UN)
ICoC	International Code of Conduct
IDIQ	Indefinite-delivery, indefinite-quantity
Inmarsat	International Maritime Satellite Organisation
Intelsat	International Telecommunications Satellite Organization
IRNSS	Indian Regional Navigation Satellite System
ISECG	International Space Exploration Coordination Group
ISRO	Indian Space Research Organisation
ISS	International Space Station
ITAR	International Traffic in Arms Regulations (U.S.)
ITU	International Telecommunication Union
JAXA	Japan Aerospace Exploration Agency
KARI	Korea Aerospace Research Institute
LADEE	Lunar Atmospheric and Dust Environment Explorer
LEO	Low Earth Orbit
LLCD	Lunar Laser Communication Demonstration
LTSSA	Long-term Sustainability of Outer Space Activities
MEO	Medium Earth Orbit
MiDSTEP	Microsatellite Demonstration Science and Technology Experiment Program (U.S.)
MIRACL	Mid-Infrared Advanced Chemical Laser (U.S.)
MiTEx	Micro-satellite Technology Experiment (U.S.)
MUOS	Mobile User Objective System (U.S.)
NASA	National Aeronautics and Space Administration (U.S.)
NEA	Near-Earth Asteroid
NEC	Near-Earth Comet
NEO	Near-Earth Object
NEOCam	NEO Camera (U.S.)
NEOSSat	NEO Surveillance Satelllite (Canada)
NFIRE	Near-Field Infrared Experiment (U.S.)
NOAA	National Oceanic and Atmospheric Administration (U.S.)
NPO	Science and Production Association (Russia)
NRL	Naval Research Laboratory (U.S.)
NRO	National Reconnaissance Office (U.S.)

ORS	Operationally Responsive Space (U.S.)
OSIRIS-Rex	Origins Spectral Interpretation Resource Identification and Security-Regolith Explorer (U.S.)
OST	Outer Space Treaty
PAROS	Prevention of an Arms Race in Outer Space
PHA	Potentially Hazardous Asteroid
PHO	Potentially Hazardous Object
POD	Payload Orbital Delivery system
PPWT	Treaty on the Prevention of the Placement of Weapons in Outer Space, and of the Threat or Use of Force against Outer Space Objects
QZSS	Quazi-Zenith Satellite System (Japan)
RF	Radio Frequency
RFI	Radio Frequency Interference
Roscosmos	Russian Federal Space Agency
RRM	Robotic Refueling Mission (U.S.)
SAR	Synthetic-aperture radar
SATCOM	Satellite communications
SDA	Space Data Association
SLV	Small Launch Vehicle
SMPAG	Space Missions Planning Advisory Group
SNAP	Secure Internet Protocol Router and Non-Secure Internet Protocol Router Access Point
SPDM	Special Purpose Dexterous Manipulator
SSA	Space Situational Awareness
SSN	Space Surveillance Network (U.S.)
SST	Space surveillance and tracking (ESA)
Stratcom	Strategic Command (U.S.)
TESS	Transiting Exoplanet Survey Satellite (U.S.)
UNGA	United Nations General Assembly
UNIDIR	United Nations Institute for Disarmament Research
UNOOSA	United Nations Office for Outer Space Affairs
UN-SPIDER	United Nations Platform for Space-based Information for Disaster Management and Emergency Response
USAF	United States Air Force
USCYBERCOM	United States Cyber Command
USML	United States Munitions List
USSTRATCOM	United States Strategic Command
VSAT	Very Small Aperture Terminal Survey Satellite
WBU-ISOG	World Broadcasting Unions International Satellite Operations Group
WGS	Wideband Global SATCOM
XDR	Extended Data Rate
XSS	Experimental Spacecraft System (U.S.)

INTRODUCTION

Space Security Index 2014 is the eleventh annual report on developments related to safety, sustainability, and security in outer space, covering the period January-December 2013. 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 search-and-rescue operations to weather forecasting, from banking to arms control treaty verification, the world has become increasingly reliant on space applications. The primary goals of the SSI are to improve transparency on space activities and to provide a common, comprehensive knowledge base to support the development of national and international policies that contribute to the security and sustainability of outer space.

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. 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.

The structure of the 2014 report is as follows:

» **Theme 1: Condition and knowledge of the space environment**
Indicator 1.1: *Orbital debris*
Indicator 1.2: *Radio frequency (RF) spectrum and orbital positions*
Indicator 1.3: *Near-Earth Objects (NEOs)*
Indicator 1.4: *Space Situational Awareness*

» **Theme 2: Access to and use of space by various actors**
Indicator 2.1: *Space-based global utilities*
Indicator 2.2: *Priorities and funding levels in civil space programs*
Indicator 2.3: *International cooperation in space activities*
Indicator 2.4: *Growth in commercial space industry*
Indicator 2.5: *Public-private collaboration on space activities*
Indicator 2.6: *Space-based military systems*

» **Theme 3: Security of space systems**

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 more than 20,000 pieces of debris 10 centimeters (cm) in diameter or larger. Experts estimate that there are over 300,000 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 significant 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.

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

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, communications, 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 role that the commercial space sector plays in the provision of launch, communications, imagery, and manufacturing services and its relationship with government, 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.

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 space system 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. Further, under some conditions protective measures can motivate adversaries to develop weapons to overcome them.

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.

While military satellite ground stations and communications links are generally well protected, civil and commercial assets tend to have fewer protective features. The vulnerability of civil and commercial space systems raises security concerns, since a number of military space actors are becoming increasingly dependent on commercial space assets for a variety of applications.

No hostile 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. Satellite resiliency measures include system redundancy, distributed architectures, and interoperability, which have become characteristics of, for example, some satellite navigation systems.

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 attack against space assets less attractive, they can also make assets more difficult to track and could potentially hinder transparency in space activities.

The SSI recognizes that the existing normative framework for outer space activities is insufficient to address the current challenges facing the outer space domain.

International instruments that regulate space activities have a direct effect on space security because they establish key parameters for acceptable behavior in space. These include the right of all countries to access space, prohibitions against the national appropriation of space, 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, 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 the current 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 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, and of the Threat or Use of Force against Outer Space Objects (known as the PPWT), and politically binding norms, such as the proposed International Code of Conduct for Outer Space Activities. The latest revised versions of each of these proposals were made public during 2014 and are included as annexes to this report.

As in the 2013 edition, *Space Security Index 2014* 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 inaugural essay was written by Claire Jolly, senior policy analyst at the Organisation for Economic Co-operation and Development (OECD). The author of the current assessment is James Clay Moltz, professor at the Naval Postgraduate School in Monterey, California.

The information in *Space Security Index 2014* is from open sources. Great effort is made to ensure a complete and factually accurate description of events, based on a critical appraisal of the available information and consultation with international experts. 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 through various processes. For example, the Space Security Working Group in-person consultation 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**, where the publication is also available free of any charge in PDF format. Comments and suggestions are welcome.

ACKNOWLEDGEMENTS

The research process for *Space Security Index 2014* was directed by Cesar Jaramillo at Project Ploughshares. Dr. Ram Jakhu and Dr. Peter Hays provided on-site supervision at, respectively, the Institute of Air and Space Law at McGill University and the Space Policy Institute at The George Washington University. The research team included:

Tom Chinick, Space Policy Institute, George Washington University
Jason Chung, Institute of Air and Space Law, McGill University
Andrea DiPaolo, Institute of Air and Space Law, McGill University
Antonina Gromyko, Space Policy Institute, George Washington University
Kinga Kolasa-Sokolowska, Institute of Air and Space Law, McGill University
Aleksandra Puscinska, Institute of Air and Space Law, McGill University
Joel Slotten, Space Policy Institute, George Washington University
Jordan Sotudeh, Space Policy Institute, George Washington University

The Governance Group for the Space Security Index would like to thank the research team and the many advisors and experts who have supported this project. Cesar Jaramillo has been responsible for overseeing the research process and logistics for the 2013-2014 project cycle. He provides the day-to-day guidance and coordination of the project and ensures that the myriad details of the publication come together. Cesar also supports the Governance Group and we want to thank him for the contribution he has made in managing the publication of this volume.

Thanks to Wendy Stocker at Project Ploughshares for copyediting, to Creative Services at the University of Waterloo for design work, and to Pandora Print Shop of Kitchener, Ontario for printing and binding. For comments on the draft research we are in debt to the experts who provided feedback on each of the report's sections during the online consultation process, and to the participants in the Space Security Working Group. For hosting the Space Security Working Group meeting held on 28 May 2014 in Montreal, we are grateful to the Institute of Air and Space Law at McGill University.

This project would not be possible without the generous financial and in-kind support from:

- The Simons Foundation
- Project Ploughshares
- Erin J.C. Arsenault Trust Fund
- Institute of Air and Space Law at McGill University
- Space Policy Institute at George Washington University.

While the Governance Group for the Space Security Index has benefited immeasurably from the input of the many experts indicated, it assumes responsibility for any errors or omissions in this volume.

Theme 1: Condition and knowledge 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 over 300,000 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 Russian Cosmos defunct 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 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.

2013 Developments

Space object population

- Cataloged debris population remains virtually unchanged; number of active objects in orbit continues to grow
- U.S. Space Surveillance Network continues to update satellite catalog

Debris-related risks and incidents

- Orbital debris continues to threaten safe space operations of both satellites and the International Space Station
- The risk posed by debris and satellite reentries remained in 2013

International awareness of debris problem increases as progress made toward solutions

- Compliance with international debris mitigation guidelines has improved in recent years, particularly at Geostationary Earth Orbit (GEO)
- International dialogues on debris problem, active debris removal, and other solutions continue in 2013
- Research and development on active debris removal continue in 2013

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 require 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. Satellite builders and operators are coping by developing new technologies and procedures to manage greater frequency usage. 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 slot assignments, 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 slot allocation backlogs and other related challenges.

2013 Developments

- Pressure on the radio frequency (RF) spectrum continues to grow
- Growing demand for and crowding of terrestrial RF spectrum with potential impacts on space RF spectrum
- Increased efforts to reduce unintentional radio frequency interference

INDICATOR 1.3: Near-Earth Objects — Near-Earth Objects (NEOs) are asteroids and comets in orbits that bring them into close proximity to the Earth. NEOs are subdivided into Near-Earth Asteroids (NEAs) and Near-Earth Comets (NECs). 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 2013 there were 10,482 known NEAs, 858 of which were one km in diameter or larger.

Over the past decade a growing amount of research has identified objects that pose threats to Earth and developed potential mitigation and deflection strategies. The effectiveness of deflection—a difficult process because of the extreme mass, velocity, and distance of any potentially impacting NEO—depends on the amount of warning time. Kinetic deflection methods include ramming the NEO with a series of kinetic projectiles. The 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. 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.

2013 Developments

- International awareness of NEO threat and progress in international response continues
- Space agencies, amateur observers produce increasingly accurate assessment of NEO population
- Russian officials contemplate space-based solutions to asteroids

INDICATOR 1.4: Space Situational Awareness — Space Situational Awareness 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 Space Surveillance Network (SSN) puts the United States far in advance of the rest of the world in space situational awareness capability. 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 EU, Canada, France, Germany, and Japan are all developing space surveillance capabilities for various purposes, although none of these states is close to developing a global system on its own.

Sharing SSA data could benefit all space actors, allowing them to supplement their own data 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—the ability to accurately predict high-speed collisions between two orbiting objects—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 over international SSA data sharing.

2013 Developments

Capabilities

- U.S. efforts to build the new-generation S-Band Space Fence continue
- Canada's Sapphire satellite becomes newest element of Space Surveillance Network
- Phase II of ESA SSA program begins

SSA sharing

- The United States signs data-sharing agreements with Australia, Canada, and France

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

INDICATOR 2.1: Space-based global capabilities — 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, communications, 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 space applications that are almost indispensable to the civil and commercial sectors and spawned such equally indispensable applications as weather monitoring and remote sensing. 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 (EO) 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. Similarly, in 2006 the UN General Assembly (UNGA) agreed to establish the UN Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER).

Although satellite-based systems can increase the accuracy and reliability of navigation, their simultaneous operation presents significant coordination challenges.

2013 Developments

Navigation systems

- Navigation systems of various nations continue to evolve
- Remote sensing capabilities continue to advance
- Azerbaijan launches its first telecommunications satellite

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. Likewise, 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 are to replace some of the aging Molniya-M launch vehicles currently in service.

2013 Developments

- Changing budgetary allotments in civil space programs

- China launches second manned mission to Tiangong-1 space station
- India launches Mars mission

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, 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. In 2007 the 14 largest space agencies agreed to coordinate future space missions in the document *The Global Exploration Strategy: The Framework for Coordination*, which highlights a shared vision of space exploration, focused on the Moon and Mars. It calls for a voluntary forum to assist coordination and collaboration for sustainable space exploration, although it does not establish a global space program.

2013 Developments

- NASA and ESA agree to cooperate on a lunar flyby and the 'Dark Universe' mission
- ESA and Roscosmos partner on two missions to Mars
- UK signs space cooperation agreement with Kazakhstan
- Ecuador launches two nanosatellites

INDICATOR 2.4: Growth in commercial space industry — The commercial space sector has experienced dramatic growth over the past decade. Companies that own and operate satellites and the ground support centers that control them are experiencing rapidly increasing revenues. Companies that manufacture satellites and ground equipment have also seen significant growth. Such companies include both direct contractors that design and build large systems and vehicles, smaller subcontractors responsible for system components, and software providers. More individual consumers are demanding these services, particularly satellite television and personal GPS devices. From satellite manufacturing and launch services to advanced navigation products and the provision of satellite-based communications, the global commercial space industry is thriving, with estimated annual revenues in excess of $200-billion.

In addition to orders for satellite fleet replenishment, manufacturers and launch providers are looking to the robust demand for new space-based services to spur new satellite orders.

The role that the commercial space sector plays in the provision of launch, communications, imagery, and manufacturing services, as well as its relationship with government, 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.

2013 Developments

Growth in satellite market

- Satellite market continues to expand
- Orbital Sciences, SpaceX conduct cargo missions to ISS
- Astrium successfully launches Ariane 5
- Swiss Space Systems develops suborbital small satellite deployment system
- Sierra Nevada Corporation makes progress with Dream Chaser Shuttle

Space tourism

- Virgin Galactic continues testing of SpaceShipTwo
- Blue Origin tests oxygen and hydrogen engine
- XCOR continues development and testing of engines for Lynx vehicle
- Golden Spike continues planning for lunar missions

Commercial spaceports

- Various commercial spaceports under development

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, will likely open up new opportunities for the commercial sector to provide 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 space situational awareness. National export regulations could gradually 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.

2013 Developments

- NASA establishes Space Technology Mission Directorate
- NASA awards indefinite delivery, indefinite quantity (IDIQ) contracts

- Russia increases efforts to increase share of space market
- European Space Agency engages in various partnership agreements
- Beidou system opened for civilian use

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 as with the programs of many other actors, it is widely believed to provide support to the military.

The Indian National Satellite System is one of the most extensive domestic satellite communications networks in Asia. To enhance its use of GPS, the country has been developing GAGAN, the Indian 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.

2013 Developments

- Various spacefaring nations continue development of space-based military capabilities

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 civil and commercial space systems raises security concerns, since a number of military space actors are becoming increasingly dependent on commercial 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. Sophisticated electronic protective measures were traditionally unique to the military communications systems of technologically advanced states, but they are slowly being expanded to commercial satellites.

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. Satellite communications links require specific electronic protective measures to safeguard their utility.

2013 Developments

- DoD continues developing the Advanced Extremely High Frequency (AEHF) satellite system, while the Netherlands and Canada become the first international partners for testing it
- Lockheed Martin completes on-orbit check of MUOS-2, improving secure communications for U.S. Navy

2013 Developments

- U.S. Air Force delays decision to deploy disaggregated satellite missions

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.

A key U.S. responsive launch initiative is the Falcon program developed by Space Exploration Technologies (SpaceX), which consists of launch vehicles capable of rapidly placing payloads into LEO and GEO. Organized under NASA's Commercial Orbital Transportation Services (COTS) program, the Falcon 9 uses less expensive components and systems than traditional rockets, including nine kerosene/liquid-oxygen-burning Merlin engines. Similarly, the development of fractionated architectures is meant to provide system redundancy and increase assurance of continued operation of critical space infrastructures.

2013 Developments

Satellite servicing

- NASA Robotic Refueling Mission and CSA "Dextre" successfully complete satellite refueling tests and begin implementing Phase 2

Distributed architectures

- NovaWurks awarded contract for DARPA Phoenix project
- Development of small satellites and microsatellite systems contributes to redundancy and resiliency of space systems
- DARPA cancels formation-flying satellite demo

INDICATOR 3.3: Earth-based capabilities to attack satellites — Some spacefaring nations possess the means to inflict intentional damage on an adversary's space assets. 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 anti-satellite 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 false radiation belts, which would have an adverse impact on many satellites. 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 space surveillance 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. Recent incidents involving the use of ASATs 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.

2013 Developments

- Missile development continues in some nations
- Russia considers potential space-based countermeasures to U.S. missile defense shield
- Jamming incidents continue

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.

2013 Developments

- Research and development of debris removal, satellite servicing capabilities
- China's unusual satellite maneuvering raises international concern

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.

Bilateral cooperation agreements on space activities are increasingly common among spacefaring actors. 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.

2013 Developments

- Australia releases its new Satellite Utilisation Policy
- Japan adopts Basic Plan on Space Policy
- United States eases export rules on less sensitive items from U.S. Munitions List
- Various countries announce goals for next stages of space exploration
- Russia, Ukraine announce plans to accelerate growth in space industry
- Chinese Vice-President calls for peaceful exploration and use of space; the United States clarifies NASA ban on Chinese scientists

INDICATOR 4.2: Multilateral forums for space governance — International institutions including the First Committee of UNGA, the UN Committee on the Peaceful Uses of Outer Space, the International Telecommunication Union, and the Conference on Disarmament (CD) constitute the key multilateral forums in which issues related to space security are addressed.

The UN General Assembly created COPUOS in 1958 to review the scope of international cooperation in the peaceful uses of outer space, develop relevant UN programs, encourage research and information exchanges on outer space matters, and study legal problems arising from the exploration of outer space. COPUOS and its two standing committees—the Scientific and Technical Subcommittee and the Legal Subcommittee—develop recommendations based on questions and issues put before them by UNGA and Member States.

In 2010 the Scientific and Technical Subcommittee established the Working Group on the Long-Term Sustainability of Outer Space Activities. The Working Group is to examine and propose measures to ensure the safe and sustainable use of outer space for peaceful purposes, for the benefit of all countries. It will prepare a report on the long-term sustainability of outer space activities that includes a consolidated set of current practices and operating procedures, technical standards, and policies associated with the safe conduct of space activities.

In 2011 the UN Secretary-General established, on the basis of equitable geographical distribution, a Group of Governmental Experts on Transparency and Confidence-building Measures (TCBMs) in Outer Space Activities to conduct a study commencing in 2012 and to report to UNGA in 2013.

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 (PAROS) at UNGA indicates broad international consensus in support of consolidating and reinforcing the normative regime for space governance to enhance its effectiveness.

2013 Developments

- UNGA receives expert report on transparency and confidence-building measures
- UNGA adopts resolutions proposed by First and Fourth Committees to enhance the peaceful use of outer space
- UN COPUOS, Member States increase cooperation on NEOs
- UN Security Council sanctions North Korean Space Agency
- Russia and the United States agree to protect satellite navigation at UN International Committee on Global Navigation Satellite Systems (ICG)

INDICATOR 4.3: Other initiatives — Historically, primary governance challenges facing 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 notable example is the process to develop an International Code of Conduct for Outer Space Activities. The European Union, which has led the process, made an early decision to carry out ad hoc deliberations and consultations, not bound by the decision-making rules of procedure of traditional UN bodies. Adoption of the Code would take place at an ad hoc diplomatic conference.

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.

2013 Developments

- EU continues multilateral consultation process on proposed International Code of Conduct for Outer Space Activities
- UNIDIR conference addresses new geopolitical context of space activity
- Russia and Kazakhstan compromise on legal framework for Baikonur; agree to collaborate on space
- Russia and United States extend space cooperation