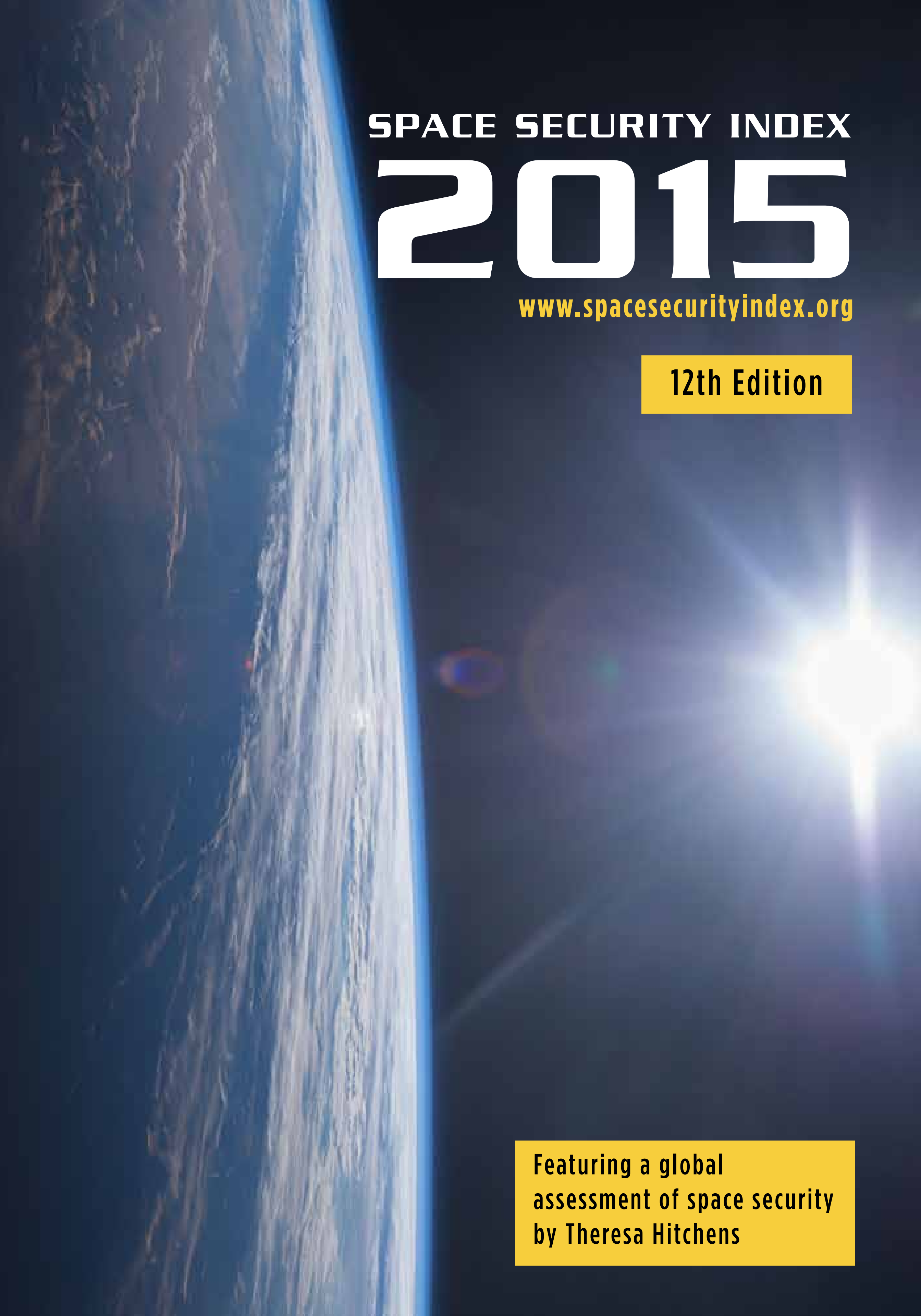

SPACE SECURITY INDEX 2015

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12th Edition

Featuring a global assessment of space security by Theresa Hitchens

SPACE SECURITY INDEX

2015

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ACRONYMS AND ABBREVIATIONS

AACE	Advanced Composition Explorer
ADR	Active Debris Removal
AEHF	Advanced Extremely High Frequency system (U.S.)
AIS	Automatic Identification System
ALASA	Airborne Launch Assist Space Access (U.S.)
ALTB	Airborne Laser Test Bed
ANGELS	Automated Navigation and Guidance Experiment for Local Space (U.S.)
APRSAF	Asia Pacific Regional Space Agency Forum
APSCO	Asia-Pacific Space Cooperation Organization
ARF	ASEAN Regional Forum
ARM	Asteroid Redirect Mission (U.S.)
ASAT	Anti-Satellite Weapon
ASEAN	Association of Southeast Asian Nations
ASI	Agenzia Spaziale Italiana
BGAN	Broadband Global Area Networks
BTRC	Bangladesh Telecommunication Regulatory Commission
CALT	China Academy of Launch Vehicle Technology
CASBAA	Cable and Satellite Broadcasting Association of Asia
CATS	Cloud-Aerosol Transport System
CCDev	Commercial Crew Development (U.S.)
CD	Conference on Disarmament
CERT	Computer Emergency Response Team
CISSM	Center for International and Security Studies at Maryland
CME	Coronal Mass Ejection
CNES	Centre national d'études spatiales (France)
CNSA	China National Space Administration
COPUOS	Committee on the Peaceful Uses of Outer Space (UN)
COSPAR	Committee on Space Research
COTS	Commercial Orbital Transportation Services (U.S.)
CSA	Canadian Space Agency
CSpO	Combined Space Operations
CSSS	Canadian Space Surveillance System
DARPA	Defense Advanced Research Projects Agency (U.S.)
DLR	German Aerospace Center
DMSP	Defense Meteorological Satellite Program (U.S.)
DoD	Department of Defense (U.S.)
DSCOVR	Deep Space Climate Observatory (U.S.)
EELV	Evolved Expendable Launch Vehicle (U.S.)
EKV	Exoatmospheric Kill Vehicle
ELINT	Electronic Intelligence
EMERCOM	Agency for Support and Coordination of Russian Participation in International Humanitarian Operations
EMI	Electromagnetic Interference
EMP	Electromagnetic Pulse (or HEMP for High Altitude EMP)

EO	Earth Observation
ESA	European Space Agency
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
EUTELSAT IGO	European Telecommunications Satellite Organization Intergovernmental Organization
FAA	Federal Aviation Administration (U.S.)
FALCON	Force Application and Launch from the Continental U.S.
FEMA	Federal Emergency Management Agency (U.S.)
FMCT	Fissile Material Cut-off Treaty
GAO	Government Accountability Office (U.S.)
GEO	Geostationary Earth Orbit
GEOSS	Global Earth Observation System of Systems
GGE	Group of Governmental Experts
GLONASS	Global Navigation Satellite System (Russia)
GMD	Ground-based Midcourse Defense
GMES	Global Monitoring for Environment and Security (Europe)
GNSS	Global Navigation Satellite System
GPS	Global Positioning System (U.S.)
GSLV	Geosynchronous Satellite Launch Vehicle
GSSAP	Geosynchronous Space Situational Awareness Program (U.S.)
HAND	High Altitude Nuclear Detonation
HELLADS	High Energy Liquid Laser Area Defense System
HEO	Highly Elliptical Orbit
IADC	Inter-Agency Space Debris Coordination Committee
IAWN	International Asteroid Warning Network
ICAO	International Civil Aviation Organization
ICBM	Intercontinental Ballistic Missile
ICG	International Committee on GNSS (UN)
ICoC	International Code of Conduct for Outer Space Activities
ICTSW	Inter-programme Coordination Team on Space Weather
IGS	International GNSS Service
IRNSS	Indian Regional Navigation Satellite System
ISON	International Scientific Optical Network
ISR	Intelligence, Surveillance, and Reconnaissance
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
JSpOC	Joint Space Operations Center (U.S.)
KARI	Korea Aerospace Research Institute
LEO	Low Earth Orbit
MDA	Missile Defense Agency (U.S.)
MEO	Medium Earth Orbit
MEOSAR	MEO Search and Rescue

MEV	Mission Extension Vehicle
MIRACL	Mid-Infrared Advanced Chemical Laser (U.S.)
MiTEx	Micro-satellite Technology Experiment (U.S.)
MOM	Mars Orbiter Mission (India)
MPC	Minor Planet Center
NASA	National Aeronautics and Space Administration (U.S.)
NDAA	National Defense Authorization Act (U.S.)
NEA	Near-Earth Asteroid
NEO	Near-Earth Object
NOAA	National Oceanic and Atmospheric Administration (U.S.)
NPO	Science and Production Association (Russia)
NRO	National Reconnaissance Office (U.S.)
OCO	Orbiting Carbon Observatory
OECD	Organisation for Economic Co-operation and Development
OPALS	Optical Payload for Lasercomm Science
ORS	Operationally Responsive Space (U.S.)
OST	Outer Space Treaty
OTV	Orbital Test Vehicle (U.S.)
PAROS	Prevention of an Arms Race in Outer Space
PASS	Preparation for the Establishment of a European SST Service Provision Function
PHA	Potentially Hazardous Asteroid
PNT	Position, Navigation, and Timing
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)
RBN-DBDS	Beidou Radio Beacon-Differential Beidou Navigation Satellite System (China)
RF	Radio Frequency
RFI	Radio Frequency Interference
Roscosmos	Russian Federal Space Agency
RPO	Rendezvous and Proximity Operations
RRM	Robotic Refueling Mission (U.S.)
RSO	Resident Space Object
SAR	Search-and-Rescue
SATCOM	Satellite Communications
SBIRS	Space-based Infrared System
SDCM	System of Differential Correction and Monitoring
SDA	Space Data Association
SDG	Sustainable Development Goal
SIA	Satellite Industry Association
SIGINT	Signals Intelligence
SMPAG	Space Missions Planning Advisory Group
SSA	Space Situational Awareness
SSI	Space Security Index
SSN	Space Surveillance Network (U.S.)

SST	Space Surveillance and Tracking (ESA)
STOIC	Spatial, Temporal and Orientation Information in Contested Environments (U.S.)
Stratcom	Strategic Command (U.S.)
STSC	Scientific and Technical Subcommittee (COPUOS)
SWPC	Space Weather Prediction Center (U.S.)
TCBM	Transparency and Confidence-building Measure
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
USSTRATCOM	United States Strategic Command
WGS	Wideband Global SATCOM
WMO	World Meteorological Organization
WRC	World Radiocommunication Conference
XSS	Experimental Spacecraft System (U.S.)

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 and knowledge of the space environment**
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Indicator 1.2: *Radio frequency (RF) spectrum and orbital positions*
Indicator 1.3: *Natural hazards originating from space*
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» **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 (SSN) to track some 23,000 pieces of debris 10 centimeters (cm) in diameter or larger. Experts estimate that there are over 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 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 (ADR).

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 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 communication, 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 (ISS), 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, 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 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 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. 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. 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 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 draft 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 (ICoC).

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 and security 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**. The report, S*pace Security Index 2015*, is available for purchase on the website in Autumn 2015. Comments and suggestions are welcome.

ACKNOWLEDGEMENTS

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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. Anna Jaikaran has been responsible for overseeing the research process and logistics for the 2015 project cycle. She provides the day-to-day guidance and coordination of the project and ensures that the myriad details of the publication come together. Anna also supports the Governance Group and we want to thank her for the contribution she has made in managing the publication of this volume.

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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 (SSN) 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 Kosmos 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. SSN 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 Geostationary Earth Orbit (GEO) than in 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 operations is driving the demand for access to radio frequencies and orbital slots. Originally adopted in 1994, the International Telecommunication Union (ITU) Constitution governs international sharing of the radio spectrum and orbital slots used by satellites in GEO, both of which it acknowledges to be limited natural resources.

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 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 ITU has been pursuing reforms to address intentional signal jamming, slot allocation backlogs, and other related challenges.

2014 Developments

- Terrestrial wireless operators seek to share C-band spectrum
- Support for allowing the ITU to track sources of interference
- Continued efforts to counter intentional satellite jamming
- Continuing proliferation and expanded impact of jamming
- Disappearance of Malaysia Airlines Flight 370 prompts calls for satellite tracking of aircraft
- Development of technical solutions to spectrum crowding continues
- Regulatory concerns about trend to large constellations of satellites
- Coordination of orbital slots in crowded GEO continues to be challenging

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, 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 Earth's orbit and has a brightness magnitude greater than 22 (approximately 150 meters [m] 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 related technical and policy challenges. 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 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 (USAF) 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

- Continued observation and assessment of potentially hazardous objects
- Asteroid impacts with Earth's atmosphere are more frequent than expected
- New international networks report to UN Committee on the Peaceful Uses of Outer Space (COPUOS) Scientific and Technical Subcommittee (STSC)
- The United States and Russia cooperate on asteroid threats
- National Aeronautics and Space Administration (NASA) seeks technology for planetary defense with Asteroid Redirect Mission

Space weather

- Awareness of threats from space weather increase
- Increased coordination in space weather observation

INDICATOR 1.4: Space Situational Awareness — Space Situational Awareness (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 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 (EU), 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 Kosmos-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

- The U.S. Air Force launches two Geosynchronous Space Situational Awareness Program (GSSAP) satellites to enhance SSA in GEO
- U.S. DoD awards contract for Space Fence
- Canada's Sapphire satellite operational in U.S. SSN
- European Space Agency (ESA) SSA program continues development
- Commercial space surveillance systems emerge
- The United States increases SSA sharing agreements
- China provides point-of-contact information to receive orbital collision-avoidance warnings directly from Joint Space Operations Center (JSpOC)
- Space Data Association (SDA) to join U.S. DoD's SSA sharing program

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 communications, 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. The International Charter on Space and Major Disasters is an international arrangement among participating agencies to provide space-based data and information in support of relief efforts during emergencies caused by major disasters. Cospas-Sarsat, the International Satellite System for Search and Rescue, was founded by Canada, France, the Union of Soviet Socialist Republics (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
- Ongoing concern about gap in data from U.S. weather satellites
- Constellations of small satellites offer better monitoring of dynamic processes
- 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 — The civil space sector comprises those organizations engaged in the exploration of space, or scientific research in or related to space, for non-commercial and non-military purposes. 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 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 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 (UAE) create new space agencies
- National satellites provide low-cost services for states in Latin America

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. Cooperation enhances the transparency of certain civil programs that could potentially have military purposes and, by allowing states to pool resources and expertise, has played a key role in the proliferation of the technical capabilities needed by states to access space.

The most prominent example of international cooperation continues to be the International Space Station (ISS), a collaborative project of NASA, Russian space agency (Roscosmos), 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 $150-billion to date, the ISS is the largest, most expensive international engineering project ever undertaken. The high costs and technical challenges associated with human spaceflight are likely to encourage collaborative efforts in this area as well.

Notably absent is significant cooperation between the United States and China. Cooperation among European states in research and technology and relevant space applications is promoted and provided for by ESA. There is no equivalent organization uniting the major spacefaring powers in Asia.

The International Committee on Global Navigation Satellite Systems (ICG), established in 2005 under the umbrella of the United Nations (UN), promotes voluntary cooperation on matters related to civil satellite-based positioning, navigation, timing, and value-added services.

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 and China seek new cooperative agreements
- International cooperation in the development of commercial space transportation continues

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, launch providers, and suppliers of ground equipment. Revenues from the global satellite industry increased nearly two-and-a-half-fold from 2005 to 2014 to reach an annual revenue of $203-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. Annual revenue from the global space industry overall was $323-billion in 2014.

Europe, Russia, and the United States are still dominant players in the commercial space industry but India and China have become increasingly involved.

2014 Developments

- Growth in the commercial satellite industry in 2014
- Mergers in the space industry continue
- Associations blur between commercial satellites and specific states
- Commercial entities provide satellite services for the developing world
- New commercial satellite services emerge
- Increasing investment in commercial space ventures
- Development of reusable launch vehicles
- Electric propulsion
- Commercial applications for CubeSats and other small satellites
- Investment in commercial space travel
- U.S. Federal Aviation Administration (FAA) releases report on commercial human spaceflight safety, certifies spaceport
- Suborbital spaceplane designed for space tourism crashes in test flight
- United Kingdom (UK) unveils eight potential locations for commercial spaceports

INDICATOR 2.5: Public-private collaboration on space activities — There is an increasingly close relationship between governments and the commercial space sector. A number of national space policies place great emphasis on maintaining a robust and competitive industrial base and encourage partnerships with the private sector. Many spacefaring states consider their space systems an extension of critical national infrastructure; a growing number view their space systems as inextricably linked to national security

Governments play a central role in commercial space activities by supporting research and development, subsidizing certain space industries, and adopting enabling policies and regulations. Full state ownership of space systems has now given way to a mixed system in which many commercial space actors receive significant government and military contracts and a variety of subsidies. 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.

As commercial capabilities evolved, the dynamic between governments and commercial actors started to shift away from subsidies. Increasingly, governments are turning to the commercial sector in search of lower-cost services and innovation.

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. In addition, 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.

2014 Developments

- Uncertainty about import of engines for U.S. government launch provider
- U.S. military continues to explore commercial partnerships
- NASA continues to partner with the commercial space industry for essential capabilities
- International Traffic in Arms Regulations (ITAR) no longer apply to most commercial satellites
- NOAA allows sale of high-resolution satellite imagery after request by DigitalGlobe
- U.S. Export-Import Bank supports satellite industry
- Increased funding for European space Research and Development (R&D) with Horizon 2020

- ESA agrees to develop Ariane 6 launch vehicle
- UK invests in space industry
- Russia plans public-private partnerships and engagement of space entrepreneurs
- Commercial payload aboard Chinese lunar probe
- JAXA partners with industry for development of new launch vehicle
- Commercial opportunities involving the ISS

INDICATOR 2.6: Space-based military systems — Since the space age began, research, development, testing, and deployment of space systems have supported terrestrial military operations. Space assets play an important strategic role in the terrestrial military operations of certain states. Space systems can augment military capabilities by enhancing battlefield awareness—including precise navigation and targeting support, early warning of missile launch, and providing real-time communications. Remote sensing satellites have served as a technical means for states to verify international nonproliferation, arms control, and disarmament regimes. These uses have resulted in an increasing dependence on space, particularly by the major spacefaring states.

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 has integrated space systems 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 has been developing GAGAN, a satellite-based augmentation system, to enhance its use of GPS. 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.

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. 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.

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

- Military systems continue to employ protective measures to counter jamming, cyber attacks
- Vulnerability to cyberattacks remains
- Demonstrations of laser-based communication

INDICATOR 3.2: Capacity to rebuild space systems and integrate smaller satellites into space operations — The capability to rapidly rebuild space systems in the wake of a space negation attack could reduce vulnerabilities in space. It is also assumed that space actors have the capability to rebuild satellite ground stations. The capability to refit space systems by launching new satellites into orbit in a timely manner to replace satellites damaged or destroyed by a potential attack is a critical resilience measure.

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. DoD 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.

Authorities are beginning to seek resilience measures other than replacement of satellites for the position, navigation, and timing data (PNT) provided by GNSS.

2014 Developments

- Development of satellite servicing capability continues
- Standardization of spacecraft components supports disaggregated architectures
- Continued development of various responsive launch capabilities
- Alternative capabilities for GNSS 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, 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

- Development of hit-to-kill technology continues
- Advances in laser technology

INDICATOR 3.4: Space-based negation-enabling capabilities — A space-based ASAT program using kinetic-kill, directed energy, or conventional explosive techniques would require foundational technologies including maneuverability, docking, and onboard optics. No hostile use of space-based ASATs has been recorded. Tests of space-based systems that could have residual ASAT capabilities must be distinguished from tests of weapons systems that are designed to provide specific, operationally useful military capabilities.

While microsatellites, maneuverability, and autonomous proximity operations are essential building blocks for a space-based negation system, they are also advantageous for a variety of civil, commercial, and non-negation military programs. Construction and manning of space stations involve both rendezvous and docking activities. More recent applications include satellite formation flying, on-orbit satellite servicing and refuelling, and some of the proposed methods for actively removing space debris from orbit. These activities, if not conducted transparently, may lead some actors to perceive additional threats to space security.

2014 Developments

- United States and Russia launch satellites capable of Rendezvous and Proximity Operations (RPO)
- Chinese satellites launched in 2013 continue maneuvers
- Programs for active debris-removal and satellite servicing continue to develop dual-use technologies

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 drafts 10-year Basic Plan
- United Kingdom announces first National Space Security Policy
- U.S. Security Space Strategy shows change in rhetoric
- 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 UN General Assembly (UNGA) First and Fourth Committees, UN-Space, the UN COPUOS, the ITU, the Conference on Disarmament (CD), and the ICG. Outside the UN, there is also an important European-led initiative to develop an International Code of Conduct for Outer Space Activities (ICoC).

UNGA

Every year the UNGA 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 (TCBMs) 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 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 UNGA 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 STSC and the Legal Subcommittee—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 for the benefit of all.

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 CD is the multilateral forum established by the UN 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 CD, overwhelming support for the resolution on the PAROS at UNGA indicates broad international consensus in support of consolidating and reinforcing the normative regime for space governance to enhance its effectiveness.

Other relevant initiatives include the ICoC and the draft Treaty on the Prevention of the Placement of Weapons in Outer Space, and of the Threat or Use of Force against Outer Space Objects. While these initiatives indicate the need for a new agreement, the way forward is not clear; global support for any one initiative has not emerged.

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
- COPUOS extends work plan to complete the draft Guidelines on the LTS for referral to UNGA in 2016
- Latest Draft ICoC released

- Russia and China submit updated draft PPWT to the CD
- 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 (APRSAF) 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 addresses implementation and compliance
- Association of Southeast Asian Nations Regional Forum holds second Space Security Workshop in Japan
- Asia-Pacific Space Cooperation Organization (APSCO) Workshop on Space Law held in China
- ESA Council at Ministerial Level emphasizes independent European access to space
- Montreal Declaration mandates study of global space governance

THEME ONE

Condition and knowledge of the space environment

Indicator 1.1: Orbital debris

Space debris—predominantly objects generated by human activity in space—represents a growing and indiscriminate threat to all spacecraft. The impact of space debris on space security is related to a number of key issues examined in this volume, including the amount of space debris in various orbits, space surveillance capabilities that track space debris to enable collision avoidance, as well as policy and technical efforts to reduce the amount of new debris and remove existing space debris in the future.

While all space missions create some debris—mainly as rocket booster stages are expended and released to drift in space along with bits of hardware—more serious fragmentations are usually caused by energetic events such as explosions. These can be either unintentional—as in the case of unused fuel exploding—or intentional—when testing weapons in space that utilize kinetic energy interceptors. Together, these events have created thousands of long-lasting pieces of space debris.

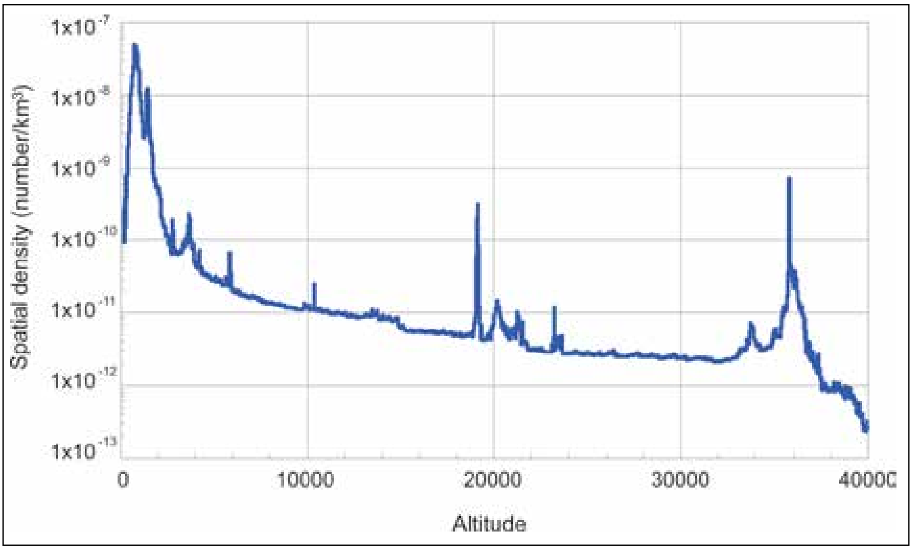
Figure 1.1 Top 10 breakups of on-orbit objects based on amount of debris produced[1]

Common name	Launching state	Owner	Year of breakup	Altitude of breakup (km)	Total cataloged pieces of debris*	Pieces of debris still in orbit*	Cause of breakup
Fengyun-1C	China	China	2007	850	3,218	3,012	**Intentional Collision**
Kosmos 2251	Russia	Russia	2009	790	1,541	1,375	**Accidental Collision**
STEP 2 Rocket Body	U.S.	U.S.	1996	625	713	63	**Accidental Explosion**
Iridium 33	U.S.	Iridium	2009	790	567	493	**Accidental Collision**
Kosmos 2421	Russia	Russia	2008	410	509	18	**Unknown**
SPOT 1 Rocket Body	France	France	1986	805	492	33	**Accidental Explosion**
OV 2-1 / LCS-2 Rocket Body	U.S.	U.S.	1965	740	473	36	**Accidental Explosion**
Nimbus 4 Rocket Body	U.S.	U.S.	1970	1,075	374	248	**Accidental Explosion**
TES Rocket Body	India	India	2001	670	370	116	**Accidental Explosion**
CBERS 1 Rocket Body	China	China	2000	740	343	189	**Accidental Explosion**

The U.S. Space Surveillance Network (SSN) currently tracks approximately 23,000 pieces of debris, most 10 cm in diameter or larger.[2] This total does not include a large number of pieces between one and 10 cm in diameter, which are more difficult to track but nevertheless have the potential to cause serious damage to spacecraft, or even smaller pieces that could damage subsystems and cause degradation over time.[3] Approximately 5% of objects being tracked are functioning payloads or satellites, 8% rocket bodies, and 87% debris and/or inactive satellites.[4]

Low Earth Orbit (LEO, less than 2,000 km above Earth) is the most highly congested area, especially the Sun-synchronous region. Some debris in LEO will reenter 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. It is particularly difficult to track objects in higher orbits; only about 1,000 objects are tracked in both medium Earth orbit (MEO, 2,000-30,000 km above Earth) and geostationary orbit (GEO, more than 36,000 km above Earth) respectively.[5] Objects need to be one meter or larger to be accurately tracked at GEO altitude.[6]

Figure 1.2 Space object density by altitude[7]



Between 1961 and 1996 approximately 240 new pieces of debris on average were cataloged each year. They were largely the result of fragmentation and the presence of new satellites. Between October 1997 and June 2004, the rate of annual increase in debris dropped by more than half—a noteworthy decrease, particularly given improvements in the cataloging system. This decline can be directly related to international debris mitigation efforts, which increased significantly in the 1990s, combined with a lower number of launches per year.

From 2007 to 2009, the annual rate of debris production increased because of two major debris-creating events. In January 2007, China destroyed its weather satellite Fengyun (FY)-1C with an ASAT and in February 2009, the inactive Russian satellite Kosmos 2251 and the U.S. satellite Iridium 33 collided accidently. There were no major debris-generating events in 2014.

The total amount of manmade space debris in orbit has been growing each year, concentrated in the orbits where human activities take place. There have already been a number of collisions between civil, commercial, and military spacecraft and pieces of space debris.

Figure 1.3 Unintentional collisions between space objects[8]

Year	Event
1991	Inactive Kosmos-1934 satellite hit by cataloged debris from Kosmos 296 satellite
1996	Active French Cerise satellite hit by cataloged debris from Ariane rocket stage
1997	Inactive NOAA-7 satellite hit by uncataloged debris large enough to change its orbit and create additional debris
2002	Inactive Kosmos-539 satellite hit by uncataloged debris large enough to change its orbit and create additional debris
2005	U.S. rocket body hit by cataloged debris from Chinese rocket stage
2007	Active Meteosat-8 satellite hit by uncataloged debris large enough to change its orbit
2007	Inactive NASA Upper Atmosphere Research Satellite believed hit by uncataloged debris large enough to create additional debris
2009	Retired Russian communications satellite Kosmos 2251 collides with U.S. satellite Iridium 33
2013	Ecuadorean satellite Pegasus collides with debris from S14 Soviet rocket launched in 1985

The average velocity of both satellites and debris in LEO is 7 kilometers per second (km/s) and 3.1 km/s in GEO.[9] As a result, collisions with large pieces of debris would be catastrophic and even very small pieces can cripple or destroy working spacecraft or endanger astronauts. Collisions between such space assets as the ISS and very small pieces of untracked debris are frequent but manageable.[10] The ISS has had to be repositioned on several occasions to avoid collision with a large piece of debris. Other precautionary measures have also been necessary.

Growing awareness of space debris threats has led to efforts to decrease the amount of new debris.

The Inter-Agency Space Debris Coordination Committee (IADC) is an international forum of national and multinational space agencies for the coordination of activities related to space debris. The IADC was formed in 1993 by the European Space Agency (ESA) and the national space agencies of the United States, Russia, and Japan.[11] IADC allows the exchange of information on space debris research activities among member space agencies, facilitates opportunities for cooperation in space debris research, reviews the progress of ongoing cooperative activities, and identifies debris mitigation options.[12]

The Scientific and Technical Subcommittee (STSC) of the United Nations Committee on the Peaceful Uses of Outer Space (UN COPUOS) began discussions on space debris in 1994 and published its *Technical Report on Space Debris* in 1999. In 2001, COPUOS asked the IADC to develop a set of international debris mitigation guidelines, on which it based its own draft guidelines in 2005.[13] In 2007, these guidelines were adopted by UN COPUOS and endorsed by the UN General Assembly (UNGA) as voluntary measures with which all states should comply.[14] The draft ICoC for Outer Space Activities (all versions) also calls on signatories to reaffirm their commitments to the UN COPUOS space debris mitigation guidelines.

Figure 1.4 UN COPUOS Space Debris Mitigation Guidelines[15]

Space Debris Mitigation Guidelines
1. Limit debris released during normal operations.
2. Minimize the potential for breakups during operational phases.
3. Limit the probability of accidental collision in orbit.
4. Avoid intentional destruction and other harmful activities.
5. Minimize potential for post-mission breakups resulting from stored energy.
6. Limit the long-term presence of spacecraft and launch vehicle orbital stages in the LEO region after the end of their mission.
7. Limit the long-term interference of spacecraft and launch vehicle orbital stages with the GEO region after the end of their mission.

The debris population in LEO is predicted to increase by an average of 30% in the next 200 years, based on the amount of debris in LEO in 2009 and assuming a 90% implementation of the commonly adopted mitigation measures (although the current level of compliance is lower), according to a study presented by the IADC in 2013.[16] The population growth will be primarily driven by catastrophic collisions between altitudes of 700 and 1,000 km; such collisions are likely to occur every five to nine years. The authors from six IADC member space agencies recommended that remediation measures, such as ADR, should be considered to stabilize the future LEO environment. To date, no active debris removal mechanisms have been implemented, although research continues.

2014 Developments

Space object population

Debris and active object populations continue to grow

The number of active satellites in orbit has continued to increase, with a total of 1,265 satellites reported in the Union of Concerned Scientists Satellite Database as of the end of January 2015.[17] This is an 8.4 % increase over the 1,167 active satellites at the end of 2013.[18]

The total mass of all objects in Earth orbit officially cataloged by the U.S. SSN continued to increase, reaching 6,700 metric tons in 2014.[19] The number of catalogued objects in Earth orbit at the end of 2014 was 17,106.[20] This total is down slightly from 2013 because high solar activity caused accelerated orbital decay and the reentry of 570 objects, compensating for the addition of new objects. It is worth noting that the *catalogued* population of objects only gives an indication of the *total* population of (large) objects in orbit. Objects, including debris, must be of a detectable size and the launching state must be identified before an object is catalogued. The National Aeronautics and Space Administration (NASA) estimates that there are, in total, more than 500,000 objects bigger than one centimeter in diameter and millions of pieces of smaller debris.[21]

Figure 1.5 Growth in on-orbit mass by orbital location[22]

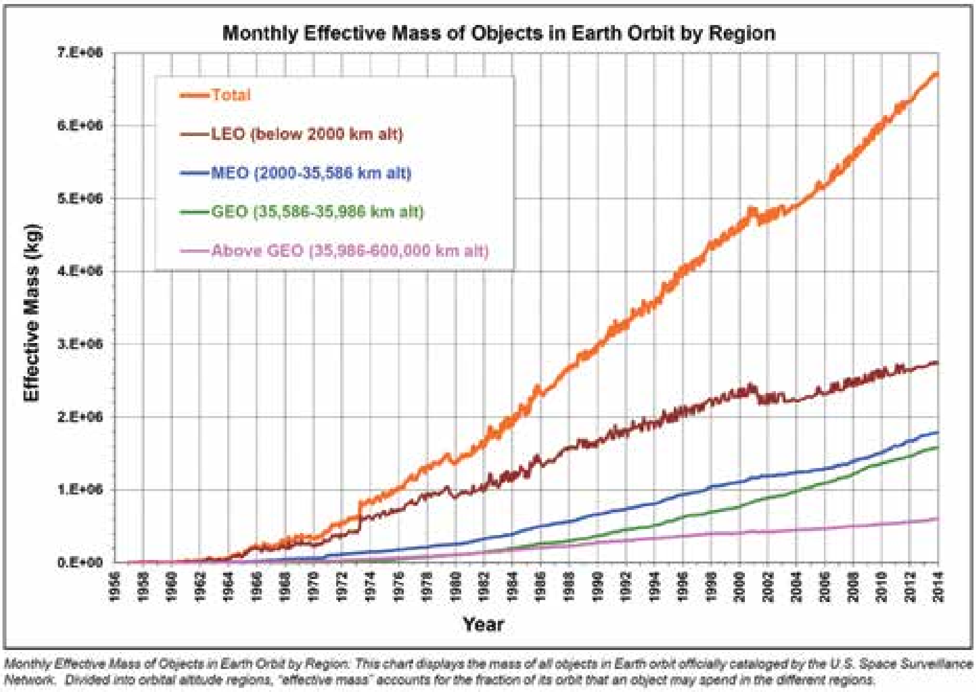
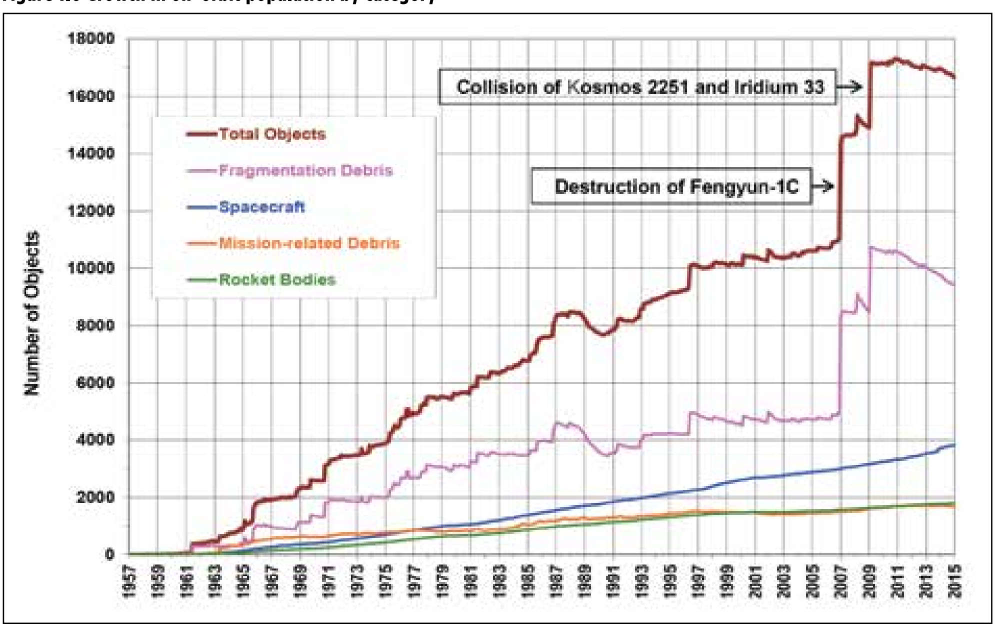


Figure 1.6 Growth in on-orbit population by category[23]



Satellite fragmentations in 2014 did not contribute large amounts of long-lived debris to the near-Earth environment,[24] but the debris in GEO from the two Long March 3 upper stages is notable. Given the difficulty of tracking objects in GEO, the identification of debris from these rocket bodies suggests the presence of a large amount of additional uncatalogued debris.[25]

Figure 1.7 Debris-causing events in 2014[26]

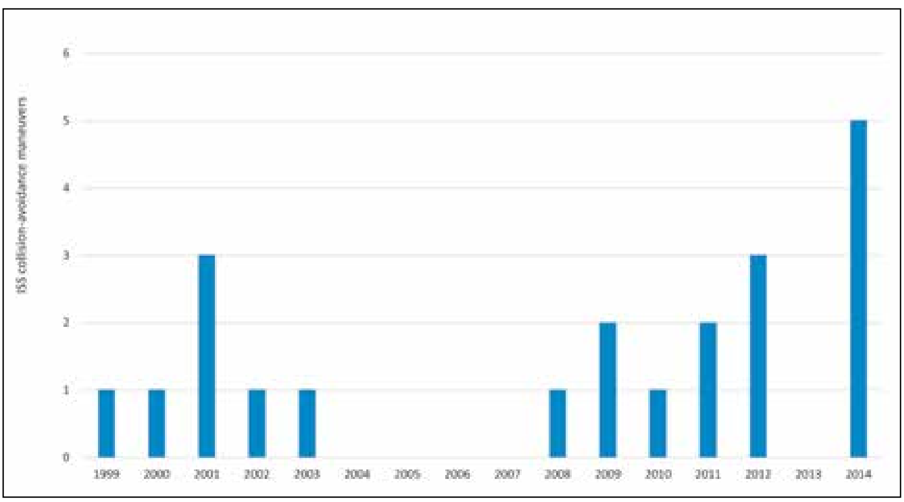
Date	Spacecraft	Pieces Added to Catalog	Launched
March	Kosmos 1867	6	10-Jul-87
April	Delta 2 second-stage rocket body	6	23-Feb-99
May	Kosmos 2428	4	29-Jun-07
May	SOZ ullage motor SSN# 23402	detected, not cataloged	20-Nov-94
May	SOZ ullage motor SSN# 33385	2	25-Sep-08
May	Kosmos 862	detected, not cataloged	22-Oct-76
June	Titan 3C	detected, not cataloged	9-Feb-69
June	Iridium 47	10	20-Dec-97
July	Haiyang 2A	detected, not cataloged	15-Aug-11
July	SOZ ullage motor SSN# 36406	detected, not cataloged	2-Mar-10
August	SOZ ullage motor SSN# 32280	detected, not cataloged	26-Oct-07
November	Iridium 91	4	11-Feb-02
Unknown	Long March Upper Stage	15	19-Dec-11
Unknown	Long March Upper Stage	14	24-Feb-12

Debris-related risks and incidents

Orbital debris continues to pose a risk to active satellites and human spaceflight operations

The International Space Station occasionally receives potential collision warnings requiring slight adjustments to station position to avoid impacts. Although the ISS did not complete any debris-avoidance maneuvers in 2013, 2014 saw a historical high of five required maneuvers[27] to avoid debris from a Soviet weather satellite Meteor 2-5 launched in 1979, a SYLDA adapter from an Ariane 5 launch,[28] a Breeze-M upper stage that exploded in 2012,[29] the 2009 collision of Iridium 33 and Kosmos 2251, and the Chinese satellite Yaogan 12.[30]

Figure 1.8 International Space Station collision-avoidance maneuvers by year[31]



NASA executed or assisted in 21 debris avoidance maneuvers in 2014. Two involved debris from the Fenyun-1C test and four resulted from conjunctions with Iridium/Kosmos debris.[32] The ESA performed 12 avoidance maneuvers.[33] The French Centre national d'études spatiales

(CNES) took part in 17 collision avoidance maneuvers in addition to processing more than 73 high-level collision risk alerts. While the total number of French avoidance maneuvers was down from 20 in 2013, the number of collision warnings increased significantly from 48 in 2013.[34]

Two Iridium satellites were affected in a manner consistent with a debris strike and later produced additional trackable debris.[35] The first observable strike occurred on 7 June 2014, when Iridium 47 produced 10 pieces of trackable debris at high velocity. The second strike occurred on 30 November, when Iridium 91 was observed to shed four pieces of trackable debris at a much lower velocity. In both cases the satellites continued to operate.[36]

Debris reentry continues to pose a risk in 2014

More than 600 individual entries of space debris, weighing more than 100 metric tons in total, reentered Earth's atmosphere during 2014.[37] This included 86 spacecraft, 49 upper rocket stages, and 467 pieces of tracked debris. No injuries or property damage were reported. Of particular note was the reentry of a satellite launched in 1960, TIROS-2, which completed a one-year mission at that time.[38]

International awareness of debris problem increases as progress toward solutions continues

Compliance with Debris Mitigation Guidelines

During 2014, 13 satellites were retired to the graveyard above the GEO belt in compliance with IADC guidelines.[39] Three GEO satellites were re-orbited too low and two spacecraft (Yamal 200 N1 and Kosmos 2479) were apparently abandoned and are in a libration orbit around L1.[40] Four rocket bodies were left in a drift orbit close or crossing the GEO.[41] There were 10 controlled landings and nine controlled deorbitings of spacecraft, representing the safe removal of a total of approximately 83 metric tons of potential orbital debris.[42]

Figure 1.9 GEO satellite retirements in 2014[43]

Spacecraft	Owner	Re-orbit	IADC Guideline Compliance*
Inmarsat 2-F2	INMARSAT	427 km x 522 km	Yes
Astra 1C	Luxemburg	391 km x 422 km	Yes
Intelsat VII F-3	INTELSAT	256 km x 291 km	Yes
Intelsat 706	INTELSAT	335 km x 360 km	Yes
GE 5	USA	251 km x 281 km	Yes
Telstar 6	USA	335 km x 388 km	Yes
Eutelsat W3	EUTELSAT	512 km x 538 km	Yes
DirecTV-IR	USA	350 km x 394 km	Yes
XM Radio 2	USA	328 km x 348 km	Yes
Fengyun 2C	China	611 km x 641 km	Yes
Xinnuo 3	China	538 km x 546 km	Yes
USA 67 (SDS 2 F2)	USA	347 km x 565 km	Yes
USA 82 (DSCS III B-12)	USA	384 km x 448 km	Yes
Apstar 1	China	239 km x 267 km	No (reorbited too low)
Apstar 1A	China	220 km x 392 km	No (reorbited too low)
Insat 3E	India	-214 km x -80 km	No (reorbited too low

* Not all space actors are members of the IADC, nor are all signatories to the IADC guidelines. This column is included to provide a frame of reference.

While ESA analysis finds continuing compliance at GEO, with the majority of satellites being raised to disposal orbits in line with prescribed guidelines,[44] compliance in LEO has been inconsistent, with no clear trends toward improvement. A CNES study of debris mitigation practices from 2000 to 2012 found that 40% of satellites and rocket bodies are left in LEO at altitudes high enough to make reentry within the 25-year window specified in the guidelines impossible.[45] Raising or lowering the orbit of a satellite or rocket stage to remove it from the busiest orbital highways takes fuel, which satellite owners prefer to use to extend mission life and launch services providers to carry more satellite payload.

Some states are already implementing space debris mitigation measures consistent with the Space Debris Mitigation Guidelines of COPUOS and/or the IADC Space Debris Mitigation Guidelines. Other states have developed their own space debris mitigation standards based on those guidelines.[46] Canada, the Czech Republic, and Germany have developed a compendium of space debris mitigation standards adopted by states and international organizations, which will be useful for improving the knowledge on space debris mitigation standards and related regulatory frameworks.[47]

International dialogues on debris problems, active debris removal, and other solutions continue in 2014

IADC members continue to undertake space debris research activities and contribute to an increased understanding of space debris issues.[48] The IADC Protection Manual was revised to include updates to damage equations, the identification of techniques to increase impact speeds in tests, and the addition of benchmark cases for risk assessment tools. After the conclusion of a major modeling study on the stability of the future LEO orbital debris environment in 2013, several follow-up studies were initiated to characterize the uncertainties in future environment projection, such as launch traffic, solar activity, and breakup models, and to quantify the benefits of active debris removal. The IADC finalized two action items on mitigation in 2014. The first was an update to the document, "Support to the IADC Space Debris Mitigation Guidelines," on such topics as the prevention of breakups, post-mission disposal of geostationary objects, and practices for the injection and operation of geostationary objects. The second was a compilation of approaches to reentry casualty risk assessment, including assumptions, reentry criteria, and applicable models. In 2014, IADC members conducted an object reentry prediction campaign for data sharing and coordination to prepare for and respond to the reentry of Kosmos 1939. The Korea Aerospace Research Institute (KARI) became the thirteenth member of IADC in October 2014.[49]

Research and development in active debris removal continue in 2014

Despite progress in mitigation, space debris is predicted to increase. Discussions continue on methods for removing debris and other solutions. In February 2014, JAXA successfully launched the Space Tethered Autonomous Robotic Satellite-2 (Stars-2) developed at Kanagawa University to test the deployment of Kevlar tether unfurling and electricity-generating mechanisms designed to assist in the cleanup of space debris. JAXA labelled the test a success after the tether properly deployed to connect two sections of the test-bed satellite and was used by one section to deorbit the system.[50] The next phase of the program, Stars-3, is planned for launch in 2016; full deployment of the project is planned for 2019.[51]

ESA has issued a road map to address new challenges for debris mitigation and compliance at different altitudes.[52] Building on the previous year's development of the CleanSpace One rendezvous and docking capable microsatellite by Swiss Space Systems, ESA announced plans for a 2021 launch of its e.DeOrbit space debris clean-up system. The e.Deorbit symposium in May 2014 explored the merits of several methods of capturing space objects; testing by the ESA and Airbus Defense and Space focused on net and harpoon mechanisms.[53]

In Paris from 16-18 June 2014, CNES hosted the third European Workshop on Space Debris Modeling and Remediation, which was attended by more than 130 representatives from 15 countries.[54] In Moscow from 2-10 August 2014, space debris was discussed as part of the Potentially Environmentally Detrimental Activities in Space Panel at the 40th Scientific Assembly of the Committee on Space Research. Several other meetings and conferences in 2014 that were not specifically focused on space debris also included discussion of this topic.[55]

There is interest in commercial and governmental solutions to problems associated with debris. In 2014, the CSA enabled research activities with partners in industry and academia to explore novel de-orbit technologies for micro and small satellites, and the development of a general purpose satellite tool to capture the Launch Adaptor Ring of a defunct satellite.[56] Canada is also developing hypervelocity launch capabilities beyond 10 km/s to permit a better understanding of the threats of space debris impacts on satellites and space platforms.

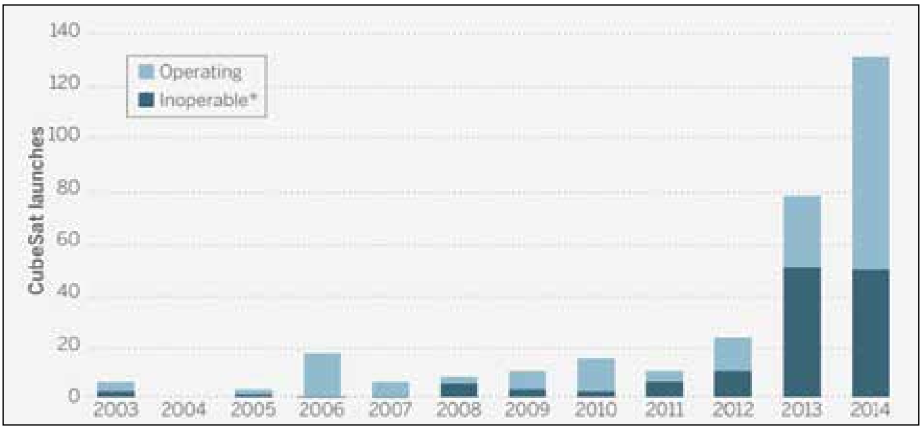
The Center for Orbital Debris Education and Research (CODER) was established at the University of Maryland in May 2014 to address critical issues in orbiting space debris and serve as a hub for academic, industry and government research collaboration.[57] "CODER is the first academically led center established to address the full range of issues surrounding the orbital debris problem," according to founder and Associate Professor of Aerospace Engineering Raymond Sedwick. The Center hosted a workshop in November.[58] Commercial concepts for active debris removal presented there included the Orbital Debris Remover, a large space tug that would approach an object in space and deploy a smaller, tethered spacecraft to grapple it and then tow it to a graveyard orbit.[59] There are currently no obvious sources of funding for large-scale efforts.

Increasing number of nanosats raises concern about debris

A nanosat is a satellite with a mass of between one and 10 kg. A CubeSat is a nanosat built according to a construction standard first developed in 1999, which includes a modular 10-cm cube design weighing less than 1.33 kg.[60] Up to six cubes can be combined along one axis to allow for bigger payloads.[61] The design has proven successful and the number of launches of CubeSats increased in both 2013 and 2014 (see Figure 1.11).

Several factors suggest that the increase in CubeSats, and nanosats in general, may result in increased orbital debris. Nanosats are often launched in constellations with several satellites working in concert to perform the function of one larger traditional space craft. This practice increases the number of, albeit smaller, spacecraft in orbit. These small satellites often travel as secondary payloads and may be launched into orbits that do not allow them to passively deorbit at the end of their missions.[62] Nanosatellites typically lack the capability for propulsion and so cannot change orbit independently to comply with mitigation guidelines. The lower cost of a CubeSat allows for more experimentation and less stringent quality control; the results can be more innovation, but also more failed satellites in orbit.

Figure 1.10 CubeSat launches[63]



* CubeSats that have reentered the atmosphere, are dead in orbit, or failed to launch, as of 10 March 2015.

Others have argued that CubeSats may pose less of a debris hazard as their small size makes them less destructive and their lack of propellant makes them less likely to explode.[64] On 16 October 2014, Planet Labs, a company that has launched more than 100 CubeSats and plans a constellation of 150 for Earth observation, posted a statement on their policies to ensure reentry of all their CubeSats within a reasonable timeframe.[65] CubeSat manufacturer Innovative Solutions In Space is developing debris mitigation technology, such as drag sails and deorbit motors.[66] NASA is testing the Exo-brake, "a passive de-orbiting system capable of accurately allowing the spacecraft to reenter Earth's atmosphere."[67] By the end of 2014, 245 CubeSats had been deployed, 163 were still in orbit and 111 of those were still working.[68]

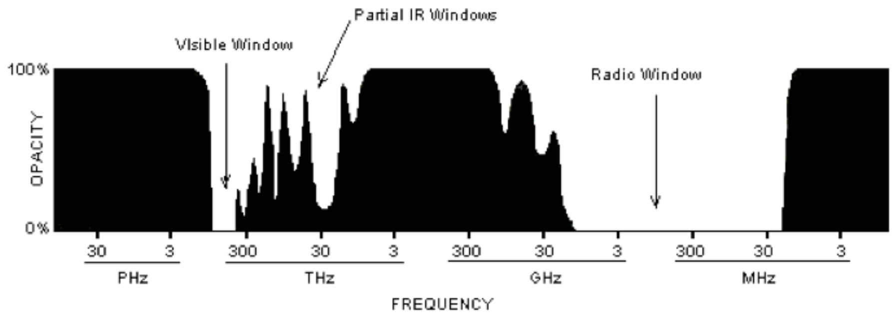
Indicator 1.2: Radio frequency (RF) spectrum and orbital positions

The growing number of spacefaring nations and satellite operations is driving the demand for access to radio frequencies and orbital slots. Originally adopted in 1994, the International Telecommunication Union (ITU) Constitution[69] governs international sharing of the radio spectrum and orbital slots used by satellites in GEO, both of which it acknowledges to be limited natural resources.

Radio frequencies

The radio frequency spectrum is part of the electromagnetic spectrum that can pass through Earth's atmosphere and is used for communication between satellites and ground stations.[70] It is divided into portions known as frequency bands. Frequency is generally measured in hertz, defined as cycles per second. Radio signals can also be characterized by their wavelength, which is the inverse of frequency. Higher frequencies (shorter wavelengths) are capable of transmitting more information than lower frequencies (longer wavelengths), but require more power to travel longer distances.

Figure 1.11 Atmospheric windows in the electromagnetic spectrum[71]



Certain widely used frequency ranges have been given alphabetical band names in the United States. Communications satellites tend to use the L-band (1-2 gigahertz [GHz]) and S-band (2-4 GHz) for mobile phones, ship communications, and messaging. The C-band (4-8 GHz) is widely used by commercial satellite operators to provide services such as roving telephone services, and the Ku-band (12-18 GHz) is used to provide connections between satellite users. The Ka-band (27-40 GHz) is now being used for broadband communications. Ultra-High Frequency, X-, and K-bands (240-340 megahertz, 8-12 GHz, and 18-27 GHz, respectively) have traditionally been reserved in the United States for the military.[72]

Article 45 of the ITU Constitution stipulates that "all stations…must be established and operated in such a manner as not to cause harmful interference to the radio services or communications of other members."[73] Military communications are exempt from the ITU Constitution, although they must observe measures to prevent harmful interference. It is observed that "interference from the military communication and tracking systems into satellite communications is on the rise,"[74] as military demand for bandwidth grows.

Issues of interference arise primarily when two spacecraft require the same frequencies at the same time and their fields of view overlap or when 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.

New technologies are being developed to manage the need for greater frequency usage, allowing more satellites to operate in closer proximity without interference. Frequency hopping, lower power output, digital signal processing, frequency-agile transceivers, and software-managed spectrum have the potential to 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.

Orbital slots

Today's satellites operate mainly in three basic orbital regions: LEO, MEO, and GEO. As of 31 January 2015, of the 1,265 active satellites in orbit, there were 669 in LEO, 94 in MEO, 465 in GEO, and 37 in Highly Elliptical Orbit (HEO).[75] HEO is increasingly used for specific applications, such as early warning satellites and polar communications coverage. LEO is often used for remote sensing and Earth observation, and MEO is home to space-based navigation systems such as the U.S. Global Positioning System (GPS).

Most communications and some weather satellites are in GEO. Because orbital movement at this altitude is synchronized with Earth's 24-hour rotation, a satellite in GEO appears to "hang" over one spot on Earth. GEO slots are located above or very close to Earth's equator. Low inclinations are also desired to maximize the reliability of the satellite footprint. The orbital arc of interest to the United States lies between 60° and 135° W longitude, because satellites in this area can serve the entire continental United States;[76] these slots are also optimal for the rest of the Americas. Similarly desirable spots exist over Africa for Europe and over Indonesia for Asia.

GEO satellites must generate high-power transmissions to deliver a strong signal to Earth, due to distance and the use of high bandwidth signals for television or broadband applications.[77] To avoid radio frequency interference, GEO satellites are required to maintain a minimum of two and up to nine degrees of orbital separation, depending on the band they are using to transmit and receive signals, the service they provide, and the field of view of their ground antennas.[78] Thus, only a limited number of satellites can occupy the prime equator (0 degree inclination) orbital path. In the equatorial arc around the continental United States there is room for only an extremely limited number of satellites.

To deal with restricted availability of orbital slots, the ITU Constitution states that radio frequencies and associated orbits, including those in GEO, "must be used rationally, efficiently and economically…so that countries or groups of countries may have equitable access" to both.[79] In practice, however, orbital slots in GEO have been secured on a first-come, first-served basis.

Originally, crowding in the MEO region was not a concern, as the only major users were the United States with GPS and Russia with its Global Navigation Satellite System (GLONASS). However, concern is increasing that problems could develop as Russia adds more satellites and both China and the EU progress with plans for constellations of their own. All four of these systems use or will use multiple orbits in different inclinations and each system has a different operational altitude. While not necessarily a problem for daily operations, the failure to properly dispose of MEO satellites at the end of their operational life could cause future problems if the disposal is done within the operational altitude of another system.

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

2014 Developments

Terrestrial wireless operators seek to share C-band spectrum

C-band (4-8 GHz) was the first frequency band used by satellites for telecommunications and is also used today for a variety of essential services, including air traffic control, maritime communications, emergency response in disaster zones, and mission critical services for the U.S. Department of Defense.[80] Terrestrial wireless broadband providers are seeking approval from the ITU to share C-band spectrum. Satellite operators argue that terrestrial wireless broadband sources operate at power levels that would wipe out the relatively weak C-band signals coming from satellites in geostationary orbit, 36,000 km above the equator, and that any sharing of the C-band spectrum in question would result in satellite signal disruption.

During 2014, the sharing of C-band spectrum was raised in various forums, including the Cable and Satellite Broadcasting Association of Asia Satellite Industry Forum on 16 June in Singapore[81] and the ITU's Plenipotentiary Conference, held from 20 October to 7 November in Busan, Korea.[82] On 9 October, the European Commission allowed terrestrial broadband operators under its jurisdiction to use a portion of C-band spectrum that had been reserved exclusively for satellite use.[83] Based on a decision made at the 2007 World Radiocommunication Conference (WRC), at which this issue was raised, many—but not all—national governments can permit sharing. A decision on the future global use of C-band will be made at the next WRC in Geneva in November 2015.

Support for allowing the ITU to track sources of interference

The ITU is responsible for regulating use of radio frequency spectrum, but has a limited ability to respond to complaints of interference because it lacks the means to verify claims. On the last day of the ITU Plenipotentiary Conference, a resolution was passed to support ITU efforts to track reported cases of interference with satellite broadcasts.[84] The resolution, "Strengthening the role of ITU with regard to transparency and confidence-building measures in outer space activities," invites the ITU to enter into agreements with satellite-monitoring facilities to detect the sources of interference (a process known as "geo-location") and calls on the ITU to create a database on interference.[85]

Continued efforts to counter intentional satellite jamming

On 18 November 2014, delegates at the annual World Broadcasting Unions-International Satellite Operations Group forum in Geneva established a working group to combat intentional interference to global satellite services.[86] The working group will prepare a step-by-step guide about what an operator should do if subjected to deliberate interference. The group will also ask the ITU to monitor cases of intentional interference. On 9 October, unnamed government and industry officials speculated that the United States will have more influence in denouncing intentional jamming of satellite transmissions in future after ending a decades-long practice of jamming television and radio broadcasts from Cuba at the end of 2013.[87]

Continuing proliferation and expanded impact of jamming

Recently, the European Telecommunications Satellite Organization Intergovernmental Organization (EUTELSAT IGO) reported persistent deliberate interference from Ethiopia of satellites operated by the Eutelsat companies on frequencies assigned to EUTELSAT IGO,[88] particularly during the first half of 2014. The BBC and other international broadcasters were affected by this jamming, with the BBC leading the call to Ethiopian authorities to end the interference. Signals provided by Arabsat to Saudi Arabia were also jammed, possibly unintentionally, from the same Ethiopian-based sources.[89] The number of incidents of deliberate interference decreased significantly in the second half of the year.[90]

Iran's jamming activities focus on preventing satellite transmissions of foreign television and radio channels. Such jamming has led to controversy. The Iran meteorological organization claimed that signals emitted by jamming devices prevented the forecasting of a dust storm that hit Tehran in June 2014 and killed five people.[91]

Disappearance of Malaysia Airlines Flight 370 prompts calls for satellite tracking of aircraft

Malaysia Airlines Flight 370 disappeared on 8 March 2014, after departing from Kuala Lumpur for Beijing with 239 passengers and crew members on board.[92] Despite the largest and most expensive search in aviation history, there has so far been no confirmation of any flight debris. In response, on 30 October, the ITU Plenipotentiary Conference adopted a resolution designed to accelerate the introduction of satellite technology for commercial aircraft tracking.[93] Some 170 governments urged the ITU to address the issue at the WRC in 2015 "as a matter of urgency." Under existing ITU rules, the 1090-megahertz frequency band used to transmit ADS-B signals is approved for air-to-ground and air-to-air links only. Governments from North and South America, Africa, and Asia are pushing for a formal resolution to approve satellite reception of the ADS-B frequency.[94] The International Civil Aviation Organization (ICAO) developed a Global Aeronautical Distress and Safety System in response to the crash.[95]

Development of technical solutions to spectrum crowding continues

The Defense Advanced Research Projects Agency (DARPA) announced a public competition to develop technologies to better share spectrum simultaneously and in real time,[96] the latest in a series of competitions. Past competitions have birthed technologies such as software-defined radios and cognitive radio technologies,[97] which aim to allow dynamic avoidance of interference.

Regulatory concerns about trend to large constellations of satellites

Between November 2014 and February 2015, the ITU registered at least a half-dozen filings for satellite networks using low, medium, and highly elliptical Earth orbits to provide broadband communications links worldwide.[98] These initial filings—ranging from dozens to hundreds to several thousand satellites each—were only identified by their regulatory home rather than their corporate sponsor, although two companies, SpaceX and OneWeb (formerly WorldVu, Ltd.), have confirmed plans to create constellations of 4,025 and 648 satellites, respectively.[99] Both companies have secured significant funding and made launch arrangements. Although some of the initial filings might be speculative, it is true that coordinating frequency spectrum for the potential increase in satellites poses regulatory challenges.

There has been a separate discussion about whether the regulatory regime should be altered to accommodate small satellites. Article IV Registration Convention requires states that put objects into space to register them with the UN Office of Outer Space Affairs.[100] Compliance with the Convention has never been universal, even for large commercial satellites, and small satellite owners argue that high-cost registration fees are a disincentive for them to register their satellites.[101] The ITU also noted that small satellites are often registered incorrectly as 'amateur' or 'experimental' to access reduced or waived licensing and registration fees.[102] In addition, many small-satellite registrants claim they will be using frequencies which are reserved for local industrial, scientific, and medical (ISM) purposes, but not allocated to any space service.[103]

Coordination of orbital slots in crowded GEO continues to be challenging

Through the ITU, the Bangladesh Telecommunication Regulatory Commission (BTRC) tried for years to coordinate several orbital slots for its first satellite, Bangabandhu 1. In March 2012, the BTRC hired Space Partnership International, based in the United States, to assist in securing an orbital position and relevant frequencies from the ITU.[104] When efforts proved unsuccessful, the BTRC entered into an agreement, announced 15 January 2015, with Intersputnik, an international satellite communications services organization, for the use of frequencies at 119.1E.[105] Peter de Selding of *SpaceNews* writes: "Other developing nations have faced the same roadblocks. In effect, they are only now arriving at a party that started 20-plus years ago and at which all the seats are occupied."[106]

Indicator 1.3: Natural hazards originating from space

Near-Earth objects

Near-Earth objects (NEOs) are asteroids and comets whose orbits bring them into close proximity to Earth. Potentially Hazardous Objects are NEOs whose orbits intersect that of Earth and have a relatively high potential of impacting Earth itself. As comets represent a very small portion of the overall collision threat, 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 m in diameter).[107]

Ongoing technical research is exploring how to mitigate a NEO collision with Earth. The challenge is considerable due to the potentially extreme mass, velocity, and distance from Earth of the impacting NEO. If warning times are in the order of years or decades, constant thrust applications could potentially be used to gradually change the NEO's orbit. Otherwise, kinetic deflection methods, such as ramming the NEO with a series of projectiles, could be applied. Some researchers have advocated the use of nearby explosions of nuclear weapons to try to change the trajectory of the NEO; however, this method would create additional threats to the environment and stability of outer space, present complex technical challenges, and have serious policy implications.

Initial efforts to find threatening NEOs focused on objects of more than one kilometer in diameter—the so-called "civilization-killer class." However, there is now a growing consensus that the greatest threat is not from asteroids that can destroy the entire Earth, but those that have the potential to destroy large areas such as cities.

It is estimated that 90% of NEOs with a diameter of 1 km or more have now been identified.[108] The NASA Authorization Act of 2005 directed the agency to identify and characterize all NEOs with diameters of 140 m or more,[109] although to date, only an estimated 10% have been identified.

The threat posed by even smaller objects was illustrated by the NEO that entered the Earth's atmosphere near Chelyabinsk, Russia on 15 February 2013.[110] The NEO was a previously undetected orbiting asteroid, 17 m in diameter, classified as a bolide because it disintegrated as it entered the atmosphere. The energy of the explosion was equivalent to 470 kilotons of TNT (30 times more powerful than the atomic bomb dropped on Hiroshima);[111] more than 1,200 people were injured and more than 4,000 structures damaged by the blast. Mitigation of the effects of small NEOs would require sufficient warning and involve civil defence/disaster plans, including evacuation. Increasing international awareness of the potential threat posed by NEOs has prompted discussions on the technical and policy challenges related to mitigation at various multilateral forums.

Space weather

"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.[112] The Sun emits energy as flares of electromagnetic radiation and as electrically charged particles through coronal mass ejections and plasma streams. Powerful solar flares can cause radio blackouts and expansion of the Earth's atmosphere, which has the effect of slowing down satellites in LEO, causing them to move into lower orbits.[113] Rapid increases in the number and energy of charged particles can induce power surges in transmission lines and pipelines, azimuthal errors in directional drilling, disruptions to high-frequency radio communication and GPS navigation, and failure or misoperation of satellites.[114] In March 1989, a geomagnetic storm generated electrical currents in power lines in Quebec, Canada, causing protective devices to take sections of the grid off-line. This tripped other protective devices and, in 90 seconds, the entire Hydro-Quebec power grid collapsed. The blackout left more than six million people in Quebec and the northeastern United States without power for nine hours.[115] The same storm also reportedly caused power outages in the UK.

The U.S. National Oceanic and Atmospheric Administration (NOAA) and the U.S. Air Force (USAF) jointly operate the Space Weather Prediction Center (SWPC), the national and world warning center for disturbances that can affect people and equipment working in the space environment.[116] Data for SWPC predictions comes from a variety of sources, ranging from satellites to ground stations.[117]

2014 Developments

Near-Earth objects

Continued observation and assessment of potentially hazardous objects

The observation and assessment of near-Earth objects by various entities continued in 2014. The NEO Observations Program, managed by the Planetary Science Division of the Science Mission Directorate, coordinates NEO activity at NASA. As well as cataloging asteroids and comets, the program maintains a list of fireball and bolide reports.[118] Funding for the NEO Program has increased tenfold in the past five years—from $4-million in fiscal year (FY)2009 to $40-million in FY2014.[119]

The ESA is developing its own SSA NEO system, with a focus on providing information about the impact threat of NEOs, awareness of the positions and physical properties of NEOs, assessing impact probabilities and effects, and gauging possible mitigation activities.[120] On 24 January 2014, the ESA and the European Southern Observatory established a partnership to enhance ESA's efforts to investigate potentially hazardous objects threatening Earth.[121]

The Russian Federation is in the process of establishing an SSA program aimed at revealing and counteracting space threats, including the asteroid/comet impact hazard.[122] A significant contribution toward this goal is being made by the International Scientific Optical Network (ISON), a growing international network of small telescopes linked together to discover and track space debris and asteroids from around the world. Canada's Near-Earth Object Surveillance Satellite (NEOSSat), launched in 2013, entered its calibration and testing phase in 2014.[123] This project of the CSA, in cooperation with Defence Research and Development Canada, is dedicated to detecting and tracking asteroids as well as orbital debris and satellites.

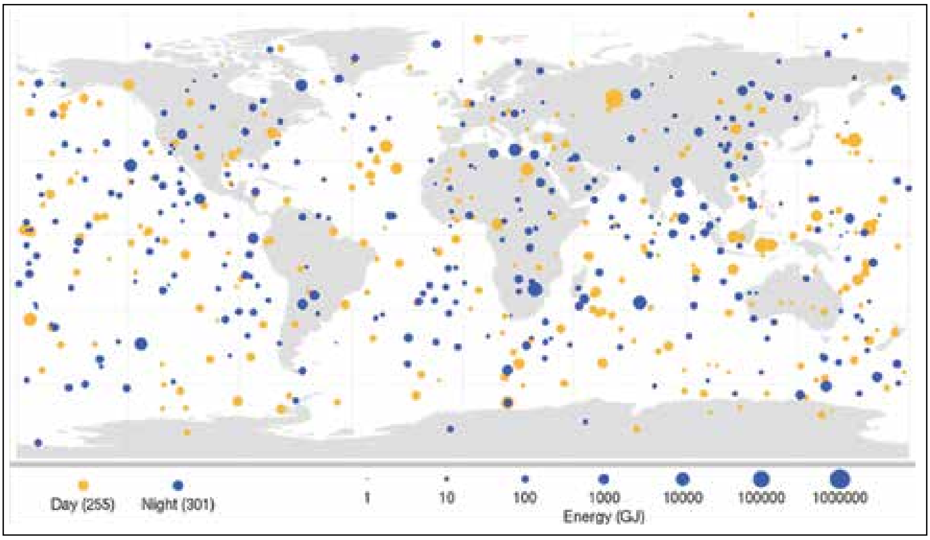
Data on NEOs is submitted to the Minor Planet Center (MPC) operated by the International Astronomical Union in Cambridge, Massachusetts, which acts as a central clearing house for asteroid and comet observations. Data from the MPC feeds into Sentry, NASA's asteroid monitoring system operated by the Jet Propulsion Laboratory. Sentry automatically retrieves new observations from the MPC database, updates orbits of NEOs, and then computes impact hazard assessments. ESA's SSA NEO Coordination Centre also analyses data from the MPC. Both NASA and ESA produce lists of NEOs and potential risks.

By the end of 2014, according to NASA, there were 12,056 known NEOs and 865 near-Earth asteroids (NEAs) 1 km in diameter or larger; of these, 152 were identified as potentially hazardous asteroids.[124] Asteroid 2007 VK184, which had been previously designated a potentially hazardous asteroid, was removed from the list on 2 April 2014.[125]

Asteroid impacts with Earth's atmosphere are more frequent than expected

On 14 November 2014, NASA published a map of all asteroid impacts with Earth's atmosphere from 1994 to 2013.[126] The number was far greater than previous studies had indicated. The new data will be used to estimate more precisely the frequency of impacts by asteroids large enough to cause ground damage.

Figure 1.12 Bolide events (small asteroids that disintegrated in Earth's atmosphere) 1994-2013[127]*



*The smallest dot on the map represents 1 billion joules (1 GJ) of optical radiant energy or, when expressed in terms of a total impact energy, the equivalent of about five tons of TNT explosives. The dots representing 100, 10,000, and 1,000,000 gigajoules of optical radiant energies correspond to impact energies of about 300 tons, 18,000 tons, and one million tons of TNT explosives respectively.[128]

New international networks report to UN COPUOS STS

In 2013, a Working Group of the Action Team on Near-Earth Objects at COPUOS recommended the establishment of two new international networks; an International Asteroid Warning Network (IAWN) and a Space Missions Planning Advisory Group (SMPAG).[129] Both networks were established by early 2014 and reported to the Scientific and Technical Subcommittee during its fifty-first session in February.[130]

IAWN is a group of governmental and intergovernmental organizations, institutes, and individuals involved in detecting, tracking, and characterizing NEOs.[131] When IAWN convened on 13 and 14 January 2014, it laid out a multiyear agenda and determined to encourage more participation of the national space agencies of countries such as China, France, India, Japan, Russia, and the UK.[132]

SMPAG is a forum for space-capable nations to build consensus on recommendations for planetary defense measures. In the event of a credible impact warning by IAWN, SMPAG would propose mitigation options and implementation plans for consideration by the international community.[133] SMPAG met in February and June 2014; in June the ESA was formally and unanimously elected as chair for two years.[134]

Various emergency response exercises have been undertaken by states to prepare for potential threats from NEOs. In November 2014, experts from ESA's SSA program and Europe's national disaster response organisations organized a two-day exercise on how to react if an asteroid, 12-38 m in diameter, were determined to be on a collision course with Earth.[135]

The United States and Russia cooperate on asteroid threats

In 2012, a Bilateral Presidential Commission was signed between the United States and Russia, regulating their response to major disasters through the Russian Agency for Support and Coordination of Russian Participation in International Humanitarian Operations (EMERCOM) and the U.S. Federal Emergency Management Agency (FEMA).[136] In August 2014, the two states agreed on the exchange of information in case of asteroid and comet hazards.[137]

NASA seeks technology for planetary defense with Asteroid Redirect Mission

In 2013, NASA announced its Asteroid Initiative, which includes two separate, but related, activities: the Asteroid Redirect Mission (ARM) and the Asteroid Grand Challenge.[138] NASA is currently developing concepts for ARM, which will employ a robotic spacecraft to capture a small NEA or remove a boulder from the surface of a larger asteroid, and redirect it into a stable orbit around the moon. Astronauts onboard NASA's Orion spacecraft will rendezvous in lunar orbit with the captured asteroid material. They will collect study samples to return to Earth. On 21 March 2014, NASA issued a Broad Agency Announcement to solicit proposals for studies on advanced technology development for ARM.

The Asteroid Grand Challenge is seeking the best ideas on how to find all asteroid threats to human populations and accelerate the work that NASA is already doing in planetary defense (see Indicator 2.5). NASA's NEO Observation Program has cataloged more than 1,000 new NEAs discovered by various search teams since the announcement of the Asteroid Initiative in 2013.[139]

Space weather

Awareness of threats from space weather increases

The United Kingdom officially opened the Met Office Space Weather Operations Centre in Exeter on 8 October 2014.[140] It is the UK's first dedicated space weather forecast center.[141] The UK and the United States signed a memorandum of understanding in 2011 to collaborate in the delivery of Space Weather alerts to help provide critical infrastructure protection around the globe.[142] Met Office Space Weather Business Manager Mark Gibbs said, "The Met Office Space Weather Operations Centre is the culmination of more than three years' work drawing on the collective resources and expertise of the UK and USA. It's a new, emerging and exciting area of science where understanding is growing rapidly."[143] Space weather is identified as the fourth most important risk on the UK National Risk Register.[144]

As awareness of the threat posed by space weather increased, so did questions about the reliability of the Advanced Composition Explorer (ACE), NASA's 17-year-old research satellite and SWPC's primary warning system for solar magnetic storms headed toward Earth.[145] ACE's replacement, the Deep Space Climate Observatory (DSCOVR), was originally expected to launch in 2014.[146] Eventually launched on 11 February 2015, DSCOVR, NOAA's first operational satellite in deep space, will monitor solar winds in real time while ACE will continue to collect data for space weather research.[147] "The instruments on DSCOVR will improve upon what we have with ACE, as they will continue to operate even during severe space weather storms. The DSCOVR data will also be used to drive the next generation of space weather models, allowing forecasters to specify where on Earth the storm conditions will be at their worst," said Doug Biesecker, DSCOVR program scientist at SWPC.[148]

Increased coordination in space weather observation

The Committee on Space Research (COSPAR), established by the International Council for Science in 1958 to promote international scientific research in space, set up a panel to produce a Roadmap on Space Weather to plan the focus of future research and related missions in the field of space weather.[149] The Roadmap group was established in 2013; progress was described in 2014 during the 40th COSPAR Scientific Assembly in Moscow; [150] and the final report was published in Advances in Space Research in 2015.[150]

In May 2010, the World Meteorological Organization (WMO) established the Inter-programme Coordination Team on Space Weather (ICTSW) to support coordination of space weather activities. A Strategic Plan for Space Weather was presented at the fourth ICTSW meeting in November 2013.[152] The main result of the fifth meeting in 2014 was the development of a four-year action plan for WMO activities in space weather coordination, which was submitted to the World Meteorological Congress in May 2015 for endorsement.[153]

An expert group on space weather was established by the COPUOS STSC in February 2014.[154] Its objective is to take stock of relevant technology, information, and observation systems around the world and make recommendations on, for example, areas of future study. The Expert Group on Space Weather met under the leadership of Canada on the margins of the fifty-second session of the STSC in February 2015 to define its program of work.[155]

Indicator 1.4: Space Situational Awareness

Space Situational Awareness (SSA) refers to the ability to detect, track, identify, and catalog objects in outer space, such as space debris and active or defunct satellites; observe space weather and NEOs; and monitor spacecraft and payloads for maneuvers and other events.[156] In an increasingly congested domain, with new civil and commercial actors gaining access every year, SSA constitutes a vital tool for the protection of space assets.

In addition to helping to prevent accidental collisions and otherwise harmful interference with space objects, 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 grave misunderstandings and false accusations of hostile actions. SSA also increases awareness of potential negative impacts of certain activities in space, such as explosions and collisions, and their role in degrading the space environment.[157] Heightened awareness encourages the development of best practices to avoid accidents or other activities that can harm the space environment.

While all spacefaring nations and even amateur astronomers have knowledge of some orbiting objects, a complete picture of the space environment and of activities in space is beyond the capability of any single actor at present. It requires a network of globally distributed sensors as well as data sharing between satellite owner-operators and sensor networks.[158] There is currently no operational global system for space surveillance, in part because of the sensitive nature of surveillance data. Characterizing objects in space—their capabilities and limitations and potential threats—has military and national security applications. Technical and policy challenges impose other constraints on data sharing, although efforts by select actors are under way to overcome these challenges, as exemplified by the U.S. government's recent measures to continue the expansion of its SSA Sharing Program.

The U.S. SSA Sharing Program is run by U.S. Strategic Command (Stratcom) through the Joint Space Operations Center (JSpOC).[159] Data from the U.S. SSN flows into the SSA Sharing Program, which has three levels of space situational awareness support services.[160] The first is emergency notifications, which alert satellite operators to potential collisions. The second level is the Stratcom-sponsored website, Space-Track.org, which serves as an available repository of basic satellite catalog information, including positional data and background information (country of origin, launch date, etc.). The third level includes specific advanced services supporting safe spaceflight operations during launch, on-orbit, and decay or reentry operations. This third level of services is available to commercial and governmental satellite and launch operators with which the U.S. DoD has established written agreements.

Russia has relatively extensive SSA capabilities; it maintains a Space Surveillance System using early-warning radars and monitors objects (mostly in LEO), although it does not widely disseminate data.[161] 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 actors plans to develop a global system.

The International Scientific Optical Network has concentrated on detecting human-made debris in high altitude orbits, primarily GEO, from 33 facilities (including 29 for space debris observations) in 14 countries, using more than 60 telescopes.[162] Like the SSA Sharing Program it produces orbital predictions, solutions, and analysis, but it asserts that the different models it uses can produce higher quality data. Because ISON has no military ties, it claims that its data is more open, free, and complete than data provided through the SSA Sharing Program.[163]

Nongovernmental actors have also recognized the increased importance of data sharing. The nonprofit Space Data Association (SDA), established by major commercial satellite operators Intelsat, SES, and Inmarsat in 2009, serves as a central hub for sharing data among participants. The SDA's main functions are to share data on the positions of members' satellites and information to prevent electromagnetic interference.

SSA also plays a role in ongoing political initiatives aimed at tackling space sustainability and security. Information exchange on space activities was cited in the 2013 report of the United Nations Group of Governmental Experts (GGE) as an important transparency and confidence-building measure for space activities.[164]

2014 Developments

The U.S. Air Force launches two GSSAP satellites to enhance SSA in GEO

On 28 July 2014, the USAF launched two satellites of the Geosynchronous Space Situational Awareness Program (GSSAP).[165] GSSAP satellites will support the U.S. Stratcom space surveillance operations as a dedicated SSN sensor tasked to collect space situational awareness data, allowing for more accurate tracking and characterization of human-made orbiting objects. From a near-geosynchronous orbit, it will have a clear, unobstructed, and distinct vantage point for viewing resident space objects (RSOs) without the interruption of weather or the atmospheric distortion that can limit ground-based systems. GSSAP satellites will operate near the geosynchronous belt and have the capability to perform rendezvous and proximity operations (RPO). RPO allows the space vehicle to maneuver near a resident space object of interest, enabling characterization for anomaly resolution and enhanced surveillance, while maintaining flight safety. Data from GSSAP will make a unique contribution to timely and accurate orbital predictions, enhancing knowledge of the GEO environment, and enabling space flight safety to include satellite collision avoidance. GSSAP satellites will communicate information through the worldwide Air Force Satellite Control Network ground stations, then to Schriever Air Force Base.

Also launched on the same flight was a nanosatellite from the ANGELS program[166] with a SSA sensor payload to evaluate techniques for detection, tracking, and characterizing space objects, as well as attribution of actions in space (see Indicator 2.6).[167]

U.S. DoD awards contract for Space Fence

On 2 June 2014, the U.S. DoD announced a contract with Lockheed Martin to build the USAF's next-generation space surveillance system.[168] Known as Space Fence, the new system will use S-band (2-4 GHz) ground-based radars to provide the USAF with uncued detection, tracking, and accurate measurement of space objects, primarily in LEO.[169] The first radar station will be located on Kwajalein Atoll in the Pacific Ocean, with a possible second site planned for western Australia.[170] Space Fence will replace the existing USAF Space Surveillance System or VHF Fence (216.9 mHz), which has been in service since the early 1960s. The geographic separation and the higher wave frequency of the new Space Fence radars will allow for the detection of much smaller microsatellites and debris. It is expected to increase the detection and tracking capacity of the SSN from approximately 20,000 to as many as 100,000+ objects.[171] Lockheed Martin's Space Fence design will significantly improve the timeliness with which operators can detect space events that could present potential threats. The initial operational capability of the new Space Fence is scheduled for 2017.

Canada's Sapphire satellite operational in U.S. SSN

The Canadian Department of National Defence is developing the Canadian Space Surveillance System (CSSS).[172] The objective of CSSS is to secure timely access to orbital data essential to Canada's sovereignty and national security by contributing to the deep space surveillance mission of the U.S. SSN. Sapphire, a minisatellite system in LEO, will form the centerpiece of the CSSS, providing an operationally flexible space-borne platform for precise tracking and identification of RSOs in altitudes from 6,000-40,000 km. Launched on 25 February 2013, on 30 January 2014 Sapphire was declared fully operational as a contributing sensor to the U.S. Space Surveillance Network and began a five-year operational phase.[173] The U.S. Space-Based Surveillance satellite, launched in 2010, is the only other satellite in the SSN solely dedicated to SSA.

ESA SSA program continues development

The Space Situational Awareness Programme is being implemented as an optional ESA program, with financial participation by 14 Member States.[174] Under the program, which began in 2009, Europe is acquiring the independent capability to watch for objects and natural phenomena that could harm satellites in orbit or infrastructure. Space surveillance and tracking (SST) is a major focus. On 31 January 2014, the EU approved €70-million ($95-million) to establish a database on all existing European space surveillance systems. [175] The EU Satellite Centre is providing recommendations on SSA governance and data policy issues through a project called "Preparation for the establishment of a European SST Service provision function" (PASS), which began on 1 September 2014.[176] With both civil and military applications, SST represents some of the greatest governance and data policy challenges.

Commercial space surveillance systems emerge

Analytical Graphics Inc. (AGI) of Exton, Pennsylvania, announced the opening of its Commercial Space Operations Center (ComSpOC™) in March 2014.[177] The company provides data for space collision avoidance, maneuver detection, and debris modeling.[178] The center is the first and most highly robust global system, consisting of a space situational awareness facility that relies on commercial optical and radio tracking assets and the company's own space surveillance software.

AGI has a long history of providing commercial software to design, develop, and operate missions in space and for national defense.[179] ComSpOC™ uses the same SSA products that have been selected by the USAF for the JSpOC Mission System program.[180] A division of AGI, the Center for Space Standards & Innovation, has operated the satellite-tracking web site CelesTrak, which includes Satellite Orbital Conjunction Reports Assessing Threatening Encounters in Space (SOCRATES), a twice-daily analysis of the probability of satellite collisions based on publicly available data, since 2004.[181]

According to AGI chief operating officer Frank Linsalata, AGI's system provides faster processing times, greater accuracy, and fewer false positives for conjunctions (close passes between orbital objects) than the data currently made available by the U.S. DoD. ComSpOC® is now tracking 4,426 space objects—75% of all active GEO satellites and 100% of all active GEO satellites over the continental United States.[182]

On 25 August 2014, Lockheed Martin Space Systems announced that it was planning a new space object-tracking site in western Australia with Australia's Electro Optic Systems. The company is hoping to sell the data to the U.S. and Australian governments.[183] In a press release, Lockheed Martin said its system will use lasers and sensitive optical systems "to offer customers a clearer picture of the objects that could endanger their satellites, and do so with great precision and cost-effectiveness."[184]

The United States increases SSA sharing agreements

In 2014, the United States signed a series of agreements relating to SSA with France[185] (21 January), Japan[186] (12 May), EUMETSAT[187] (9 August), South Korea[188] (5 September), and the ESA[189] (31 October). The United States has a SSA-sharing agreement with Italy and, as of 28 January 2015, with Germany, in addition to agreements with 46 commercial entities in 16 countries.[190]

China provides point-of-contact information to receive orbital collision-avoidance warnings directly from JSpOC

When a potentially dangerous close approach between a satellite and another object is discovered, U.S. Stratcom notifies the spacecraft owner-operators within 72 hours.[191] JSpOC contacts all owner-operators directly. Until 2014, China had not provided contact information for their satellite operators and JSpOC was forced to relay information through the State Department.[192] In July 2014, China agreed to provide direct operational points of contact and, on 4 December, General John Hyten, commander of Air Force Space Command, announced that the Air Force would send the warnings directly.[193] During the July meeting, the Chinese Ministry of Foreign Affairs and the U.S. Department of State also committed to ongoing discussions on China's designating a point of contact for more detailed technical collision avoidance information through Stratcom's Spacetrack website, which provides basic satellite catalog information, including positional data and background information.[194]

SDA to join U.S. DoD's SSA sharing program

On 8 August 2014, the Space Data Association signed an agreement with the U.S. DoD to participate in the DoD's Space Situational Awareness Data Sharing Program—the first such agreement with a non-satellite operator. SDA had been seeking to access data from the JSPoC for several years. In addition to concerns about physical collisions between space objects, there is growing concern about electromagnetic interference (EMI) and radio frequency interference (RFI), particularly intentional jamming of satellite frequencies by countries that object to certain programming or otherwise choose to interfere with transmissions. SDA called the agreement a "major milestone" that allows the two organizations to formally collaborate on SSA issues, including EMI and RFI. The agreement creates "a framework to exchange data," said SDA Chairman Ron Busch.[195]

THEME TWO

Access to and use of space by various actors

Indicator 2.1: Space-based global capabilities

Space-based global utilities are space assets that can be used by any actor equipped to receive the data they provide. The use of space-based utilities has grown substantially over the last decade. Millions of individuals rely on space applications on a daily basis for functions as diverse as communications, earth observation, 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 capabilities such as the Global Positioning System (GPS) and weather satellites were initially developed by military actors, today these systems have grown into space applications that have become indispensable to the civil and commercial sectors.

Satellite navigation systems

There are currently two operational global satellite navigation systems: U.S. GPS and Russian GLONASS. Work on GPS began in 1978 and it was declared operational in 1993, with a minimum of 24 satellites that orbit in six different planes at an altitude of approximately 20,000 km in MEO. GPS operates a Standard Positioning Service for civilian use and a Precise Positioning Service that is intended for use by the U.S. DoD and its military allies. GPS military applications include navigation, target tracking, missile and projectile guidance, search-and-rescue, and reconnaissance. However, by 2001, military uses of the GPS accounted for only about 2% of its total market. The non-military market for GPS includes automotive, marine, and aviation users as well as GPS-enabled mobile phones and GPS cameras.

GLONASS uses principles similar to those used in GPS. It is designed to operate with a minimum of 24 satellites in three orbital planes, with eight satellites equally spaced in each plane, in a circular orbit with an altitude of 19,100 km.[1] The first GLONASS satellite was orbited in 1982[2] and the system initially attained full operational capability in 1995. This capability was subsequently degraded by the loss of a number of satellites but regained in 2011.[3] GLONASS operates a Standard Precision service available to all civilian users on a continuous, worldwide basis and a High Precision service available to all commercial users since 2007.[4] Russia has extended cooperation on GLONASS to China and India[5] and continues to allocate significant funding for system upgrades independent of the main Roscosmos budget.

Two additional independent, global satellite navigation systems are being developed: the EU/ESA Galileo Navigation System and China's Beidou Navigation System. Galileo is designed to operate 30 satellites in MEO in a constellation similar to that of the GPS, providing Europe with independent navigation capabilities. The first pair of satellites were launched in 2011 and a second pair in 2012.[6] The system is expected to be fully deployed by 2020.[7] Galileo will offer open service; commercial service; safety-of-life service; search-and-rescue service; and an encrypted, jam-resistant, publicly regulated service reserved for public authorities that are responsible for civil protection, national security, and law enforcement.[8]

The Chinese Beidou system consists of two separate satellite constellations: BeiDou-1, a limited test system that has been operating since 2000, and COMPASS or BeiDou-2, a full-scale global navigation system that is currently under construction. The planned global system will include five satellites in GEO and 30 in MEO. Beidou currently provides regional coverage, but is expected to evolve into a global navigation system by 2020.[9]

Japan is developing the Quazi-Zenith Satellite System (QZSS), which is to consist of seven satellites interoperable with GPS in HEO to enhance regional navigation over Japan, but operating separately from GPS, providing guaranteed service in the framework of global navigation satellite systems (GNSS) project.[10] The first satellite in the QZSS, Michibiki, was launched in 2010. [11] India is developing an independent, regional system—the Indian Regional Navigation Satellite System (IRNSS)—intended to consist of a seven-satellite constellation.[12]

The underlying drive for independent systems is based on a concern that reliance on foreign global satellite navigation systems such as GPS may be risky, since access to signals is not assured, particularly during times of conflict. Nonetheless, almost all states remain dependent on GPS service and many of the proposed global and regional systems must cooperate with it. The most serious long-term challenge for global utilities such as GPS is ensuring the security, accuracy, availability, and integrity of architectures built on open signal and cyber standards against the activities of malicious actors.

Remote sensing

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. To ensure broad access to data, agencies across the globe have sought to enhance the efficiency of data sharing with international partners.[13]

The European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) provides meteorological data for Europeans, while NOAA provides the United States with meteorological services.[14] Satellite operators from China, Europe, India, Japan, Korea, Russia, and the United States, together with the World Meteorological Organization, make up the Co-ordination Group for Meteorological Satellites, a forum for the exchange of technical information on geostationary and polar-orbiting meteorological satellite systems.[15]

The Global Earth Observation System of Systems (GEOSS), coordinated by the Group on Earth Observation, has the goal of "establishing an international, comprehensive, coordinated and sustained Earth Observation System."[16] GEOSS members include 97 state governments and the European Commission;[17] 67 intergovernmental, international, and regional organizations are recognized as Participating Organizations.[18] The European Global Monitoring for Environment and Security (GMES) initiative and the Japanese Sentinel Asia program are examples of centralized databases of Earth observation data made available to users around the world.[19]

Disaster relief & search-and-rescue

Space has also become critical for disaster relief. The International Charter on Space and Major Disasters, is an international arrangement among participating space agencies to provide space-based data and information in support of relief efforts during emergencies caused by major disasters.[20] Member organizations include the Argentine Space Agency, CNES, China National Space Administration (CNSA), CSA, ESA, EUMETSAT, the German Aerospace Center, ISRO, JAXA, the Korea Aerospace Research Institute (KARI), National Institute for Space Research, NOAA, Roscosmos, the UK Space Agency, the U.S. Geological Survey, and DMC International Imaging.

The International COSPAS-SARSAT Programme is a satellite-based search-and-rescue (SAR) distress alert detection and information distribution system, best known for detecting and locating emergency beacons activated by aircraft, ships, and backcountry hikers in distress.[21] Participants include the four original parties to the COSPAS-SARSAT International Programme Agreement (Canada, France, Russia, and the United States), 26 Ground Segment Providers, 10 User States, and two Organizations.[22] COSPAS-SARSAT provides alert and location data to national SAR authorities worldwide, without discrimination, independent of country participation in management of the program.[23]

The UN Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER) is an open network of providers of space-based solutions to support disaster management activities.[24] Its official mission is to "ensure 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 the full disaster management cycle."

2014 Developments

Navigation systems continue to improve

As the positioning, navigation, and timing (PNT) from these systems has dual use applications, see also Indicator 2.6.

GPS

The USAF launched four block 2F GPS satellites in 2014 in support of the constellation. Navstar GPS 2F-05, Navstar GPS 2F-06, Navstar GPS 2F-07, and Navstar GPS 2F-08 were launched from Cape Canaveral, on 20 February, 16 May, 1 August, and 29 October.[25] GPS IIF offers improved civil and defense capabilities, including more accuracy, greater security and anti-jam capabilities, and more reliable performance than previous blocks of GPS satellites.[26]

GLONASS

Russia launched two GLONASS-M satellites in March and June 2014,[27] and the second GLONASS-K satellite in November[28] (the first was launched in 2011). The GLONASS-K satellite is Russian's next-generation navigation satellite, designed to provide a longer lifespan and better accuracy. After GLONASS suffered an unprecedented outage on 2 April, the entire system broadcast corrupt information for 11 hours.[29] The cause was determined to be mathematical mistakes in the software.[30]

Galileo

The Galileo satellite system now has the operational nucleus of its own navigation constellation; 2014 test results indicate that it works well.[31] In August, Galileo FOC M1 Sat-5 and FOC M1 Sat-6 were launched by Soyuz rockets from the Guiana Space Center, but failed to reach targeted orbits.[32] Arianespace cancelled Galileo launches planned for December to test the satellites further.[33] ESA managed to manoeuver the satellites into new positions and it is hoped that they might yet be used for navigational purposes.[34]

Beidou

China's Beidou Navigational Satellite System made a major breakthrough in 2014, achieving a positioning accuracy within one meter via an augmentation system, the Beidou Radio Beacon-Differential Beidou Navigation Satellite System.[35] In May, the International Maritime Organization ratified the performance standard for Beidou—a first step toward global coverage.[36] Chinese authorities have announced that the Beidou navigation systems is seeing increasing use in civilian Chinese projects, particularly those involving environmental sanitation, logistics, school buses, and management of road safety.[37] Currently providing precision positioning and real-time navigation in China and the Asia-Pacific region, the system is expected to be global by 2020, with 35 satellites.[38]

In May, it was announced that China had set up a Beidou network in Pakistan, the first outside China.[39] With five base stations and a processing center, it covers Karachi. The second stage of the network will cover all of Pakistan. In July, China signed a Memorandum of Understanding (MOU) with Russia to establish a working mechanism for cooperation.[40]

Indian Regional Navigation Satellite System

India launched IRNSS-1B and IRNSS-1C satellites in April and October 2014.[41] The first satellite of the constellation, IRNSS-1A, was launched in 2013. The system is expected to be operational in 2015.[42]

Quazi-Zenith Satellite System

Although Japanese QZSS was described early in 2014 as a four-satellite system,[43] the 10-Year Basic Plan on Space Policy drafted in 2014 described it as a network of seven satellites."[44]

Remote sensing capabilities continue to advance

EO capabilities continue to improve, while a diversified demand for EO data drives market growth. According to a 2014 Euroconsult report, 353 EO satellites are expected to be launched in the next decade—more than double the number launched in the previous decade.[45] Government supply continues to grow, while newcomers are increasing EO capacity. The following EO programs and initiatives are worthy of note.

NASA programs and initiatives

In 2014, NASA began one of its busiest periods for new Earth science missions in more than a decade.[46] In February, NASA and JAXA launched a joint EO mission, the Global Precipitation Measurement Core Observatory. By mapping global precipitation every three hours, the observatory will enable scientists to better understand Earth's weather and climate cycles.[47]

In July, NASA launched the Orbiting Carbon Observatory 2 (OCO-2), a follow-up mission to a 2009 failed launch of the first OCO satellite.[48] OCO-2 "is an Earth satellite mission designed to study the sources and sinks of carbon dioxide globally and provide scientists with a better idea of how carbon is contributing to climate change."[49]

In September, NASA launched the International Space Station-Rapid Scatterometer (ISS-RapidScat).[50] RapidScat is designed to boost global monitoring of ocean winds to allow improved weather and marine forecasting, including hurricane monitoring, as well as climate studies. It is seen as a speedy, cost-effective replacement for the QuikScat Earth satellite. Also planned for launch in 2014 was NASA's Cloud-Aerosol Transport System (CATS).[51] Launched and installed on ISS in early 2015,[52] CATS will investigate the layers and composition of clouds and tiny airborne particles such as dust, smoke, and other atmospheric aerosols.[53]

Ongoing concern about gap in data from U.S. weather satellites

The United States relies on two complementary satellite systems for weather observations and forecasts: polar-orbiting satellites that provide a global perspective every morning and afternoon, and geostationary satellites that maintain a fixed view of the United States. Both systems are critical to weather forecasters, climatologists, and the military. U.S. federal agencies are currently planning and executing major satellite acquisition programs to replace existing polar and geostationary satellite systems that are nearing the end of their expected lifespans.

NOAA acknowledges that for a year or more there could be a gap in polar satellite data in the afternoon orbit,[54] depending on how long the current satellite lasts and whether there are any delays in launching or operating the new one. A satellite data gap would result in less accurate and timely weather forecasts and warnings of extreme events such as hurricanes, storm surges, and floods.

The potential gap in weather satellite data was labelled high-risk by the U.S. Government Accountability Office (GAO) in 2013. Continuing concern in 2014 prompted discussion on the advisability of purchasing data for weather forecasting from commercial sources.[55] Companies proposing to provide data include PlanetiQ,[56] GeoOptics,[57] Tempus Global Data,[58] and GeoMetWatch.[59]

U.S. National Plan for Civil Earth Observation

In July, the National Science and Technology Council of the Executive Office of the President of the United States announced the 2014 National Plan for Civil Earth Observation.[60] The plan was the result of a congressional mandate in the NASA Reauthorization Act of 2010 that allowed for the creation of the National Earth Observation Task Force, which developed the 2013 National Strategy for Civil Earth Observation and conducted a first assessment of civil earth observation enterprises. The plan defines a framework to construct a balanced portfolio. Space-based observation is still the most expensive component, but the plan includes aircraft, sea-based, and terrestrial-based observations. It reclassifies research and operational systems as sustained operations (long-term) or experimental operations (short-term). Sustained operations are further divided into operations for research and public service.

EU and ESA: Copernicus

In March 2014, the European Parliament adopted the Copernicus Regulation, which defines the objectives, governance, and funding of its Earth Observation Program Copernicus.[61] Copernicus is intended to provide data to improve maritime security, climate change monitoring, and support in emergency and crisis situations. In April, Europe launched the first satellite of the Copernicus constellation, ESA's Sentinel-1A, from its spaceport in Kourou, French Guiana.[62] The two-satellite constellation featuring Sentinel-1A and 1B is the first of six families of missions that will make up the core of the Copernicus network. In October, the European Commission and ESA signed an agreement worth more than €3-billion ($3.8-billion) to manage and implement Copernicus through 2021.[63] The agreement also formalized the transfer of ownership of Sentinel-1A from ESA to the EU.

Russian Resurs P2 Earth observation satellite

In December 2014, Russia launched the Resurs P2 spacecraft from the Baikonur Cosmodrome in Kazakhstan.[64] The satellite is designed to collect imagery of Earth's surface for distribution to Russian governmental agencies responsible for agriculture, the environment, emergency situations, fisheries, meteorology, and cartography. Resurs P2 will join the Resurs P1 EO spacecraft launched in June 2013.[65] Russia announced that it would declassify and provide public access to Earth-sensing satellite data received from domestic and foreign satellites.[66]

China's Fengyun, Yaogan, and Gaofen satellites

China's major push into medium- and high-resolution satellite imagery has reduced to nearly zero the amount of EO data that China purchases from non-Chinese sources, the head of China's center for Earth imagery applications said at the World Satellite Business Week conference on 12 September 2014.[67] Over the next 10 years, China plans to build a comprehensive EO system, integrating air-, space-, and ground-based technologies.[68]

China's Fengyun Meteorological Satellite Program consists of a constellation of polar-orbiting and geostationary satellites.[69] In May 2014, the China Meteorological Administration announced that the third second-generation polar orbiting satellite, FY-3C, was operational.[70] In December, FY-2G, the eighth first-generation geostationary satellite, was launched on a Long March 3A rocket from the Xichang Satellite Launch Center in Sichuan Province.[71]

The Yaogan Weixing satellites are intended for scientific experiments, surveying natural resources, estimating crop yields, and disaster relief. In 2014, China launched Yaogan-20 (A-C) in August,[72] Yaogan-21 in September,[73] Yaogan-22 in October,[74] Yaogan-23 and Yaogan 24 in November,[75] and Yaogan 25 (A-C) and Yaogan 26 in December.[76] Yaogan satellites are likely also used as military reconnaissance satellites (see also Indicator 2.6). Tiantuo-2, a small experimental satellite weighing 67 kg built by students at the National University of Defense Technology, was launched with Yaogan-21.[77] It is able to track and record moving targets and send images to Earth in real time.

By 2020, the Gaofen constellation is supposed to have seven satellites capable of carrying out high-definition EO.[78] According to the State Administration of Science, Technology and Industry for National Defense, the primary users of the satellites will be the Ministry of Land and Resources, the Ministry of Housing and Urban-Rural Development, the Ministry of Transport, and the State Forestry Administration. In August 2014, China launched Gaofen-2 aboard a Long March-4B rocket. It is reported that Gaofen can see a meter-long object from space in full color.[79]

Constellations of small satellites offer better monitoring of dynamic processes

The Landsat program, a joint initiative of the U.S. Geological Survey and NASA, has provided satellite imagery of Earth since 1972. Landsat currently operates two satellites and repeated observations of the same location are made every eight days.[80] The trend toward using constellations of small satellites for Earth observation allows imagery to be updated more frequently. For example, Planet Labs expects to be able to image the entire Earth daily once it has between 150 and 200 CubeSats in orbit.[81] Curtis Woodcock, co-leader of the science team for Landsat, says plenty of scientists would like to get their hands on Planet Labs data, which allow more precise monitoring of dynamic processes, both natural and caused by human activity.[82] Skybox Imaging, which launched the second of its 24 planned microsatellites in 2014, plans to provide high-resolution imagery of any spot on Earth many times a day.[83] In August 2014, Skybox announced that it had been acquired by Google; Skybox currently offers sub-meter satellite imagery and high-definition video.[84]

Emerging programs and initiatives

Earth observation is often among the first space-based capabilities pursued by states. KazEOSat-1 and KazEOSat-2, high- and medium-resolution elements, respectively, of Kazakhstan's civil space remote sensing system, were launched in April and June of 2014.[85] Uruguay's first satellite, Antelsat, a technology demonstration of locally built satellite subsystems and capabilities, including the transmission of color and infrared images of Earth's surface, was launched on 19 June 2014.[86] Launched in November 2013, Dubai's second EO satellite, DubaiSat-2, was declared operational on 14 April 2014.[87] By June 2014, two companies had submitted bids to build an EO satellite for Bolivia.[88] In September, Nigeria announced plans to develop and launch its first indigenous remote sensing satellite by 2018.[89] On 5 October, Venezuela signed a contract with the China Great Wall Industry Corp. for construction and launch of an EO satellite.[90]

Advances made in global maritime ship location

The Automatic Identification System (AIS) is a tracking system used on ships and by vessel traffic services to identify and locate vessels.[91] When it was initially developed in the 1990s, shipboard transponders exchanged electronic data about identity, position, course, and speed with other nearby ships and shore-based receivers within 80 km.[92] Since 2008, companies such as exactEarth, ORBCOMM, Spacequest, and PortVision and government programs have deployed AIS receivers on satellites.

Satellites launched in 2014 with AIS payloads included exactEarth's Aprizesat 9 and 10; Dauria Aerospace's Dx-1, Perseus M1 and M2; ORBCOMM's OG2 FM-103, FM-104, FM-106, FM-107, FM-109, FM-111; Germany's AISat-1; Norway's AISSat-2; and China's Tiantuo 2.[93] exactEarth operates the largest AIS satellite network, providing global coverage with seven satellites. This network will be significantly expanded in the future. The six second-generation satellites (OG2) launched by ORBCOMM on 14 July 2014 are the nucleus of a future 17-satellite constellation. Successful commissioning of the six satellites will give ORBCOMM the largest constellation with eight AIS-equipped satellites, including two existing VesselSat satellites built by Luxspace.[94]

Satellite AIS has the potential to provide global coverage of AIS transmissions, although there are still technical limitations, especially in detecting lower power signals of Class B transceivers.[95] exactEarth is developing technology to improve detection of these signals. Satellite-based radar and other sources can complement Satellite-AIS data by detecting ships not using AIS transceivers. In November 2014, MDA Corp. announced a new research program to better coordinate radar and optical satellites to track such ships.[96]

Space-based initiatives for disaster relief and search-and-rescue continue

EO applications are being employed for a wide range of disaster relief and search-and-rescue programs.

The International Charter on Space and Major Disasters

The International Charter on Space and Major Disasters was activated 41 times in 2014.[97] In March, the Charter was activated by China's Meteorological Administration to aid in the search for Malaysian Airlines Flight MH370, with NASA mining archives of satellite data and using space-based assets to acquire new images of possible crash sites.[98] Chinese Foreign Ministry spokesperson Hong Lei stated that China had tasked 21 satellites to assist in the search for the missing plane.[99] In October, the Charter was activated to assist with response to the Ebola crisis in Sierra Leone and Guinea.[100] This is the first time the Charter had been activated to assist with response to a disease.

Cospas-Sarsat

The Cospas-Sarsat System, with satellites in LEO and GEO, is upgrading to include satellites in MEO.[101] The new component is known as the Medium-altitude Earth Orbit Search and Rescue (MEOSAR) system. Search-and-rescue receivers are being placed on new GPS satellites operated by the United States, Russian GLONASS navigation satellites that began deployment last year, and European Galileo navigation satellites, first launched in 2012. The MEOSAR system is currently in the demonstration-and-evaluation phase (2013-2015), which aims to show that distress alerts received from MEOSAR have the required reliability and accuracy. Once operational, MEOSAR will dramatically improve both the speed and location accuracy of detecting beacons.

UN-SPIDER

Raising awareness of the benefits of space-based tools and applications for disaster risk reduction and emergency response is one responsibility of UN-SPIDER. In 2014, UN-SPIDER organized four major events: the Central American expert meeting on the use of space-based information in early warning systems, the UN/Germany Expert Meeting on the Use of Space-based Information for Flood and Drought Risk Reduction in Bonn, the UN International Conference on Space-based Technologies for Disaster Management: Multi-hazard Disaster Risk Assessment, and the Sixth Asian Ministerial Conference on Disaster Risk Reduction pre-conference event.[102]

The UN-SPIDER knowledge portal hosts information on all activities conducted by the program and relevant activities conducted by the disaster risk, emergency response, and space communities. In February 2014, the Spanish-language version of the knowledge portal was unveiled[103] and the number of visitors to the site from Latin America and the Caribbean immediately increased radically.

Technical advisory support is a prime activity of UN-SPIDER at the national level. In 2014, technical advisory missions were conducted in Kenya, El Salvador, Zambia, Bhutan, and Mongolia.[104]

Chinese SAR programs and initiatives

In August, China launched the Chuangxin-1-04 satellite, the fourth in a series built by the Chinese Academy of Sciences for disaster relief.[105] In November, China launched another natural disaster monitoring satellite, Kuaizhou-2,[106] which joined low-orbiting Kuaizhou-1, launched in 2013 (see also Indicators 2.6, 3.2).[107] In April 2014, *China Daily* reported that in 2016, China plans to launch its first test satellite to detect electromagnetic anomalies from space.[108] The polar-orbiting satellite will collect and transmit data on electromagnetic signals in Earth's ionosphere to assist the China Earthquake Administration in its attempts to improve its earthquake monitoring network.

Japan's Advanced Land Observing Satellite-2

In May, Japan launched the Advanced Land Observing Satellite-2 (ALOS-2), which is intended to collect data related to deformation of the Earth's crust and the impact of floods and landslides.[109] The initiative is intended to assist with earthquake monitoring and relief.

Indicator 2.2: Priorities and funding levels in civil space programs

The civil space sector is made up of those organizations engaged in the exploration of space, or scientific research in or related to space, for non-commercial and non-military purposes. Civil space activity is, in itself, a significant aspect of the overall use of space and typically includes national (non-military) satellites, science missions, the development of launch vehicles, and space exploration. Civil space programs have the potential to contribute to economic growth, social well-being, and sustainable development. The prestige associated with civil space accomplishments can be a significant driver of national policy. Depending on the organization of a space program, distinguishing civil space activity from other types of activity may be problematic. In addition, because the capabilities developed by civil space programs often find later applications in the military or commercial sectors, investment in civil space activities can be a predictor of a state's plans for future use of space.

In 2014, the ESA, the United States, Russia, China, Japan, India, Israel, Iran, North Korea, and South Korea had launch capabilities.[110] Besides the ESA, the Union of Concerned

Scientists Satellite Database listed 51 countries as owners/operators of active satellites as of January 2015: Algeria, Argentina, Australia, Austria, Azerbaijan, Belarus, Belgium, Bolivia, Brazil, Canada, Chile, China, Denmark, Egypt, Estonia, France, Germany, Greece, India, Indonesia, Iran, Israel, Italy, Japan, Kazakhstan, Luxembourg, Malaysia, Mexico, Morocco, Netherlands, Nigeria, Norway, Pakistan, Peru, Russia, Saudi Arabia, Singapore, South Africa, South Korea, Spain, Sweden, Switzerland, Taiwan, Thailand, Turkey, United Arab Emirates, United Kingdom, United States, Uruguay. Venezuela, and Vietnam.[111]

Space agencies

The main U.S. agency that deals with civil space programs, NASA, is in charge of mission design, integration, launch, and space operations, while also conducting aeronautics and aerospace research. Although much of the operational work is carried out by NASA itself, major commercial contractors such as Boeing and Lockheed Martin are often involved in developing technologies for new space exploration projects.

Roscosmos, also known as the Russian Federal Space Agency, is the coordinating hub for space activities in Russia. It performs numerous civilian activities (including Earth monitoring and the astronaut program) and coordinates military launches with the Defense Ministry of the Russian Federation.[112] A lot of work is done by design bureaus, state-owned companies established during the Cold War and headed by top scientists, that have been integrated into "Science and Production Associations" (NPOs) such as NPO Energia, NPO Energomash, NPO Lavochkin, and the Khrunichev Space Center. A major provider of launch services to other countries, Roscosmos is currently battling a string of failed launches of its Proton rockets, managed by International Launch Services.[113]

In 1961, France established its national space agency, the Centre national d'études spatiales (CNES), which remains the largest of the EU national-level agencies. Italy established a national space agency (ASI) in 1989, and Germany consolidated various space research institutes into the German Aerospace Center (DLR) in 1997. The European Space Research Organisation and the European Launch Development Organisation were merged in 1975 into the European Space Agency, which is now the principal space agency for the region. Canada participates in ESA programs and activities as an associate member.

The China National Space Administration (CNSA) was established in 1993. It remains the central civil space agency in China and reports to the State Administration for Science, Technology and Industry for National Defense, a civilian authority under the Ministry of Industry and Information Technology.

The Japanese Aerospace Exploration Agency (JAXA) was formed in 2001 in the merger of the Institute of Space and Aeronautical Science of the University of Tokyo, the National Aerospace Laboratory, and the National Space Development Agency.[114] The Indian Space Research Organisation (ISRO) was founded as a dedicated civil space agency in 1969. The Israel Space Agency was formed in 1982, the Canadian Space Agency in 1989, and Brazil's Agência Espacial Brasileira in 1994.

Currently there are more than 70 national space agencies in the world.

Human spaceflight

The early years of human spaceflight were dominated by the USSR. Russia maintains domestic human spaceflight capability with the Soyuz program. The 2006-2015 Federal Space Program includes human spaceflight, featuring ongoing development of a reusable spacecraft to replace the Soyuz vehicle and completion of the Russian segment of the ISS.[115]

The first U.S. human space mission was completed in 1961. The Space Shuttle program provided human spaceflight capability from 1981 until 2011. In 2004, the United States announced a new NASA plan that included returning humans to the Moon by 2020 and a human mission to Mars thereafter. A new strategy for lunar exploration was announced in 2006.[116] Future plans include a permanent human presence on the lunar surface.[117] These plans were examined in 2009 by the Review of United States Human Space Flight Plans Committee, which found that the U.S. human spaceflight program was on an unsustainable trajectory, with the growing scope of the program outstripping the government's ability to fund it.[118]

China began developing the Shenzhou human spaceflight system in the late 1990s and completed a successful human mission in 2003, becoming the third state to develop an independent human spaceflight capability.[119] A second mission was successfully completed in 2005, followed by missions in 2008, 2012, and 2013.

2014 Developments

NASA

On 16 December 2014, NASA's budget for fiscal year 2015 (October 2014 to September 2015) was signed into law as part of an omnibus spending bill.[120] NASA was allotted $18-billion—an increase of $350-million or 2% over the previous year's budget.[121] (It is worth noting that the budget for NASA, a *civil space agency*, is a fraction of the *total* U.S. space budget – see Figure 2.4. NOAA, the other U.S. civil space agency, received $5.4-billion for FY2015.[122])

Figure 2.1 NASA FY2008-FY2015 budget, $-billions

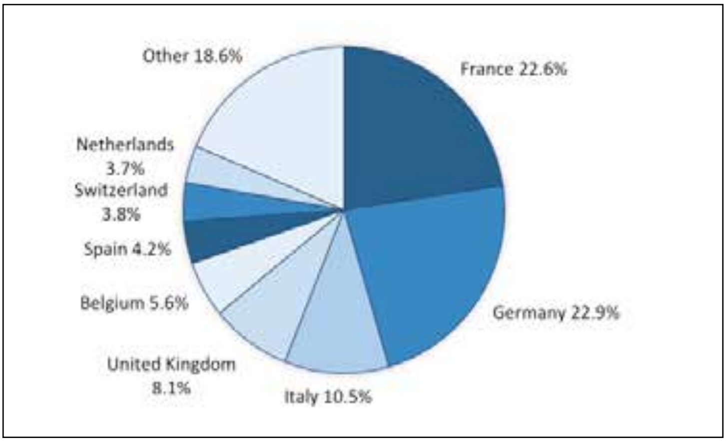
Budget discussions in 2014 reflected tension between NASA and members of Congress who were impatient with NASA's emphasis on technology development and the pace of progress toward crewed missions to deep space.[123] NASA launched the first test flight of the Orion Multi-Purpose Crew Vehicle aboard a United Launch Alliance Delta IV Heavy rocket on 5 December 2014.[124] NASA plans to use Orion for the ARM and eventually for a mission to Mars, while some in Congress urged use of the new spacecraft for a near-term crewed Mars flyby.[125]

In June 2014, in accordance with Section 204 of the NASA Authorization Act 2010, the U.S. National Research Council released *Pathways to Exploration—Rationales and Approaches* *for a U.S. Program of Human Space Exploration*,[126] a report on the rationale for, and value of, human spaceflight beyond low Earth orbit.

ESA

In January 2014, the member states of ESA approved a budget of €4.1-billion ($5.7-billion) for 2014—a 4.2% decline from 2013.[127] *SpaceNews* reports that the decrease in ESA's top-line budget masks a continued trend in increased investment by its 20 member states. Additional funding came from the EU later in the year, as well as catch-up payments accumulated by its member states. For example, France's contribution for 2014 of €754.6-million ($1.0-billion) was actually approximately €811-million ($1.1-billion), when debt reduction was included.[128]

Fig. 2.2 Top contributors to ESA's 2014 General Budget[129]



In December, ESA member states agreed to a 10-year spending package of €8.2-billion ($10.2-billion) for launch-related programs, including the development of the next-generation Ariane rocket,[130] Ariane 6, which is expected to consume roughly half the budget. Funding was also given to the Euro-Russian ExoMars mission, with a European rover to launch in 2018; maintenance of the Ariane 5 launch program; and the ISS through 2017.

ESA's Rosetta mission was a significant civil space event in 2014. Rosetta was the first spacecraft to orbit a comet; the successful mission on 12 November to soft-land the Philae probe on comet 67P/Churyumov-Gerasimenko was also a first.[131]

Roscosmos

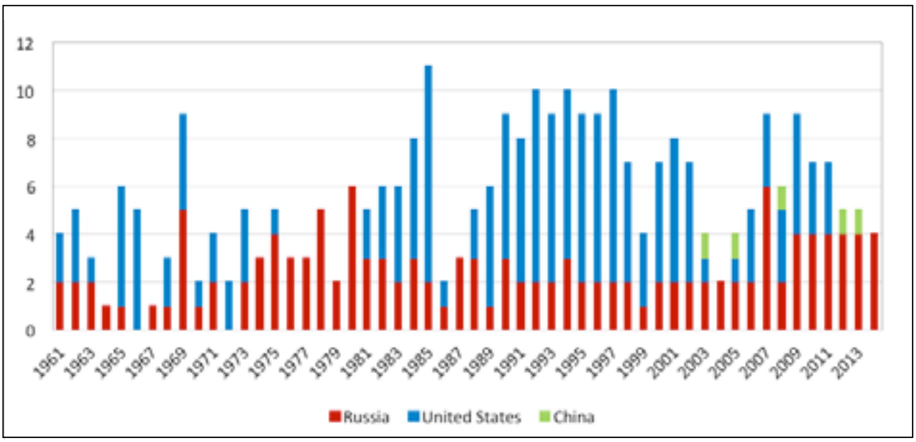
In 2014, the budget of Russia's space agency Roscosmos was approximately 166-billion rubles ($4.88-billion),[132] a 0.4% increase over the 2013 budget of 165-billion rubles ($4.86-billion). Following a presidential decree signed in December 2013, the Russian government consolidated organizations involved in developing, manufacturing, testing, shipping, and selling rockets. This joint stock company, United Rocket and Space Corporation (URSC), was wholly owned by the Russian Federation. Roscosmos drafted a new 10-year Federal Space Program for 2016 to 2025,[133] in which it requested 2,315-billion rubles ($64.6-billion) in federal funding, including 1,493-billion rubles ($41.7-billion) for research and development, and 110-billion rubles ($12.9-billion) for capital expenses. In January 2015, the Russian government announced that Roscosmos and URSC were to be combined.[134] The new entity will retain the name Roscosmos but is described as a state corporation rather than an agency. The head of URSC, Igor Komarov, will run the new entity and is to develop a draft federal space plan by the end of 2015.

Roscosmos continued work on the new Vostochny Cosmodrome and renovation of existing cosmodromes at Plesetsk and Baikonur. Other priorities in the Russian space program identified in 2014 were modernization of the Soviet-era industrial base responsible for producing the rockets and technology;[135] the super-heavy-lift rocket project; studies of the Moon and Mars, including a draft manned space program for lunar studies; response to asteroid threats;[136] and construction of a new space station.[137] With a change in leadership at the newly reorganized Roscosmos, the 2015 priorities could be different.

A notable achievement for Roscosmos in 2014 was the successful test flight of the heavy-lift version of its long-awaited Angara series of rockets on 23 December.[138] Angara is a modular series of rockets designed to launch different classes of payloads to various orbits. The heavy-lift version will allow Russia to launch geostationary-orbiting satellites from its own territory. Currently such satellites are launched from the Baikonur Cosmodrome in Kazakhstan aboard the Proton rocket, which uses a highly toxic hydrazine fuel. The Angara-A5 flight follows the successful launch in July of the smaller Angara 1.2 on a suborbital mission.

Russia was the only nation to conduct human spaceflight missions in 2014. Carrying crews to the ISS, Soyuz TMA-12M,[139] Soyuz TMA-13M,[140] Soyuz TMA-14M,[141] and Soyuz TMA-15M[142] launched from the Baikonur Cosmodrome in Kazakhstan on 25 March, 28 May, 25 September, and 23 November respectively.

Figure 2.3 Human spaceflight missions by country 1961–2014



CNSA and associated agencies

Organisation for Economic Co-operation and Development (OECD) report, *The Space Economy at a Glance 2014*, listed China's space budget (total as opposed to civil) in 2013 as $6.1-billion.[143] Officially, the CNSA sets overall guidance and policy for the entire space program and a consortium of technology contractors, academies, and partner universities comprise the primary limbs of the program.[144] This structure makes obtaining data on the Chinese national space enterprise, including budget and organization, difficult.

As with Russia, China's space program currently places a heavy emphasis on the Moon. With the successful Chang'e-3 mission in 2013,[145] China became the third country to successfully execute a soft-landing on the lunar surface and the first to do so in 37 years.[146] The Yutu rover released from the Chang'e remained largely functional, sending signals to Earth throughout 2014, although a fault in its motor control system rendered the vehicle stationary at the end of the mission's second lunar day.[147]

Notable in 2014 was the lack of observable progress on the next generation of Long March rockets.[148]

In the waning days of China's first orbital space laboratory, Tiangong 1,[149] China disclosed that it will launch a second space laboratory, Tiangong 2, in 2016 and a space station c. 2022.[150]

JAXA

In January, JAXA President Naoki Okumura unofficially announced the space agency's budget for 2014.[151] The total budget of 181.5-billion yen ($1.7-billion) included a main budget of 155-billion yen and a supplementary budget of 27-billion yen. This constituted a decline of 3.9-billion yen ($37- million) from the previous fiscal year. Budget allocations included 7-billion yen ($67-million) for a new flagship launch vehicle and, in March, JAXA issued calls for new launcher proposals.[152] The Hayabusa-2 asteroid explorer completed the critical operation phase of its scientific mission near the end of 2014.[153]

ISRO

In 2014, India's Department of Space received a budgetary allocation of 72.4-billion rupees ($1.2-billion) for the fiscal year from April 1, 2014 to March 31, 2015. This represented a 6.57% increase over the 2013 budget of 67.9-billion rupees ($1.1-billion). Although given almost 68-billion rupees in 2013, ISRO—the executor of the Department of Space's policies—spent only 58-billion rupees ($965-million), as was standard practice.[154]

On 24 September 2014, ISRO's Mars Orbiter Mission (MOM) probe entered Mars orbit. With MOM, India's first interplanetary mission, ISRO became the fourth space agency to reach Mars, after the Soviets, NASA, and the ESA.[155] MOM reportedly cost $74-million—11% of the cost of NASA's Mars Atmospheric and Volatile EvolutioN mission probe, which entered Mars orbit a week earlier.[156]

On 18 December 2014, ISRO successfully conducted the first suborbital test flight of GSLV Mark III. The vehicle carried a passive, or non-functional, cryogenic upper stage. The rocket also carried an unmanned crew module designed to accommodate three astronauts and built in India.[157]

CNES

France's CNES, had a 2014 budget of €2.15 billion ($3 billion), which represented a 5% increase over its 2013 budget of €2.04 billion ($2.65 billion).[158] These funds were divided between domestic projects and contributions to ESA.

DLR

The German Aerospace Center acts as Germany's space agency as well as conducting research in aeronautics, energy, and transportation. DLR's 2014 national space budget was €272-million ($372-million) and its research and technology budget amounted to €179-million ($244-million).[159] Germany's total 2014 civil space budget, including its contribution to the European Space Agency, was €1.26-billion ($1.7-billion), a 3.3% increase over its 2013 civil space budget.

CSA

The budget for the Canadian Space Agency for FY 2014-2015, supplemented by additional funding for specific projects, was $442-million, an 11.8% increase over the previous fiscal year.[160] In line with the principles of the new Space Policy Framework, the Government of Canada announced or confirmed its contribution to several projects and missions in 2014, including the James Webb Telescope project,[161] the NASA-led OSIRIS-REx mission,[162] the development of products by 12 companies to better use data from CSA-supported EO missions,[163] and the international Surface Water and Ocean Topography Mission.[164] Canada confirmed its continuing participation in the ISS until 2020.

UK Space Agency

According to the UK government's *Annual Report and Accounts for 2013-2014*, the UK Space Agency was allocated £340-million ($580-million).[165] The central goal of the agency's civil space strategy is to ensure that space continues to be a key enabler of economic growth;[166] its primary role is to regulate the UK space sector. Scientific activities are carried out largely through the ESA; in December 2014, the UK announced over £200-million in new funding for European space projects (see Indicator 2.5). The UK Space Agency collaborated with industry and academia to launch its first CubeSat from Baikonur in Kazakhstan on 8 July 2014. UKube-1 is intended to be the pilot for a full national CubeSat program.[167]

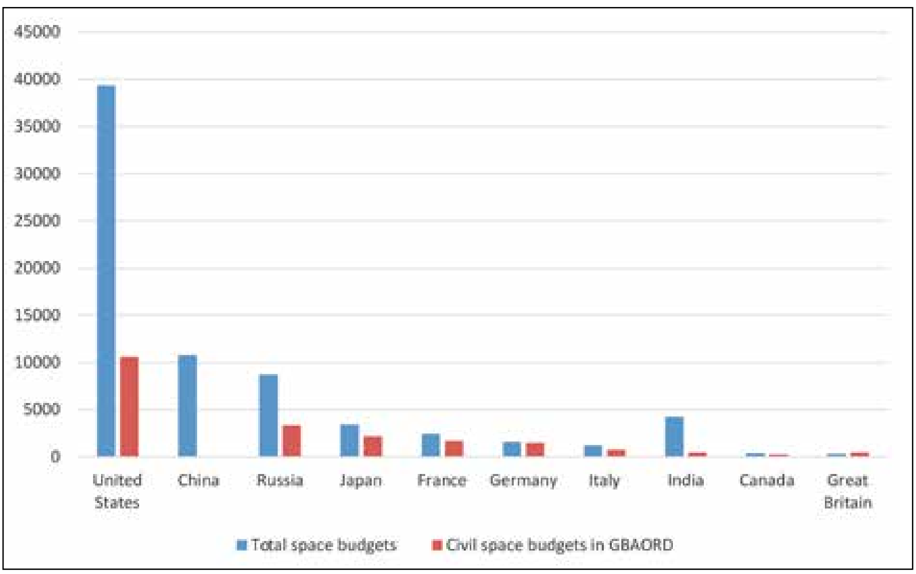
Iranian Space Agency

Iran's space program began in 2004. The Iranian Space Agency, as currently constituted, began on 27 September 2010, when President Mahmoud Ahmadinejad brought the national space consul and several small research institutes under the direct supervision of the presidential office.[168] Iran has successfully launched three satellites into orbit, although none in 2014. In July, the space agency formulated a 10-year strategic plan to send humans as well as telecommunications and remote-sensing satellites into space.[169]

Comparative funding

The OECD's *The Space Economy at a Glance 2014* includes some interesting comparisons of national spending on space.

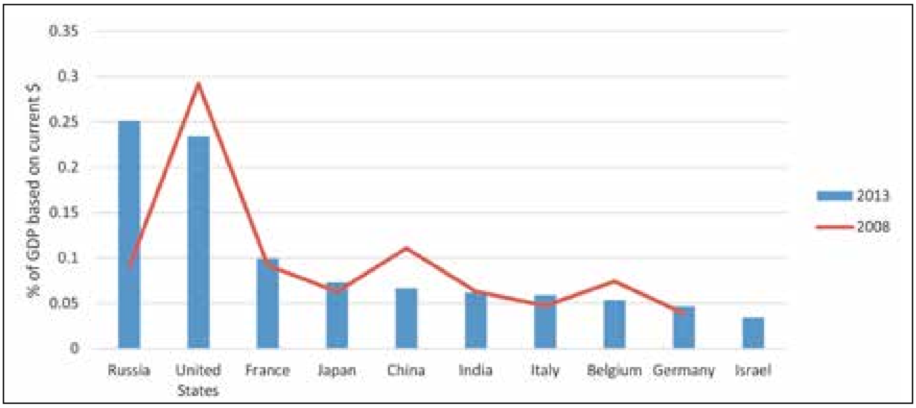
Figure 2.4 Total space budgets and civil space budgets in GBAORD* in $millions (purchasing power parities), 2013**[170]



* Government Budget Appropriations or Outlays for R&D (GBAORD) information is assembled by national authorities analysing their budgets for R&D content and classifying them by "socio-economic objective." These diverse objectives represent the intentions of governments at the time of funding commitments. There is a special category for "exploration and exploitation of space."

**Purchasing power parities are the rates of currency conversion that equalise the purchasing power of different countries by eliminating differences in price levels between countries.

Figure 2.5 Space budget as a share of GDP for selected countries, 2013 and 2008[171]



Emerging and newly created national space agencies, first satellites

In March, it was reported that Syria, despite its protracted civil war, had created a national space agency.[172] In September, the UAE established a space agency.[173]

Uruguay's first satellite, Antelsat, a two-unit Cubesat, was launched in 2014 (see Indicator 2.1).[174]

Belgium's first two satellites were launched from the ISS on 19 June 2014. The CubeSats are the first satellites of the QB50 mission, which aims to investigate the properties of the lower thermosphere by doing in-situ measurements with between 40 and 50 nanosatellites, to be launched in 2016. The project is funded by the European Committee and EU.[175] This launch was the first under a Belgian space law that was adopted in 2005 and revised at the end of 2013, which allows Belgium to authorize and supervise satellite missions in full accordance with international treaties, the associated safety standards, and the mitigation of space debris.[176]

Lithuania's first two satellites were launched aboard the Cygnus cargo spacecraft on 9 January 2014 on route to the ISS.[177] Lituanica SAT-1 and LitSat-1, both CubeSats with a camera and amateur radio payload,[178] were released into orbit from the ISS with other satellites between 26 and 28 February using the NanoRacks CubeSat Deployer.[179] LituanicaSat-1 reentered Earth's atmosphere on 28 July 2014 and LitSat-1 on 22 May 2014.[180] On 7 October 2014, Lithuania became the eighth country to sign a European Cooperating State Agreement with ESA.[181]

The Tigrisat satellite was built by Iraqi students in Rome, funded by an Iraqi government grant and under the auspices of the University of Rome 'La Sapienza'.[182] Although press reports and an official Iraqi government press release claimed the CubeSat to be the first Iraqi satellite, it was registered with the UN by Italy and appears to be owned by La Sapienza.

National satellites provide low-cost services for states in Latin America

Bolivia's first telecommunications satellite, Túpac Katari 1 (TKSat-1) was launched on 20 December 2013 and commercial operation began in March 2014.[183] President Evo Morales said that Bolivian internet service providers have committed to reducing tariffs 20-50%.[184] Cellular telephone subscription costs have been slashed and are now the lowest in South America, after Venezuela. Both Bolivia and Venezuela purchased satellites from China as part of bundled deals that included satellite, launch, and financing.

Argentine telecommunications satellite Arsat-1 was launched 16 October 2014.[185] It was built by INVAP, a state-owned company. According to Argentine officials, Arsat-1, including launch and ground infrastructure, cost about $270-million. It will usher in a series of domestic satellite programs while saving about $25-million per year in hard currency that went to non-Argentine companies with satellites covering Latin America.

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 (see Indicator 2.2) throughout the space age. Scientific satellites, in particular, have been cooperative ventures. Cooperation enhances the transparency of certain civil programs that could potentially have military purposes.[186]

The earliest large international cooperation program was the Apollo-Soyuz Test Project, which saw two Cold War rivals work collaboratively to achieve a joint docking in space of U.S./USSR human modules in July 1975. The 1980s saw a plethora of international collaborative projects, involving the USSR and partners that included the United States, Afghanistan, Austria, Bulgaria, Canada, France, Germany, Japan, Slovenia, Syria, and the United Kingdom, that enabled astronauts to conduct experiments onboard the Mir space station.[187] Many barriers to global partnership have been overcome since the end of the Cold War.

The most prominent example of international civil space cooperation is the ISS, a multinational effort with a focus on scientific research at an estimated cost of more than $150-billion. The project partners are NASA, Roscosmos, ESA, JAXA, and the CSA. Brazil participated through a separate agreement with NASA from 1998 to 2007.[188] The ISS has hosted astronauts from 15 countries.[189]

Notably absent is significant cooperation between the United States and China. The Chinese ASAT test that destroyed a weather satellite in 2007 ended all discussion.[190] In April 2011, the 112th U.S. Congress passed legislation prohibiting any joint scientific activity between the United States and China that involves NASA or is coordinated by the White House Office of Science and Technology Policy.[191]

Cooperation among European states in research and technology and relevant space applications is promoted and provided for by ESA.[192] No such organization unites the major spacefaring powers in Asia, where space activities have been described as "highly nationalistic, sometimes secretive, and mostly competitive."[193]

Some Asian-based organizations do foster space cooperation. The Asia Pacific Regional Space Agency Forum (APRSAF) was established by Japan in 1993 as an open cooperative framework.[194] By December 2014, 558 organizations from 46 countries and regions and 28 international organizations had participated in Forum events. The intergovernmental Asia Pacific Space Cooperation Organization (APSCO) was established by China in 2005;[195] members include Bangladesh, Iran, Mongolia, Pakistan, Peru, Thailand, and Turkey.

By allowing states to pool resources and expertise, international civil space cooperation has played a key role in the dissemination 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 to access space independently.

Global utilities (see Indicator 2.1) are another area of significant cooperation. The International Committee on Global Navigation Satellite Systems (ICG), established in

2005 under the umbrella of the UN, promotes voluntary cooperation on matters of mutual interest related to civil satellite-based positioning, navigation, timing, and value-added services.[196] Among the core missions of the ICG are to encourage coordination among providers of GNSS, regional systems, and augmentations to ensure greater compatibility, interoperability, and transparency; and to promote the introduction and utilization of these services and their future enhancements, including in developing countries, through assistance, if necessary, with integration into existing infrastructures. The U.S. 2010 National Space Strategy encourages international cooperation related to GPS and GNSS.[197]

The year 2014 also saw cooperation in responding to the threat of NEOs (Indicator 1.3), observation of space weather (Indicator 1.3), and Space Situational Awareness (Indicator 1.4).

2014 Developments

U.S.-Russian civil space cooperation damaged by events in Ukraine

Geopolitical developments in Ukraine in 2014 created tension between Russia and the United States. In March, NASA announced that, despite such tension, it was maintaining a normal relationship with Russia.[198] In April, NASA reversed this policy: with the exception of activities involving the ISS, NASA employees were barred from traveling to Russia, hosting Russian visitors, and emailing or holding teleconferences with Russian counterparts.[199]

In response to U.S. sanctions imposed on Russia after it annexed Crimea, Deputy Prime Minister Dmitri Rogozin announced in May that Russia would prohibit U.S. military use of the RD-180 engine.[200] Despite this announcement, delivery of the engines, which are used for defense launches, was not interrupted[201] and was expected to continue until the end of the year.[202] In December 2014, the United States passed the 2015 National Defense Authorization Act (NDAA), prohibiting their future purchase.[203] The Act, however, contains a waiver provision allowing such purchases when suitable replacements cannot be obtained at a fair and reasonable cost (see Indicator 2.5).

The CSA adopted a policy similar to NASA's. In April 2014, General (retired) Walter Natynczyk, the head of the CSA, said that sanctions against Russia would not affect operations on the ISS, and that cooperation on other space projects would be decided on a case-by-case basis.[204] On 24 April, Com Dev International Ltd. announced that the Canadian government had revoked the license to export its Maritime Monitoring and Messaging Microsatellite (M3M), scheduled for launch from the Russian-run Baikonur Cosmodrome in Kazakhstan on a Russian Soyuz rocket in June 2014.[205] The M3MSat is now scheduled for launch in 2016.[206]

ESA continued to cooperate with Russia. On 4 June 2014, during the Global Space Applications Conference organized by the International Astronautical Federation in Paris, ESA Director-General Jean-Jacques Dordain said that he had no concerns that Europe's multiple space ventures with Russia might suffer because of the Ukrainian situation.[207] ESA, in addition to relying on Russia's Soyuz for manned flights, is developing its principal space exploration endeavor, the two-mission ExoMars program, in collaboration with Russia.

ISS update

On 8 January 2014, the Obama Administration announced an extension of ISS until at least 2024.[208] The announcement stressed the importance of ISS for the study of Earth and climate change and noted several upcoming experiments to be hosted by ISS, including the Stratospheric Aerosols and Gases Experiment, the RapidSCAT ocean winds measurement instrument, the Orbital Carbon Observatory, the Cosmic Ray Energetics and Mass experiment, and the Calorimetric Electron Telescope. NASA also emphasized the economic benefits of ISS, noting that "commercial use of the space station is growing for research and development each year."[209]

In May, after the United States and the EU had imposed sanctions on Russia over the annexation of Crimea, Russian Deputy Prime Minister Dmitri Rogozin announced that Russia would consider ending its participation in the ISS program in 2020.[210] Russia built the station's core module, operates the facility jointly with NASA, and currently provides the only means of transporting U.S. astronauts to and from the station.[211] In early 2015, Russia agreed to the 2024 extension and was developing plans to undock its part of the ISS to set up its own space station post-2024.[212]

NASA's cooperative arrangements and programs

NASA and JAXA signed an agreement to share asteroid specimens from the OSIRIS-REx and Hayabusa 2 sample return missions.[213] In the latter case, NASA will receive a portion of the Hayabusa2 sample in exchange for providing Deep Space Network communications and navigation support for the mission.[214] (See also Indicator 2.2.)

NASA and ISRO signed two agreements to launch a NASA-ISRO satellite mission to observe Earth and establish a pathway for future joint missions to explore Mars.[215] The first defines how the two agencies will cooperate on the NASA-ISRO Synthetic Aperture Radar mission, scheduled to launch in 2020. The second is a charter that establishes a NASA-ISRO Mars Working Group to investigate enhanced cooperation in Mars exploration.

In February 2014, NASA and CNES signed an implementing agreement for cooperation on a future NASA Mars lander called the Interior Exploration Using Seismic Investigations, Geodesy, and Heat Transport (InSight) mission.[216] InSight will investigate the dynamics of Martian tectonic activity and meteorite impacts using the CNES Seismic Experiment for Interior Structure instrument. Partners in developing the instrument include the DLR, UK Space Agency, Swiss Space Office (through the ESA), and NASA.

Russia's cooperative arrangements and programs

In the wake of increased tensions with the United States, Russia strengthened cooperative efforts with India and China.[217] In February 2014, India and Russia agreed to a series of consultations on space cooperation and joint ventures.[218] In May, Russia and China agreed to create a joint high-level working group for strategic Russian-Chinese space cooperation projects.[219] Some projects involved tapping Russia's transit potential and cooperation in navigation systems.

In June, Russia ratified an agreement with Kazakhstan on the peaceful exploration and use of outer space. The agreement covers the distribution and protection of intellectual property rights, export control, defense of property and technology, and customs clearance procedures. In October, Russia ratified a similar agreement with Cuba.[220]

Additional cooperative programs include an agreement for the placement of a satellite navigation monitoring system in Nicaragua,[221] and a deal with Iran on broad cooperation in space exploration, including the training of Iranian cosmonauts and the construction of an Iranian reconnaissance satellite.[222] Russia and the EU were preparing an agreement on the joint exploration of the Moon.[223] The research program includes the launch of the Trace Gas Orbiter in 2016, the exploration of ice on Mars, and the landing of a Martian rover in 2018.

China's cooperative arrangements and programs

In January 2014, during the International Space Exploration Forum held at the U.S. State Department, Xu Dazhe, head of the China National Space Administration, announced that China was willing to cooperate with all countries in the world, including the United States.[224] Xu also noted that the U.S. invitation for China to participate in the forum sent a positive signal. Jean-Yves Le Gall, head of CNES, noted that "there is a change in the Chinese attitude, with a call for cooperation in space. And Americans aren't reticent—on the contrary."[225]

On September 18, China and India signed an MOU.[226] The agreement encourages exchanges and cooperation in the exploration and use of outer space for peaceful purposes, including research and development of scientific experiment satellites, remote sensing satellites, and communications satellites.

On 11 December, the Chinese Manned Space Agency and ESA signed a cooperative agreement on human spaceflight activities.[227] Three potential areas of cooperation were identified: joint scientific experiments utilizing in-orbit infrastructures; astronaut selection, training, medical operations, and flights; and space infrastructure cooperation in human space exploration. The ESA indicated a willingness to continue to advocate for Chinese participation in the ISS.

More informally, China's space industry leaders invited other nations to take part in China's emerging space station program at the 27th Planetary Congress of the Association of Space Explorers, held in September 2014 in Beijing.[228] In September 2011, China initiated a multistep space station program, sending the Tiangong 1, its first space lab and still-operating spacecraft, into orbit. The liftoff of China's Tiangong 2 space lab is scheduled for 2016. "We reserved a number of platforms that can be used for international cooperative projects in our future space station when we designed it," said Yang Liwei, deputy director of China Manned Space Engineering.

Canada's cooperative arrangements and programs

Canada signed and renewed a number of cooperative agreements in 2014, including those with Brazil, France, Israel, Norway, and the United States, to enhance space remote sensing of the ocean environment and climate in the Arctic, in particular to observe Canada's Far North and the Northwest Passage, increase research and development, enhance space-based search-and-rescue systems, and exchange expertise.[229]

Regional cooperative initiatives

APRSAF held its twenty-first session 2-5 December 2014 in Tokyo, Japan.[230] Ten proposals for new cooperative ventures were presented, including industrial cooperation, micro-satellite application, workshops for the younger generation, asteroid observation networks, engineering design methodology, and spaceports.

APSCO held a workshop on space law in China from 17-20 November 2014 (see Indicator 4.3).

In 2014, member states of the Group of Latin American and Caribbean States held several events to strengthen regional cooperation in space-related initiatives. In Argentina in May and Bolivia in July, Venezuela conducted a course on "Space Project Management" hosted by the Bolivarian Agency for Space Activities.[231] The course analyzed future strategies on cooperation in space activities. Also in July, a seminar on international space-based cooperation for sustainable development in Latin America was held in Bogota, Colombia. The seminar examined space cooperation opportunities for, inter alia, preserving the environment, reducing the effects of global warming, protecting natural resources, and border control.[232]

Cooperation in global utilities

The United States and Russia initiated bilateral GNSS cooperation in December 2004, with the primary goal of enabling civil interoperability at the user level between GPS and GLONASS.[233] In June 2012, the two nations issued a renewed statement of cooperation on GNSS.[234] Shortly before the 2012 bilateral statement of cooperation, Russia had requested that the U.S. government consider hosting sites of Russian System of Differential Correction and Monitoring (SDCM) on U.S. territory.[235]

SDCM is a space-based augmentation system designed to provide integrity alerts and improve positioning accuracy for users, including civil aviation.[236] Many of the SDCM ground reference stations track and have been providing data on, not only GLONASS, but also GPS signals.[237] SDCM should not be confused with the ground stations that Roscosmos and Ministry of Defense use as part of the GLONASS operational control segment.[238] As of June 2014, the U.S. State Department was still considering the request, noting that Russia has yet to provide a written civil signal performance standard to accompany its request.[239] In April the same U.S. government directive that suspended bilateral cooperation between NASA and Russia also put all U.S.-Russia cooperation to do with GNSS on hold.[240] As of November 2014, negotiations had not resumed.[241]

However, concern from U.S. military and security officials prompted Congress to become involved.[242] The House and Senate announced on 9 December 2013 that they had agreed on language in the 2014 National Defense Authorization Act to require the president to obtain certification from the secretary of defense and the director of national intelligence before authorizing construction in the United States of any GNSS monitoring station that would be directly or indirectly controlled by a foreign government.[243] The requirements for certification set by the 2014 NDAA, Section 2279 are very specific and would be very difficult to meet: “The President may not authorize or permit the construction of a global navigation satellite system ground monitoring station directly or indirectly controlled by a foreign government (including a ground monitoring station owned, operated, or controlled on behalf of a foreign government) in the territory of the United States unless the Secretary of Defense and the Director of National Intelligence jointly certify to the appropriate congressional committees that such ground monitoring station will not possess the capability or potential to be used for the purpose of gathering intelligence in the United States or improving any foreign weapon system.”

In response, Russian Deputy Prime Minister Dmitri Rogozin announced that GPS base stations in Russia could not be used for military purposes and would be shut down on 1 September if the United States did not to agree to allow GLONASS monitoring stations on U.S. territory.[244] The 11 stations to which Rogozin referred, the North Eurasian GPS Deformation Array, are not operated by the United States, but are a Russian-controlled network of scientific research stations that are part of the International GNSS Service (IGS) network.[245] Russia has reportedly been providing post-processed, but not real-time data from the stations.[246]

There is speculation that Russia may request the use of existing IGS sites in the United States for monitoring and augmentation of GLONASS.[247] The main difference between using the IGS service for monitoring and augmentation of GLONASS and setting up a proprietary Russian monitoring station is the service and availability guarantee that IGS is not able to offer.

Iran[248] and Cuba[249] agreed to host GLONASS and SCDM monitor/reference stations in May and June 2014, respectively; in September, the Deputy Director General of Russian

Space Systems indicated that Russia is planning to place three SDCM reference stations in China, two in Kazakhstan, and one in Belarus in the near future.[250]

On 19 May 2014, the United States and China began bilateral consultations on civil cooperation concerning GPS and the Beidou Navigation Satellite System.[251]

International cooperation in development of commercial space transportation

In March 2014, the U.S. Federal Aviation Administration (FAA) Office of Commercial Space Transportation executed a Memorandum of Cooperation (MOC) with the Italian Ente Nazionale l'Aviazioine Civile.[252] In July 2014, the FAA office signed a similar agreement with the UK Civil Aviation Authority and UK Space Agency.[253] MOC participants intend to cooperate in enhancing the free movement of space transport vehicles between the respective countries, compiling safety data, recovery of persons and vehicles involved in space transportation, and in developing safety regulations for commercial space transportation.

Indicator 2.4: Growth in commercial space industry

While commercial space activity is for profit, commercial operation, commercial manufacture, commercial (contracted) service provision, fully commercial service, and fully commercial have different standards that are often conflated.[254] This section covers primarily activities that can be described as fully commercial—activities in which only private entities are involved in financing, decision making, and management. Indicator 2.5 focuses on joint government-private ventures.

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, makes 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.

Today's space telecommunications sector emerged from what were previously government-operated bodies that were deregulated and privatized in the 1990s. For example, the International Maritime Satellite Organisation (Inmarsat) and International Telecommunications Satellite Organization (Intelsat) were privatized in 1999 and 2001, respectively.

Revenues from the global satellite industry nearly tripled from 2004 to 2013, approaching annual revenues of $200-billion. While the average annual growth rate of the industry in that period was 11%, growth has slowed since 2010.

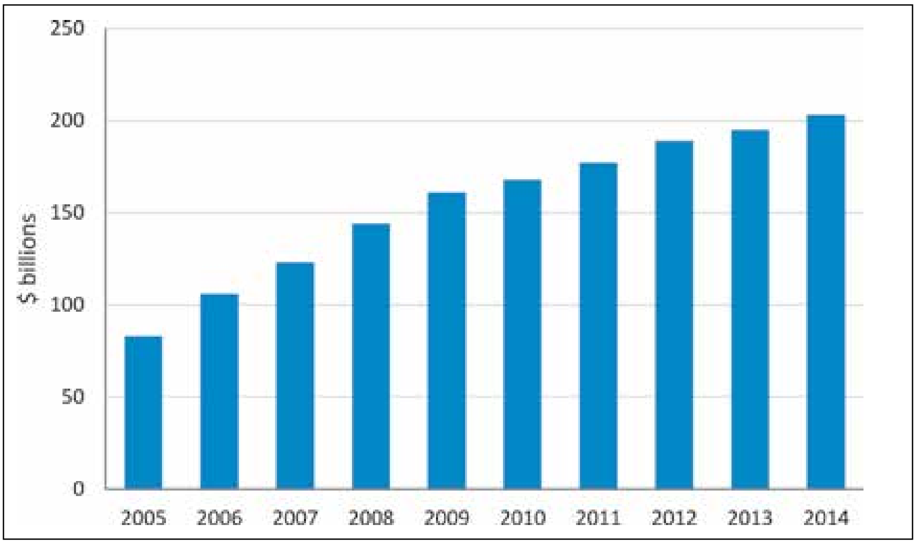
The shape of the commercial space industry began to shift as it became more global. Although Europe, Russia, and the United States are still dominant players, India and China have become increasingly involved, with developing countries the prime focus of their efforts.[255] Since the commercial arm of ISRO—Antrix Corporation Limited—was established in 1992, India has been positioning itself to compete for a portion of the commercial launch service market by offering lower-cost launches.[256] The China Great Wall Industry Corporation is the only commercial organization authorized by the Chinese government to provide satellites and commercial launch services and to carry out international space cooperation. For the first time in 2007, China both manufactured and launched a satellite for another country: Nigeria's Nigcomsat-1.[257]

2014 Developments

Growth in the satellite industry in 2014

The satellite industry accounts for 63% of the global space industry. According to the Satellite Industry Association (SIA), estimated global revenue for the satellite industry in 2014 was $203-billion, a 4% increase over the $195.2-billion of the previous year (outpacing the worldwide economic growth rate of 2.6%).[258]

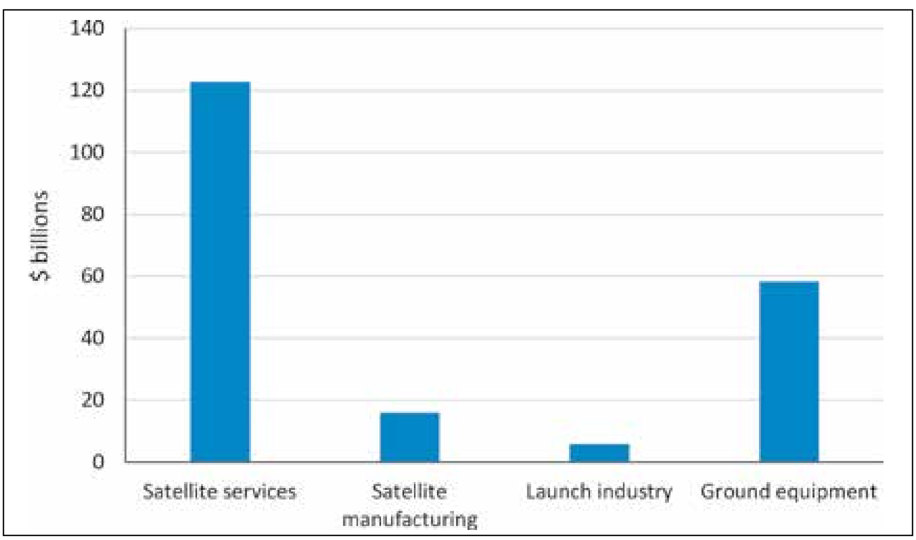
Figure 2.6 Global satellite industry revenues*[259]



* includes fully commercial activities and public-private collaborations

The global commercial satellite industry consists of satellite service providers, satellite manufacturers, the launch industry, and providers of ground equipment.

Figure 2.7 Satellite industry revenue by sector in 2014*[260]



* includes fully commercial activities and public-private collaborations

Launch industry revenues grew the most (9%), followed by the ground equipment segment (5%), satellite services (4%), and satellite manufacturing equipment (1%).[261] The consumer services segment is the most profitable of satellite services; 95% of revenue for that segment is from satellite television.[262]

Figure 2.8 Satellite industry revenue (in $-billion) by sector over five years*[263]

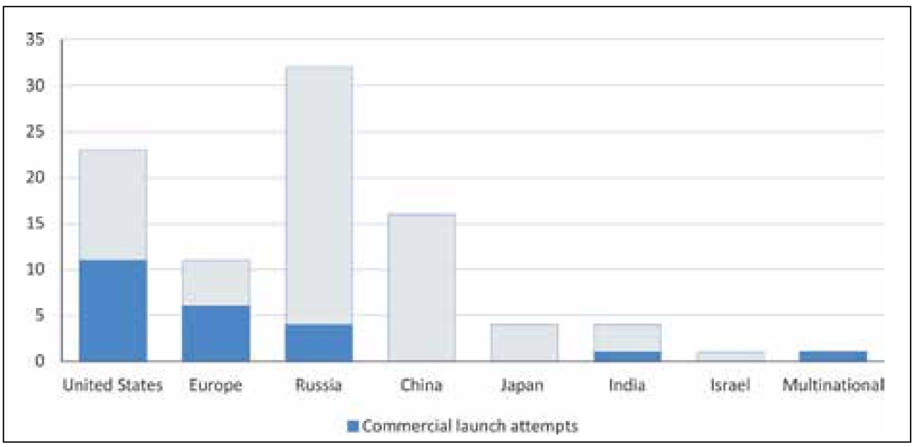
	Satellite services	Satellite manufacturing	Launch industry	Ground equipment
2009	92.8	13.4	4.5	49.9
2010	99.2	10.7	4.4	51.6
2011	107.8	11.9	4.8	52.8
2012	113.5	14.6	5.8	54.9
2013	118.6	15.7	5.4	55.5
2014	122.9	15.9	5.9	58.3

* includes fully commercial activities and public-private collaborations

Satellite launches in 2014

Twenty-three of the 92 launch attempts in 2014 are described as commercial by the FAA; in 2013, 20 of 81 launches were commercial.[264] The number of commercial geosynchronous launches decreased from 11 in 2013 to 10 in 2014—the lowest number since 2007.[265] The only providers of commercial launches in 2014 were Russia, the United States, Europe, India, and the multinational Sea Launch.[266] Revenues from 2014 commercial launches were approximately $2.36-billion, nearly half a billion dollars more than in 2013.[267]

Figure 2.9 Total and commercial* orbital launch attempts by state in 2014[268]

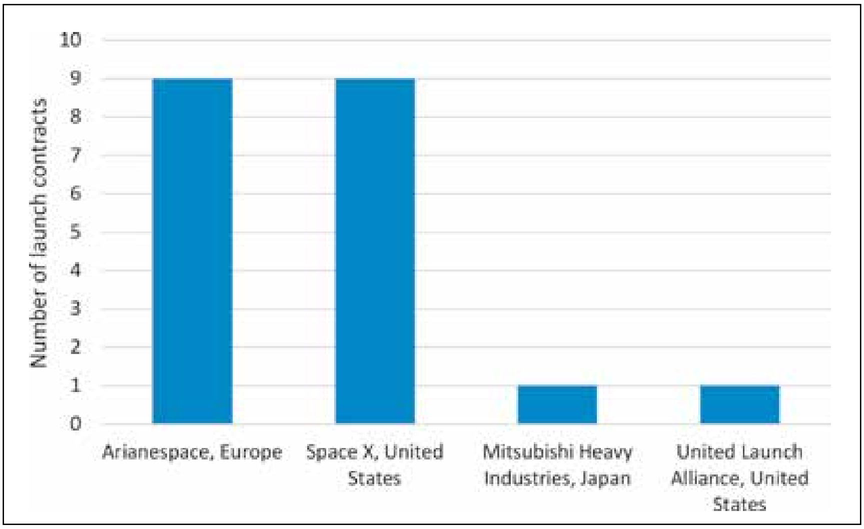


* privately financed without government support

Governmental satellites are typically launched domestically in the United States, Russia, China, and India.[269] There is no policy on the choice of launcher for the institutional satellites of ESA member states.

In 2014, commercial launch service providers "booked 19 orders open to competitive bidding for satellites to launch into geostationary orbit."[270] Another eight satellites, including Indian and Chinese spacecraft, were booked, or were soon to be booked, by national launch providers without competitive bids.[271] The most striking feature of the 2014 contract tally is the absence of Russian and Russian-Ukrainian launch service providers International Launch Services and Sea Launch AG, which have had reliability or supply chain concerns. Both specialize in launching larger satellites, which were out of favor in 2014—a year dominated by small and midsize spacecraft.

Figure 2.10 Orders in 2014 for commercial* launches into GEO[272]



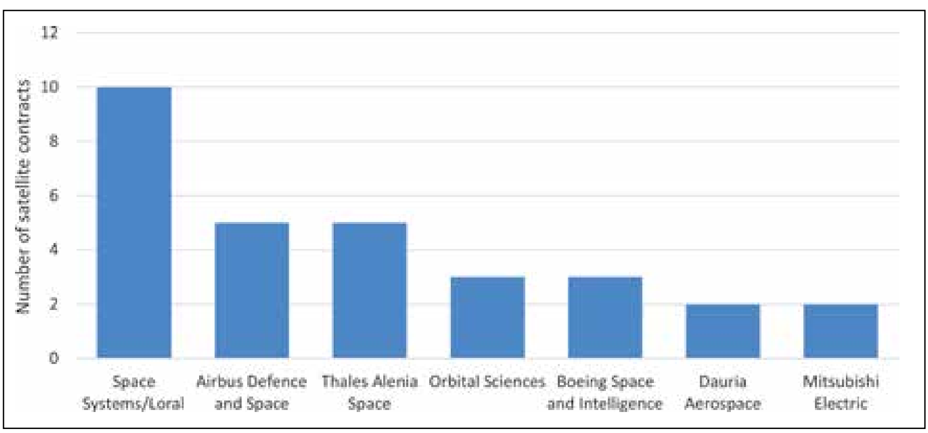
* open to competitive bidding

Commercial satellite market

According to the brochure for the 2014 Euroconsult Report, *Satellites to be Launched by 2023*, 350 satellites will be launched over the next decade, most replacing existing capacity. These satellites will be spread between GEO and lower-altitude orbits (MEO and LEO).

Twenty-six commercial satellites open to competitive bidding and intended for GEO were ordered in 2014, up from 23 the previous year.[273] Contracts for satellites in lower orbits included several for Earth imaging satellites; two hyperspectral missions booked by Boeing for its new, smaller satellite platform; Airbus's contract for a Peruvian optical reconnaissance satellite; and SSL's agreement to build 13 low-orbiting satellites for SkyBox Imaging.

Figure 2.11 Orders in 2014 for commercial* geostationary satellites[274]



* open to competitive bidding

Developments in space insurance

According to space insurance underwriters, 2013 was their first money-losing year since 2007, with more than $800-million in claims likely.[275] Final figures for 2014 will not be available until December 2015 when the last in-orbit policy expires, but insurers expect 2014 to be only marginally profitable, with estimated income of approximately $700-million and claims of approximately $650-million.[276] The largest claims came from the total loss of a Russian government communications satellite due to failure of the Proton-M launch vehicle on 22 May, and the failure of six Russian Ku-band beam transponders on the ABS-2 successfully launched on February 6.

The industry notes that in-orbit reliability of all mainstream satellite manufacturers has dramatically improved in the last decade, but the market continues to be nervous of Russian hardware—in particular, the Proton launch vehicle.[277] Favorably viewed are the Ariane 5 and, more recently, the Falcon 9, which has an excellent public relations department and offers full transparency to underwriters.

Mergers in the space industry continue

Established actors are creating larger groups in an attempt to increase the vertical integration of their production lines.[278] Notable 2013 mergers included the acquisition of U.S. commercial satellite builder Space Systems/Loral by Canada's MDA Corporation, the merger of GenCorp's Aerojet and Pratt & Whitney's Rocketdyne to form Aerojet Rocketdyne, and the creation of the URSC from 49 Russian organizations and companies involved in space activities (see Indicator 2.2). The merger of U.S. satellite- and rocket-builder Orbital Sciences Corporation and Aerospace and Defense groups of Alliant Techsystems Inc. (ATK) was announced in April 2014 and finalized on 9 February 2015.[279]

Associations blur between commercial satellites and specific states

Assigning space activity to particular states makes less sense today, when every aspect of each launch can involve organizations from several countries and international organizations.[280] While governments retain a vital role in space affairs—as funders of major institutional R&D programs and as customers—the private industry supply chains are getting more complex, influenced by major multinational space companies.[281]

For example, the Antares 120 rocket, a medium-class launch vehicle, is integrated in the United States and owned by U.S. company Orbital ATK, but uses a first stage built in Ukraine with a Russian engine. It is counted as a U.S. rocket.[282]

Commercial entities provide satellite services for the developing world

Thuraya Telecommunications Company, a leading Mobile Satellite Services operator, and Airtel Africa, Africa's largest internet service provider, announced the commercial launch of Thuraya's mobile satellite products and services across 12 countries in Africa on 3 November 2014.[283] The collaboration spearheads the convergence of satellite and mobile communications to address the growing demand for communications technology in Africa. Airtel Africa is the only African mobile phone network to offer instant, ubiquitous, 100% geographical coverage through terrestrial and mobile satellite connectivity. "Thuraya's partnership with Airtel Africa is a very positive development in bridging the digital divide in Africa," Samer Halawi, chief executive of Dubai-based Thuraya, said in a prepared statement.[284]

O3b has continued to launch satellites that provide internet and telecommunications service to developing countries, launching four satellites from Guiana in December 2014. "O3b," which stands for "other three billion," refers to the number of people in the world with no access to reliable or fast internet services.[285] OneWeb[286] and SpaceX[287] (see below) announced plans to provide affordable broadband internet services to rural and under-served regions.

Emerging trends

Several commercial satellite-based services are emerging: SSA (see Indicator 1.4), data for weather forecasting (see Indicator 2.1), satellite AIS (see Indicator 2.1), and satellite servicing (see Indicator 3.2).

Increasing investment in commercial space ventures

According to 2015 reports, the number of companies in the global space industry has increased six-fold since 2010, to more than 800.[288] Increasing investment in commercial space ventures, which is expected to total $10-billion from 2010 to 2015, is supporting substantial growth.[289] Silicon Valley is a key player in the new space race. Big and small enterprises aim to disrupt space technology, revolutionizing telecommunications, Earth observation, satellite manufacturing, and space travel.[290] Spire Global Inc. (formerly Nanosatisfi, Inc.) launched its first satellite in 2013 after raising funds through crowdfunding. In 2014, Spire raised $25-million for the 2015 launch of 20 CubeSats that track shipping and weather.[291]

In the most notable example of large enterprise investment in commercial space, in August 2014, Google bought SkyBox Imaging, which provides commercial high-resolution EO satellite imagery and video (see Indicator 2.1).[292] In January 2015, together with investment firm Fidelity, Google invested $1-billion in SpaceX.[293] This deal is expected to support the development of SpaceX satellites that could beam low-cost internet to underserviced areas around the globe.[294] In April 2014, Google purchased Titan Aerospace to provide internet service to the developing world from a fleet of solar-powered drones.[295]

Development of reusable launch vehicles

Reusable launch vehicles would significantly reduce the cost of launching spacecraft. SpaceX continued flight tests of a planned reusable first-stage motor (see Indicator 3.2). Blue Origin is working on reusable launch vehicles for both orbital and suborbital flights.[296] Virgin Galactic and XCOR Aerospace are developing reusable space planes SpaceShipTwo and Lynx, respectively, which will take paying passengers to suborbital space and back.[297]

Electric propulsion

According to many industry actors, by 2020 the commercial market will be shared by satellites with conventional chemical propulsion and satellites with all-electric propulsion.[298] Propulsion systems transfer the satellite from its injection orbit to its final orbit, modify the orbital moves induced by natural disturbances, correct orientation of the satellite as needed, and enable appropriate end-of-life disposal maneuvers.[299] The electric propulsion system is lighter than a traditional chemical system.[300] Half the weight of most communications satellites with conventional chemical propulsion is fuel. The lighter electric-propulsion satellite can carry a heavier payload and be launched more cheaply. On the down side, satellites with all-electric propulsion are slightly more expensive to purchase; more importantly, because electric propulsion systems generate less thrust, these satellites can take months to reach their operating orbits, while satellites with chemical propulsion take only days. In March 2015, Boeing confirmed commercial orders for five all-electric satellites and three sales to the U.S. government for classified missions in the last year.[301] Airbus Defence and Space sold three of its all-electric satellites in the last year.[302]

Commercial applications for CubeSats and other small satellites

While most research and development satellites launched in 2013 were CubeSats, the eight commercial CubeSats launched that year accounted for less than 1% of revenue.[303] In 2014, 101 commercial CubeSats were launched for EO services and communications. Ninety-three were built and operated by Planet Labs.[304] There is continued and growing interest in commercial applications of CubeSats and other small satellites. Other companies that use small satellites (less than 200 kg) include Dauria/Elcnor, DigitalGlobe, Skybox, and Spire; companies with plans to use small satellites include Aquila Space, GeoOptics, NorStar, OmniEarth, and PlanetiQ.[305]

Commercial space travel

Investment in commercial space travel

Commercial space travel is benefitting from investment by 70 identified ultra-high net worth individuals—people with at least $30-million in net assets.[306] "Investment in commercial space flight has become one of the big trends among the super-rich," says Liam Bailey, head of global research at Knight Frank.[307] There are now about 10 private companies engaged in space transport, including SpaceX, created by billionaire PayPal co-founder Elon Musk, and Blue Origin, founded by Amazon's chief executive Jeff Bezos. Space tourism, driven by companies such as Sir Richard Branson's Virgin Galactic and Jeff Greason's XCOR Aerospace, will offer suborbital spaceflights.

U.S. FAA releases report on commercial human spaceflight safety

On 27 August 2014, the Office of Commercial Space Transportation at the FAA released the report *Recommended Practices for Human Space Flight Occupant Safety,*[308] which provides safety guidelines for suborbital and orbital crewed vehicles. The 56-page document covers the design, manufacturing, and operations of these vehicles.

A provision in the Commercial Space Launch Amendments Act of 2004 temporarily restricts the ability of the FAA to enact safety regulations, except in the case of accidents that cause serious or fatal injuries, or incidents that pose a "high risk" of such injuries. In the original act, that provision was set to expire in December 2012; however, an FAA authorization bill passed in early 2012 extended the deadline to 1 October 2015.

Suborbital spaceplane designed for space tourism crashes in test flight

SpaceShipTwo is an air-launched suborbital spaceplane designed for space tourism by Virgin Galactic.[309] During a test flight on 31 October 2014, the first SpaceShipTwo craft broke up in-flight and crashed in the Mojave Desert. One of the two pilots was killed. U.S. federal investigators from the National Transportation Safety Board led the investigation into the crash.[310]

Southwest Research Institute plans to add solar observatory to manned suborbital spaceflights

Southwest Research Institute hopes to use commercial manned suborbital spaceflights as a platform for testing space instruments. They have developed the Solar Instrument Pointing Platform, a miniature portable solar observatory, which will be deployed on XCOR's Lynx spacecraft to allow inexpensive space-based observation. Although the platform was initially intended to operate inside the spacecraft, new plans are to mount a full system on the exterior of a host vehicle.[311]

Bigelow showcases full-scale model of BA 330 space habitat

Bigelow Aerospace unveiled a full-scale model of their BA 330 expandable space habitat at their facility in Las Vegas in 2014.[312] The craft will support zero-gravity research, including scientific missions and manufacturing processes and has potential as a destination for space tourism. The Bigelow Expandable Activity Module, which will be attached to the ISS, is on schedule for launch in 2015. NASA is paying Bigelow $17.8-million for the module.[313]

Midland International Airport receives FAA license

Midland Airport in Texas has officially become the first primary commercial service airport to receive FAA certification as a spaceport. The approval was announced in a joint release that included XCOR Aerospace and Orbital Outfitters. Next steps include hangar renovation to accommodate the XCOR Lynx vehicle and the development of procedures to integrate spaceflight operations into airport operations and airspace. The goal is to leverage existing facilities until the construction of new facilities is needed.[314] Other spaceport developments in Texas include a SpaceX facility in Brownsville[315] and a Blue Origin Facility in Van Horn.[316]

Virgin Galactic/FAA reach agreement on Spaceport America

Virgin Galactic and Spaceport America signed a joint agreement with the FAA to help clear the path for upcoming SpaceShipTwo commercial operations. Outlined in the agreement is the procedure by which Albuquerque Air Route Traffic Control Center and the New Mexico Spaceport Authority can work with Virgin Galactic to provide clear airspace for their operations. The agreement is a step toward the safe integration of commercial launch operations and aviation in the National Airspace System. This agreement supplements the agreement between the New Mexico Spaceport Authority and the neighboring White Sands Missile Range to support launch activities in their airspace. Virgin holds a 20-year lease on the terminal building at Spaceport America.[317]

UK unveils eight potential locations for commercial spaceports

The UK government announced plans to construct at least eight spaceports, with as many as six sites in Scotland. The UK aims to establish its first spaceport by 2018. The spaceports are intended to be sites for both satellite launches and commercial spaceflights. The space industry is among the UK's fastest growing industries, generating more than $18.8-billion annually.[318]

Indicator 2.5: Public-private collaboration on space activities

There is an increasingly close relationship between governments and the commercial space sector. A number of national space policies place great emphasis on maintaining a robust and competitive industrial base and encourage partnerships with the private sector. Many spacefaring states consider their space systems an extension of critical national infrastructure; a growing number view their space systems as inextricably linked to national security

Governments play a central role in commercial space activities by supporting research and development, subsidizing certain space industries, and adopting enabling policies and regulations. Full state ownership of space systems has now given way to a mixed system in which many commercial space actors receive significant government and military contracts and a variety of subsidies.

The United States, in particular, has partnered with the private sector to subsidize the commercial development of systems intended to meet national needs. The Evolved Expendable Launch Vehicle (EELV) program was initiated in 1994 to provide the U.S. government with competitively priced, assured access to space.[319] The EELV program produced two families of launch vehicles—Boeing's Delta IV and Lockheed Martin's Atlas V—to provide critical spacelift capability to support Department of Defense and other National Security missions. Boeing and Lockheed Martin merged the Delta IV and Atlas V programs to form the United Launch Alliance (ULA) in 2006. November 2011 saw the approval of a new EELV Acquisition Strategy, which continues procurement of launch services and launch capability from ULA for the next several years, but provides for a full and open competitive environment for alternative sources as soon as they are certified.

NASA's Commercial Crew and Cargo Program Office manages a number of programs to facilitate U.S. private industry demonstrations of cargo and crew space transportation capabilities with the goal of achieving safe, reliable, cost-effective access to LEO.[320] The Commercial Orbital Transportation Services (COTS) program coordinates delivery of crew and cargo to the ISS by private companies.[321] COTS, which is involved in the development of vehicles, is related to, but separate from, the Commercial Resupply Services program, which deals with actual deliveries[322] Commercial Crew Development (CCDev) is another related program, aimed specifically at developing crew rotation services.[323]

Europe has long sought access to space through partnership with its commercial space industry. Arianespace was founded in 1980 as the world's first commercial satellite launch company.[324] Its launcher, Ariane 5, is a solid success, commanding half the global commercial launch market and undergoing progressive modification and performance enhancements.[325] While commercial activity finances a significant amount of launcher exploitation costs, over the years Ariane-5 has benefited from continuous support from the ESA-funded Ariane Research and Technology Accompaniment program.[326] Other support has come from the public funding of member states, injected through the European Guaranteed Access to Space Program,[327] which covered selected fixed costs associated with the production of a batch of Ariane-5 for the period 2004 to 2010.

As commercial capabilities evolved, the dynamic between governments and commercial actors started to shift away from subsidies. Increasingly, governments are turning to the commercial sector in search of lower-cost services and innovation. The U.S. National Security Space Strategy of 2011 states, "Strategic partnerships with commercial firms will be pursued in areas that both stabilize costs and improve the resilience of space architectures on which we rely."[328] The growing interdependence between the military and commercial space industry could have an adverse impact on space security by making commercial space assets potential targets of military attacks.

National security concerns continue to play an important role in the commercial space industry, particularly through export controls. Trade restrictions aim to strike a balance between commercial development and the proliferation of sensitive technologies that could pose security threats. Achieving this balance is not easy, particularly in an industry characterized by dual-use technology. Space launchers and intercontinental ballistic missiles use almost identical technology, and many civil and commercial satellites contain advanced capabilities with potential military applications.

International Traffic in Arms Regulations (ITAR) control the export and import of defense-related articles and services on the United States Munitions List. Satellites and satellite components have been subject to ITAR since 1999. ITAR add reporting and licensing requirements that must be met by U.S. satellite manufacturers, which complicate or prevent sales of satellites and satellite components to foreign customers. The commercial satellite industry has argued that the regulation of space-related commodities by ITAR has eroded U.S. competitiveness in the international space market.[329]

2014 Developments

United States

Uncertainty about import of RD-180 engines for EELV contractor ULA

With future imports of RD-180 engines uncertain (see Indicator 2.3), the U.S. government and industry actors have been exploring ways to avoid a disruption of EELV national space security launches. In September 2014, ULA announced a partnership with Blue Origin to develop a domestically sourced rocket engine.[330] In December, the FY2015 National Defense Appropriations Act allotted $220-million for the development of a new U.S.-built engine, with a target demonstration date of 2019.[331] The DoD has not supported the idea of initiating a large, government-run program to replace the RD-180[332] and, at a February 2015 hearing of the Senate Appropriations Committee's Defense Subcommittee on the Air Force FY2016 budget request, Air Force Secretary Deborah Lee James said that meeting the congressional mandate to have a new engine by 2019 may not be doable.[333]

There is also concern that the exemptions on the ban on importing RD-180 engines, intended to allow ULA to continue launches through 2019, do not apply to many of the engines on order (see Indicator 2.3).[334]

U.S. military continues to explore commercial partnerships

Customers and contractors explored new payload arrangements in 2014 in an effort to lower costs, increase efficiencies, and augment security. On 28 July 2014, the USAF Space and Missile Systems Center awarded 14 companies contracts from the $495-million Hosted Payload Solutions Program.[335] The term "commercially hosted payloads" refers to the use of available capacity on commercial satellites to accommodate additional transponders, instruments, and other space-bound items.[336] By "hitchhiking" on commercial spacecraft already scheduled for launch, government agencies can send sensors and other equipment into space on a timely and cost-effective basis.

On 22 October 2014, the USAF awarded a contract to Intelsat to explore opportunities to leverage commercially available satellite tracking, telemetry, and command technologies for use on government satellites as part of the Air Force Satellite Control Network Commercial Provisioning Study.[337]

The USAF awarded study contracts to four companies in September 2014 to gauge how the companies might maintain one or more of the seven ground-based satellite-operating facilities of the Air Force Satellite Control Network. In response to possible budget cuts, these companies might provide data uplink and downlink, command and control, communications, software, and testing if one or more of the sites were closed in response to possible budget cuts.[338] Centered at Schriever Air Force Base in Colorado, these facilities are reported to have antiquated, inefficient infrastructure in need of modernization.[339] While there is a degree of concern that outsourcing such options could privatize military operations or increase chances of security breaches, industry involvement in these areas is not unique. Harris Corp. was awarded $26-million in October 2014 in a one-year contract extension of their current maintenance of Air Force satellite operations facilities. Similarly, BAE Systems Aerospace Services received a three-year contract extension in March to maintain the Solid State Phased Array Radar System, used for missile warning and space surveillance.[340]

The DoD's satellite communication purchasing practices have been the subject of much debate. Some lawmakers have emphasized the high costs of military-owned communication satellites and the advantages of using commercially available bandwidth.[341] However, in October, a DoD report found that the purchase of bandwidth from commercial providers is nearly four times more expensive than using the military's own constellation, the Wideband Global SATCOM (WGS) system.[342] These findings were corroborated by U.S. allied governments, which generally, if not unanimously, agreed that WGS bandwidth was less expensive than commercial.[343] Nevertheless, key USAF stakeholders, such as Gen. John Hyten, commander of Air Force Space Command, voiced support for a blended approach, buying both commercial and military bandwidth.[344]

NASA continues to partner with the commercial space industry for essential capabilities

Part of the CCDev program, Commercial Crew Transportation Capability is the second phase of a two-phase certification plan for commercially built and operated integrated crew transportation systems. In September 2014, Boeing and SpaceX were awarded contracts worth a total of $6.8-billion to continue development of spacecraft capable of transporting NASA astronauts to and from the ISS.[345]

In 2008, NASA awarded Orbital Sciences a $1.9-billion contract for commercial cargo resupply services for eight flights to take place between 1 January 2009 and 31 December 2016.[346] Orbital Sciences designed the Cygnus spacecraft, an automated cargo spacecraft, to transport supplies to the ISS following launch on an Antares rocket. The first two missions, Orb-1 on 9 January 2014 and Orb-2 on 13 July 2014, were successful. Orb-3 failed on 28 October 2014, when the Antares rocket exploded seconds after launch and the Cygnus spacecraft and its scientific payload were lost.[347] Subsequently, Orbital Sciences contracted with Russia's Energomash to supply RD-181 engines to replace the AJ-26 engine that powered the first stage of the Antares rocket and are suspected of causing the 28 October failure.[348]

NASA collaborations included the Lunar Cargo Transportation and Landing by Soft Touchdown initiative announced on 30 April 2014.[349] NASA will help three companies advance robotic lunar lander capabilities that could deliver payloads to the Moon's surface. Another project is the Collaborations for Commercial Space Capabilities initiative; in one case, NASA will work with Final Frontier Design "to collaborate on the development, design review, and testing of its launch and re-entry space suit for orbital space flight."[350]

NASA seeks partners to detect asteroids

NASA's Asteroid Grand Challenge is "a large-scale effort that will use multidisciplinary collaborations and a variety of partnerships with other government agencies, international partners, industry, academia, and citizen scientists to detect, track, characterize, and create mitigation strategies for potentially hazardous asteroids"[351] (see Indicator 1.3). Achievements of the Challenge, which began in 2013, include the development of new algorithms for asteroid detection and the creation of the Asteroid Explorers Web Tool, "which provides better visualizations for datasets used to find asteroids."[352]

DARPA seeks public-private partnership for cooperative robotic servicing

DARPA issued a Request for Information, "seeking insights to help to develop a sustainable, commercially owned and operated space robotics servicing enterprise"[353] (see Indicator 3.2).

ITAR no longer apply to most commercial satellites

On 13 May 2014, the U.S. Departments of State and Commerce released a set of interim final rules that move many commercial satellites and related items from the U.S. Munitions List to the Commerce Control List.[354] The new rules took effect in stages between 27 June and 10 November 2014. As of November 10, most U.S. commercial communications satellites were no longer considered defense articles subject to the ITAR. The space industry was reportedly generally pleased with the changes, but still considered the export control rules too complicated and was concerned that the Commerce Department, which oversees the Commerce Control List, was stepping up its export control enforcement efforts.[355]

NOAA allows sale of high-resolution satellite imagery after request by DigitalGlobe

Since commercial satellite remote sensing was first envisioned in the 1980s, the U.S. government has steadily relaxed image-resolution limits on commercial imaging satellites. NOAA, which is part of the Department of Commerce, is responsible for licensing commercial remote sensing satellites under the 1992 Land Remote Sensing Policy Act.[356] The resolution limits reflect a tension between those who want to restrict availability of the very best imagery to those involved in protecting U.S. national security and those who want to make such data widely available for multiple uses and to more easily enable sharing with other countries.

Previously, U.S. companies were allowed to sell commercial images up to 0.5 m resolution. In response to a 2013 request by DigitalGlobe, which operates a fleet of five high-resolution imaging satellites, two of which can provide better than 0.5 m resolution, NOAA changed the threshold for legal resolution to 0.4 m. The threshold will fall to 0.25 m six months after DigitalGlobe's WorldView-3 satellite, launched 13 August 2014, becomes operational.[357]

The White House made the decision to loosen restrictions after soliciting input from other government stakeholders, including the intelligence community, which publicly endorsed the change in April, and State and Defense departments.[358] Ken Hyatt, Deputy Undersecretary for International Trade in the Commerce Department, said the U.S. government's decision "to permit the commercial export of satellite Earth imagery with a sharper resolution than what was permitted before is another example of a trade-friendly policy addressing industry requests."[359]

U.S. Export-Import Bank supports satellite industry

The Export-Import Bank of the United States is the official export credit agency of the U.S. federal government.[360] Satellite financing has become the bank's fastest growing sector, "rising from $50 million annually to $1 billion per year since 2010."[361] By early 2014, more than 60% of all U.S.-built commercial satellites received financing from the Export-Import Bank, with 16 major loans totaling $4.1-billion.

Europe

Increased funding for European space R&D with Horizon 2020

European space-related research and development are funded by ESA, the EU, and seven-year R&D Framework Programmes that have had, in recent years, a dedicated budget line for space. The Framework program FP6 received €240-million ($300-million) for space R&D (2000-06). FP7, for the period 2007-13, received €1.43-billion ($1.8-billion). In the Horizon 2020 programme (2014-20), space R&D funding will reach €1.73-billion ($2.27-billion). The key objective of the Horizon 2020 program on space research and innovation is "to foster a competitive and innovative space industry and research community to develop and exploit space infrastructures to meet future Union policy and societal needs."[362]

ESA agrees to develop Ariane 6 launch vehicle

On 2 December 2014, the member states of the ESA agreed to develop a new-generation Ariane 6 rocket to maintain Europe's share of the global commercial launch market (see Indicator 2.2).[363] There has been tension regarding the financing structure for the project.

The ESA will continue to make annual support payments to the Arianespace launch consortium so that it can avoid financial losses.

UK invests in space industry

The new investment by the UK Space Agency of more than £200-million in ESA (see Indicator 2.2) was intended to enable the UK space industry to pursue new markets worth more than £1.5-billion ($2.3-billion); the British hope to grow their space industry to £30-billion by 2030. One hundred and thirty million pounds ($200-million) will go to develop new telecommunications technologies.[364]

DLR and OHB fund study of SNC's Dream Chaser spacecraft

DLR and German satellite manufacturer OHB funded a study with American Sierra Nevada Corporation to assess the feasibility of using SNC's Dream Weaver spacecraft for a variety of missions including microgravity research and ADR. The initial study was completed in February 2015 and John Olsen, an official at SNC, indicated the company was working with OHB on the next phase of an ongoing collaboration with DLR.[365]

Other developments

Russia plans public-private partnerships and engagement of space entrepreneurs

At a March 2014 board meeting of Roscosmos, Russian Deputy Prime Minister Dmitry Rogozin recommended public-private partnerships to develop space exploration projects.[366] He declared that Roscosmos was "bound to play a prominent role and coordinate interaction with the private sector." To meet Russia's ambitions and capacities, Rogozin recommended seeking an off-budget source of financing. "It is a shame that Russia holds 3% of the space market, the market of space services," he said.[367]

The Russian government plans to transform the status of the whole space industry into an open joint stock company. In December 2014, Denis Lyskov, deputy director of Roscosmos, revealed government plans to gradually transfer LEO to private businesses: "We are willing to support them so they can create healthy competition for the government in space in the future."[368] According to Lyskov, the latest draft of the 2016-2025 Federal Space Program gave entrepreneurs the opportunity to learn about upcoming technologies and build on them to create their own products.

Commercial payload aboard Chinese lunar probe

The Chang'e 5-T1, an experimental unmanned lunar mission, was launched on 23 October 2014 by CNSA to conduct atmospheric reentry tests on the capsule design planned for use in the Chang'e 5 mission. Chang'e 5 T1 also carried the first private mission, Luxspace's 4M, to the Moon as a piggyback payload. The payload—battery, solar panel, radio, and radiation detector—remained attached to the rocket's upper stage for a lunar flyby and return to Earth.[369] LuxSpace developed the mission for approximately $500,000 in private funding.[370]

JAXA partners with industry for development of new launch vehicle

JAXA plans to partner with a private company to develop a new launcher to replace Japan's H-2A rocket by the early 2020s. "The Committee on the National Space Policy of the Cabinet Office has recommended that the private sector play a role throughout the flagship launch vehicle project to make an internationally competitive spacecraft,"[371] JAXA said in its 27 February invitation for bids. JAXA hopes that the new H-3 rocket will reduce launch costs from the $100-million for the H-2A rocket to between $50-million and $65-million. The H-2A rocket found little success in luring commercial contracts, despite 22 flawless launches in 23 attempts since its debut flight in August 2001.

Commercial opportunities involving the ISS

On 27 January 2014, two cameras belonging to Canadian company Urthecast were installed on the ISS as part of a commercial agreement between Urthecast and Roscosmos.[372] UrtheCast plans to sell images and videos to governments, corporations, and non-profit agencies. NASA issued a Request for Information to solicit ideas from companies that want to use the ISS LEO environment on how to develop the commercial market and help NASA achieve its goals of exploration.[373] NASA is committed to reducing and removing barriers to a commercially driven U.S. space market.

Indicator 2.6: Space-based military systems

Since the space age began, research, development, testing, and deployment of space systems have supported terrestrial military operations. Space assets play an important strategic role in the terrestrial military operations of certain states. Space systems can augment military capabilities by enhancing battlefield awareness—including precise navigation and targeting support, early warning of missile launch, and providing real-time communications. Remote sensing satellites have served as a technical means for states to verify international nonproliferation, arms control, and disarmament regimes. These uses have resulted in an increasing dependence on space, particularly by the major spacefaring states.

Extensive military space systems were developed by the United States and the USSR during the Cold War. Satellites offered an ideal vantage point from which to monitor Earth, providing strategic warning of signs of nuclear attack, such as the launch plume of a ballistic missile or the light signature of a nuclear detonation. Satellites also offered the first credible tool for arms control verification. The space age broke new ground in the development of intelligence, surveillance, and reconnaissance (ISR) through the use of satellite imagery and space-based electronic intelligence collection. Satellite communications also provided extraordinary new capabilities for real-time command and control of military forces deployed anywhere in the world.

By the end of the Cold War, the United States and Russia had begun to develop satellite navigation systems that provided increasingly accurate geographical positioning information. Building on the capabilities of its GPS, the United States began to expand the role of military space systems, integrating them into virtually all aspects of military operations, from providing indirect strategic support to military forces to enabling the application of military force in near real-time tactical operations through precision weapons guidance. Radar satellites offered the potential to detect opposition forces on the ground in all weather conditions at all times.

The United States has dominated the military space arena since the end of the Cold War and currently leads in deployment of dedicated space systems to support military operations, accounting for roughly half of all dedicated military satellites.[374] The United States continues to give priority to its military and intelligence programs.

Russia maintains the second largest fleet of dedicated military satellites.[375] Its early warning, imaging intelligence, communications, and navigation systems were developed during the Cold War and by 2003, 70-80% of these spacecraft had exceeded their designated lifespan.[376] Forced to prioritize upgrades, Russia focused first on its early warning systems and continues to attempt to complete the GLONASS navigation system, which was declared fully operational in 2011.[377] Since 2004, Russia has focused on “maintaining and protecting” its fleet of satellites and developing satellites with post-Soviet technology.[378] In 2006, the first year of a 10-year federal space program, Russia increased its military space budget by as much as a third, following a decade of severe budget cutbacks.[379] The Russian space budget rose 144% between 2008 and 2013.[380]

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 programs of many other actors, it is widely believed to provide support to the military. The Beidou regional navigation system is designed to enable China to maintain navigational capability if the United States were to deny GPS services in times of conflict.[381] Beidou may also improve the accuracy of China's intercontinental ballistic missiles (ICBMs) and cruise missiles.[382] Inside the People's Liberation Army, the General Armament Department is responsible for military space procurement.

India's National Satellite System is one of the most extensive domestic satellite communications networks in Asia. India has been developing GAGAN, a satellite-based augmentation system to enhance its use of GPS, as well as IRNSS to provide independent satellite navigation capability. Although these are civilian-developed and -controlled technologies, they are used by Indian military applications. The Cartosat-series remote sensing satellites are also generally considered dual-use.[383]

Australia, Canada, France, Germany, Israel, Italy, Japan, and Spain are developing multiuse satellites with a wide 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.

ESA is involved in a number of space projects with dual-use applications, including Galileo and Sentinel. The 2007 European Space Policy notes the necessity for interoperability of space systems for civilian and military users.[384] While ESA remains an exclusively civilian agency, European defense interests such as the European Defence Agency have expressed increasing interest in making use of data from ESA satellites and coordinating European space technology development.[385]

Concern has been expressed that extensive use of space in support of terrestrial military operations blurs the notion of "peaceful purposes" enshrined in the Outer Space Treaty, but state practice over the past 40 years has generally accepted these applications as peaceful insofar as they are not aggressive in space.

2014 Developments

Military satellites perform navigation, communications, weather, and technology development missions, in addition to intelligence gathering, which can be further divided into reconnaissance, signals intelligence, and space surveillance and early warning. U.S. and European intelligence organizations continue to supplement information from military spy satellites with data from commercial imaging satellites; Russia and China probably rely mostly on their dedicated intelligence systems.[386] Signals intelligence (SIGINT) is "intelligence derived from electronic signals and systems used by foreign targets, such as communications systems, radars, and weapons systems."[387] SIGINT satellites are the least known and probably most prevalent spy satellites.

United States

The uncertainty around the import of RD-180 engines for EELV contractor ULA is significant for the U.S. military space program (see Indicator 2.5).

Space surveillance

The USAF launched two GSSAP satellites in 2014 to conduct space surveillance missions by collecting SSA data from near-geosynchronous orbit (see Indicators 1.4, 3.4).[388] The launch of a second pair is planned for 2016.[389]

Onboard as secondary payload was the Automated Navigation and Guidance Experiment for Local Space (ANGELS) satellite (see Indicators 1.4, 3.4).[390] The ANGELS program is part of the USAF Research Laboratory's continuing effort to develop new, small satellite technologies capable of providing localized monitoring and awareness in space. The ANGELS spacecraft hosts an SSA sensor payload to evaluate techniques for detection, tracking, and characterizing space objects, as well as attribution of actions in space. ANGELS will test maneuvering concepts around its Delta-4 launch vehicle upper stage several hundred km above GEO as well as exploring increased levels of automation in mission planning and execution.

U.S. military launches CLIO satellite with unidentified mission

On 16 September 2014, the U.S. government launched the CLIO spacecraft.[391] CLIO's mission and operating agency remain unknown.[392] The satellite is based on the A2100 bus, fueling speculations that it serves as a replacement for the similarly secretive PAN military communication satellite launched in 2009.[393] CLIO was launched on a ULA Atlas V rocket and is currently positioned in GEO.[394]

Updates to existing military satellite systems

GPS

The USAF launched four GPS Block IIF satellites in 2014 (see Indicator 2.1). GPS III, the newest generation of U.S. military and civilian positioning, navigation, and timing satellites, initially planned for launch in 2014, is now expected to be operational no earlier than 2017.[395] According to contractor Lockheed Martin, the GPS III program will deliver three times greater accuracy and up to eight times improved anti-jamming capabilities, and extend spacecraft life over the prior GPS block by 25%. It will also carry a new civil signal designed to be interoperable with other international global navigation satellite systems.

Signals intelligence

In 2014, the National Reconnaissance Office's (NRO) Office of Space Launch successfully completed three separate launches in support of intelligence-gathering missions. Mercury 3 (NRO L-67) was launched on 10 April 2014.[396] The spacecraft's mission and orbit are classified.[397] However, many have speculated that the satellite likely functions as an electronic signals intelligence (ELINT) gathering platform in geostationary or Molniya orbit.[398] SDSIII-8 (NRO L-33) was successfully launched on 22 May 2014; its mission is classified, but the spacecraft is believed to be a Quasar communications satellite that forms part of the NRO's Satellite Data System constellation, which functions to securely relay data from other NRO spacecraft to ground stations.[399] Advanced Trumpet 3 (NRO L-35) was launched on 12 December 2014, and is also classified. The spacecraft, which is likely part of the Trumpet electronic intelligence (ELINT) system currently undergoing modernization,[400] is believed to have hosted the third USAF space-based infrared system (SBIRS)-HEO early missile warning satellite, which was completed and shipped for integration in June 2013.[401] The public navigation warnings distributed in anticipation of the launch of L-35 suggest it was delivered to the Molniya Orbit.[402]

Weather forecasting

When Defense Meteorological Satellite Program (DMSP) 5D3 F19 was launched on 3 April 2014,[403] it became the fifty-second satellite launched in the longstanding program, which is operated by NOAA and managed by USAF Space Command.[404] Data from the satellites is used to conduct three-dimensional cloud analyses and identify severe weather events, aiding military commanders in real-time targeting and route decisions.[405] The DMSP-5D3 series was to have been succeeded by the National Polar-orbiting Operational Environmental Satellite system, a joint NASA/NOAA project that was cancelled in 2010 after massive cost overruns. Later plans called for the DMSP-5D3 series to be replaced by the military Defense Weather Satellite System series, which was also cancelled.[406]

The last satellite in the series, DMSP-5D3 F20, has been in storage since the 1990s and may never be launched. The Senate drafted a defense spending bill for 2016 that prohibits the Air Force from spending any money on the launch pending certification from the Secretary of Defense that the military cannot obtain comparable data at a lower cost from other sources, such as civilian or international weather satellites.[407]

Slowdown in U.S. acquisition of military space systems

In a report released in July, the Air Force outlined a strategy to shift from expensive, big-ticket weapon systems in response to sustained congressional budget constraints for the next 20 years.[408] Co-author Major General David Allvin, stated, “We have to buy things very differently and develop and employ our people differently.”[409] Separately, after an 18-month examination of intelligence community procurement practices, the House Permanent Select Committee on Intelligence released a report outlining the need to scale back NRO satellite orders.[410] The report focused on the NRO’s practice of purchasing superfluous satellites “to provide stability to the industrial base, particularly component suppliers”; it recommended that “the Office of the Director of National Intelligence verify the NRO’s assumptions about the industrial base and that the NRO justify its proposed satellite acquisition pace to Congress.”[411]

Figure 2.12 U.S. dedicated military satellites launched in 2014[412]

Satellite	Operator	Function	Orbit	Launch Date
DMSP 5D3 F19	DoD/NOAA	Earth Science/Meteorology	LEO	03-Apr-14
Mercury 3 (NROL-67)	National Reconnaissance Office (NRO)/ US Air Force	Electronic Intelligence	GEO	10-Apr-14
SDS III-8 (NRO L-33)	National Reconnaissance Office (NRO)/ US Air Force	Communications	GEO	22-May-14
GSSAP 1	Air Force Satellite Control Network	Space Observation	GEO	28-Jul-14
GSSAP 2	Air Force Satellite Control Network	Space Observation	GEO	28-Jul-14
Angels	Air Force Research Laboratory (AFRL)	Technology Development	GEO	28-Jul-14
CLIO	Unknown US agency	Communications	GEO	16-Sep-14
Improved Trumpet 6 (NROL-35)	National Reconnaissance Office (NRO)	Electronic Intelligence	Elliptical	12-Dec-14

Russia

Continuing defense modernization includes space

Defense modernization continued in Russia. In early 2014, President Vladimir Putin ordered Deputy Prime Minister Dmitry Rogozin, director of Roscosmos Vladimir Popovkin, and Defense Minister Sergei Shoygu to produce proposals for the creation of strategic systems for military and space defense.[413] There are other efforts to boost space defense forces in response to perceived threats that include the buildup of NATO forces in eastern Europe, the development of the U.S. missile shield in Europe and Alaska, and the development of the U.S. "Prompt Global Strike" program.[414]

The successful test flight of the Angara rocket in December 2014 is significant for the Russian military space program (see Indicator 2.2).

Signals intelligence

Olimp K1, also designated Luch, was launched on 27 September 2014. Olimp-K is a Russian geostationary satellite built for the Russian Ministry of Defence and the Russian intelligence agency FSB. Its purpose is unclear; various reports suggest ELINT, secure communications, and navigational correction for GLONASS.[415]

Kosmos 2499

A small 50-kg satellite, designated Kosmos 2499, was launched with the Strela 3M satellites Kosmos 2496, 2497, and 2498. Russian sources stated that the satellite was a test of a new generation of plasma thruster, although observation of its movements led to speculation about its purpose[416] (see Indicator 3.4).

Updates to existing military satellite systems

GLONASS

Russia launched two GLONASS M satellites and one GLONASS K satellite in 2014 (see Indicator 2.1).

Communications

Four military and government communications satellites were added to existing constellations in 2014. Kosmos 2496, 2497, and 2498—part of the Strela 3M/Rodnik constellation—were launched on 23 May.[417] Strela satellites were designed for "store-and-dump" communications.[418] A satellite records a piece of communication, such as a fax, a telex or an e-mail, in its onboard recorder as it overflies a sender; when the satellite enters the range of receiving antennas of an addressee, it downlinks the message. The method was intended primarily for communications in very remote areas lacking more traditional ground-based communications channels. Strela-3 satellites are believed to be used by military and civilian intelligence services and other government agencies.

On 30 October, a Meridian 7 satellite was launched.[419] The Meridian constellation provides dedicated secure communications to the Russian government and military users, including mobile terminals.[420] Details on the payload of the spacecraft are classified, but Meridian satellites are known to operate in the VHF, UHF, and S-Band frequencies."

Reconnaissance

Russia's reconnaissance satellite system is depleted.[421] Russia launched a small military radar EO satellite, Kondor No. 1 (Kosmos 2487), in 2013 and another, Kondor-E1, on a Russian Strela rocket from the Baikonur Cosmodrome on 19 December 2014, for operation by South African defense and intelligence agencies.[422] Manufactured by NPO Mashinostroyeniya, Kondor satellites carry optical imaging instruments or radar payloads for use by Russian operators or by foreign agencies under the Kondor-E designation.[423] NASA's National Space Science Data Center could not determine if South Africa owns the satellite.[424]

The Kobal't M-9 satellite, also designated Kosmos 2495, was launched on 6 May 2014.[425] Likely the penultimate Kobal't, it is a rare surviving example of a film-return photoreconnaissance satellite. The spacecraft produces images of Earth that are physically returned to Earth by means of one or more small recoverable capsules. The Kobal't-M series is the final development of the film-return variant of the Yantar reconnaissance satellite series, which is being retired in favor of the more modern Persona series of satellites.[426]

Signals intelligence

Russia has an older-generation Tselina-2 signals intelligence satellite and two more recent Lotos satellites in low orbit.[427] Lotos S is a test of the Lotos design. Lotos S (802), which will likely be known as Kosmos 2503 when it reaches orbit, was launched on 24 December 2014.[428] It joins Lotos-S#1 (Kosmos 2455), which was launched in 2009.[429] Lotos is part of Russia's Liana program, which is intended to modernize the country's ELINT capabilities. When operational, Liana will consist of two series of satellites: Lotos for intercepting radio communications and Pion-NKS satellites for naval reconnaissance duties.

Early warning

Kosmos 2479, the last satellite of the Oko-1 ballistic missile attack early warning system, was lost in June 2014. The satellite was positioned in GEO above the United States and had exhibited problems since its March 2012 launch. The loss left Russia with greatly diminished early-warning capability; with its remaining non-geostationary early warning satellites, it is only able to monitor U.S. missile launches for three hours of the day.[430]

Figure 2.13 Russian dedicated military satellites launched in 2014[431]

Satellite	Operator	Function	Orbit	Launch Date
Kobal't M-9 (Kosmos 2495)	Russian Defense Ministry	Earth Observation	LEO	6-May-14
Kosmos 2496 (Strela 3M/ Rodnik)	Russian Defense Ministry	Communications	LEO	23-May-14
Kosmos 2497 (Strela 3M/ Rodnik)	Russian Defense Ministry	Communications	LEO	23-May-14
Kosmos 2498 (Strela 3M/ Rodnik)	Russian Defense Ministry	Communications	LEO	23-May-14
Kosmos 2499 (RS-47)	Russian Defense Ministry	Technology Development	LEO	23-May-14
Olimp K1	Russian Defense Ministry	Communications	GEO	27-Sep-14
Meridian-7 (Meridian 17L)	Military Space Forces (VKS)	Communications	Elliptical	30-Oct-14
Kondor E2	South African Defense and Intelligence Agencies	Earth Observation	LEO	19-Dec-14
Lotos-S (802)	Ministry of Defense	Electronic Intelligence	LEO	24-Dec-14

China

Further integration of air and space defense capabilities

On a visit to the People's Liberation Army Air Force headquarters in Beijing on 14 April 2014, Chinese President Xi Jinping urged further integration of air and space defense capabilities.[432] He told the air force to "speed up airspace integration and sharpen their offensive and defensive capabilities."

Updates to existing systems

In May 2014, the Beidou system achieved positioning accuracy within one meter—a major breakthrough[433] (see also Indicator 2.1).

Reconnaissance

China's imaging satellite constellation is strong. Four optical imaging satellites (Yaogan 21,[434] Yaogan 22,[435] Yaogan 24,[436] and Yaogan 26[437]) and one radar imaging satellite (Yaogan 23[438]) were launched in 2014 to join as many as six optical and five radar Yaogans and one ZY-3 satellite already in operation (see Indicator 2.1). Two low-orbit, optical imaging Kuaizhou satellites were launched in 2013 and 2014, using the new rapid-response Kuaizhou launch vehicle[439] (see Indicators 2.1, 3.2).

Signals intelligence

China appears to have two dedicated LEO signals intelligence programs, both involving multiple satellites.[440] The Shijian 6 system operates in pairs; its last launch was in 2010. Two sets of three Yaogan satellites, 20 (A, B, and C, launched 9 August[441]) and 25 (A, B, and C, launched 10 December[442]) supplemented the existing triplet series, Yaogan 9, 16, and 17 (see Indicator 2.1). This series appears to be a version of an older triplet U.S. Naval Ocean Surveillance System used to locate radio signals from ships by the difference in their arrival time at the different satellites.

Early warning

Three new Shijian 11 satellites were added to the constellation in 2014: Shijian 11-06 on 31 March 2014, Shijian 11-07 on 28 September, and Shijian 11-08 on 27 October.[443] While the purpose of this constellation has not been disclosed, there is speculation that it might be an experimental missile tracking and early warning constellation.[444]

Figure 2.14 Chinese dedicated military satellites launched in 2014[445]

Satellite	Operator	Function	Orbit	Launch Date
Shijian 11-06	Chinese Academy of Space Technology	Technology Development	LEO	31-Mar-14
Yaogan 20A	People's Liberation Army	Electronic Intelligence	LEO	09-Aug-14
Yaogan 20B	People's Liberation Army	Electronic Intelligence	LEO	09-Aug-14
Yaogan 20C	People's Liberation Army	Electronic Intelligence	LEO	09-Aug-14
Yaogan 21	People's Liberation Army	Optical Imaging	LEO	08-Sep-14
Shijian 11-07	Chinese Academy of Space Technology	Technology Development	LEO	28-Sep-14
Yaogan 22	People's Liberation Army	Optical Imaging	LEO	10-Oct-14
Shijian 11-08	Chinese Academy of Space Technology	Technology Development	LEO	27-Oct-14
Yaogan 23	People's Liberation Army	Radar Imaging	LEO	14-Nov-14
Yaogan 24	People's Liberation Army	Optical Imaging	LEO	20-Nov-14
Kuaizhou-2	National Academy of Sciences	Optical Imaging	LEO	21-Nov-14
Yaogan 25A	People's Liberation Army	Electronic Intelligence	LEO	10-Dec-14
Yaogan 25B	People's Liberation Army	Electronic Intelligence	LEO	10-Dec-14
Yaogan 25C	People's Liberation Army	Electronic Intelligence	LEO	10-Dec-14
Yaogan 26	People's Liberation Army	Optical Imaging	LEO	27-Dec-14

Increasing cooperation in space-based military activities

France and Italy cooperate on military communications satellite

Athena-Fidus is "a French-Italian geosynchronous military and governmental EHF/Ka-band wideband communications satellite."[446] According to one commentator, the satellite, launched on 6 February 2014, "represents the high-water mark thus far of European collaboration in military satellite telecommunications."[447] France and Italy had their own payloads, sharing a satellite skeletal structure and launch charges. Each nation will be able to operate the satellite separately, but will need to consult the other constantly to avoid interference.

The Athena-Fidus program is managed jointly by French space agency CNES, French defense procurement agency DGA, Italian space agency ASI, and the Italian Ministry of Defense; it will be used by French, Belgian, and Italian armed forces and by French and Italian civil protection services.[448]

Canada, United Kingdom, Australia, and United States sign CSpO MOU

The Combined Space Operations (CSpO) Memorandum of Understanding was announced publicly in May 2014 and signed by the United Kingdom, the United States, Canada, and Australia in September 2014.[449] Participating nations will gain "an understanding of the current and future space environment, an awareness of space capability to support global operations and military-to-military relationships to address challenges and ensure the peaceful use of space, [U.S.] DoD officials said."[450] The agreement came out of a November 2011 forum on combined space cooperation co-hosted by the U.S. Office of the Secretary of Defense and Stratcom.

UK connects to U.S. AEHF System for secure military communications

In February 2014, the UK connected to the U.S. Advanced Extremely High Frequency (AEHF) System, joining Canada and the Netherlands, which connected in 2013.[451] The AEHF System is a U.S. military satellite communications system for high-priority military ground, sea, and air assets.[452]

Other developments

Galileo 5 and 6 navigation satellites fail to reach orbit

The Galileo 5 and 6 satellites, launched from French Guiana aboard a Russian Soyuz rocket on 22 August 2014, failed to reach their intended orbital position (see Indicator 2.1).

India launches two IRNSS satellites

India launched IRNSS-1B and IRNSS-1C in 2014[453] (see Indicator 2.1). The first suborbital test flight of GSLV Mark III, India's next-generation launch vehicle, in December 2014 marked a significant step for the Indian military space program (see Indicator 2.2).

Israel launches Ofeq-10 intelligence satellite

On 9 April 2014, Israel launched Ofeq-10, using an indigenously developed three-stage launcher called Shavit, which, according to foreign sources, is based on a ballistic missile system.[454] This EO remote-sensing satellite employs SAR technology to deliver advanced, high-resolution imagery and is capable of operating day or night and in all weather conditions.[455] Ofeq-10 is the third SAR satellite built by IAI MBT Space Division and Elta Systems. The first two were launched on Indian PSLV rockets. OFEQ 10 carries a more advanced version of the EL/M-2070 SAR payload, introducing evolutionary enhancements of the first two models.[456]

Taiwan builds sensitive satellite equipment

On 25 February 2014, Taiwan's National Space Organisation announced that it had developed a key satellite component to receive signals from global positioning systems, which is on the export control list of space powers such as the United States, France, and Germany. The equipment will be installed on the Formosa-7 satellite, which is due to be launched in 2018.[457]

Egyptian EO satellite achieves first light

EgyptSat 2 (or MisrSat 2) is Egypt's second remote sensing EO satellite built by Russian RSC Energia and the Egyptian National Authority for Remote Sensing & Space Sciences.[458] The launch of EgyptSat 2 on 16 April 2014 from the Baikonur Cosmodrome[459] was a milestone on the road to the establishment of the Egyptian Space Agency.[460] The satellite will supply the Egyptian government with high-resolution views of Earth for environmental, scientific, and military applications. RSC Energia released the first light photos from the satellite on 5 May 2014.[461]

Security of space systems

Indicator 3.1: Vulnerability of satellite communications, broadcast links, and ground stations

Satellites typically transmit data to ground stations and receive information from ground stations using radio waves. Computer networks coordinate the process. Ground stations, communications links, and computer systems are likely targets for space negation efforts, since they are vulnerable to a range of negation techniques. Technology to interfere with satellite radio communication is mature and widely available, even at a consumer level. The USAF's Counter Communications System, designed to block a potential enemy's satellite communication using radiofrequency interference, became operational in 2004.[1]

Most, if not all, space actors are capable of providing effective physical protection for their satellite ground stations. Safeguarding satellite communication links requires specific electronic measures. Although unclassified information on these capabilities is difficult to obtain, one can assume that most space actors, by virtue of their technological capabilities to develop and operate space systems, also take advantage of simple but reasonably robust electronic protections.

Basic protection capabilities include 1) data encryption; 2) error protection coding to increase the amount of interference that can be tolerated before communications are disrupted; 3) directional antennas that reduce interception or jamming vulnerabilities, or antennas that utilize natural or manmade barriers as protection from line-of-sight electronic attacks; 4) shielding and radio emission control measures that reduce the radio energy that can be intercepted for surveillance or jamming purposes; and 5) robust encryption onboard satellites.[2]

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 concerns since a number of military space actors are becoming increasingly dependent on commercial space assets for a variety of applications. Responding to such concerns, the U.S. GAO recommended that "commercial satellites be identified as critical infrastructure."[3] In the event of an attack, the use of standardized protocols and communications equipment could allow alternative commercial ground stations to be brought online.

Laser-based communication is being developed as an alternative to satellite radio communication. While these optical communications systems could provide some immunity from conventional jamming techniques and more rapid communications, they have significant technological challenges.[4]

Because the vast majority of space assets depend on cyber networks, the link between cyberspace and outer space constitutes a critical vulnerability. The United States established a Cyber Command (USCYBERCOM) to be responsible for the military's Internet and other computer networks, which reached Full Operational Capability in 2010.[5]

2014 Developments

Military systems continue to employ protective measures to counter jamming, cyber attacks

U.S. military increases investments in information security

Air Force institutions relating to space and intelligence, such as the Space and Missile Systems Center in Los Angeles, which handles much of the space acquisition, are increasingly addressing methods to prevent cyberattacks early in a program's formulation. This fundamental shift, meant to address the growing international threat of offensive cyberweapons, was noted by U.S. Director of National Intelligence James Clapper in February 2015 when he spoke before the Senate Committee on Armed Services.[6] In 2014, Brigadier General Kevin Wooton, Director of Communications and Information at Air Force Space Command, noted that roughly 5-10% of space program costs are now aimed at defending against cyberattacks—a critical expenditure when off-the-shelf modules or software for their equipment are used.[7]

Boeing continues testing of anti-jamming technology

The USAF describes Wideband Global SATCOM as the backbone of U.S. military global satellite communications.[8] Australia, Canada, Denmark, Luxembourg, The Netherlands, and New Zealand also use WGS. Boeing has developed anti-jamming communications technology that can be applied quickly and affordably to existing assets, especially operational satellites in the WGS system and ground terminals.[9] The new anti-jamming technology uses a protected tactical waveform that shields signals from interference by adversaries or cyber-terrorists. In November 2014, it was reported that Boeing had proven its anti-jamming communications technology was capable of operating as either a ground-based user terminal or satellite-based networking hub, enabling the military to send and receive secure communications.[10] This demonstration followed a test in December 2013 in which Boeing successfully sent a government-developed protected signal through the WGS-6 satellite.[11]

Vulnerability to cyberattacks remains

Potential vulnerabilities in U.S. and British software and satellite systems

In January 2014, the Computer Emergency Response Team (CERT) based at Carnegie Mellon University, which works with the Department of Homeland Security, reported on vulnerabilities affecting the satellite terminals for Broadband Global Area Networks (BGAN).[12] BGAN satellite terminals are used by the military, including NATO, for tactical radio communications. In April 2014, global security consultant IOActive released a more comprehensive report describing various vulnerabilities in software and ground-based satellite systems that could be exploited to disrupt military operations and flight-safety communications.[13] Companies that manufactured vulnerable systems included British suppliers Cobham and Inmarsat; U.S. firms Harris Corporation, Hughes, and Iridium; as well as UAE-based Thuraya and Japan Radio Company. Of the manufacturers contacted by CERT, only Iridium confirmed that it was working on fixes.

NOAA networks hacked

In July 2014, the U.S. Department of Commerce Office of Inspector General issued a report that outlined significant security deficiencies in the NOAA networks, urging officials to make system updates a top priority.[14] In September, four NOAA networks were hacked by an outside source[15] and cybersecurity teams responded by shutting down some NOAA services for two days. NOAA officials did not say whether the attack removed material or inserted malicious software in its system, which is used by civilian and military forecasters in the United States and also feeds weather models at the main centers for Europe and Canada. NOAA did not comment publicly on the source of the hack.[16]

Demonstrations of laser-based communication

There were two successful demonstrations of optical communications technology in 2014. NASA's Optical Payload for Lasercomm Science (OPALS), mounted on the ISS, established an optical communications link when its laser locked onto a ground beacon emitted by the Optical Communications Telescope Laboratory's ground station at JPL's Table Mountain Observatory in Wrightwood, California on 5 June 2014.[17] During the 148 seconds that the payload and the receiver maintained line of sight, OPALS transmitted video data to the ground station.

On 28 November 2014, the EU's Sentinel-1A in LEO transmitted EO images by laser to Inmarsat's Alphasat in GEO.[18] This was the first demonstration of laser data linkups in space. The data was then transmitted to ESA's Copernicus Ground Segment for processing.

Indicator 3.2: Capacity to rebuild space systems and integrate smaller satellites into space operations

The capability to rapidly rebuild space systems in the wake of a space negation attack could reduce vulnerabilities in space. It is also assumed that space actors have the capability to rebuild satellite ground stations. The capability to refit space systems by launching new satellites into orbit in a timely manner to replace satellites damaged or destroyed by a potential attack is a critical resilience measure.

During the Cold War, the USSR and the United States led in the development of economical launch vehicles capable of launching new satellites to repair space systems following an attack. The USSR/Russia has launched less expensive, less sophisticated, and shorter-lived satellites than those of the United States, but has also launched them more often. In 2004, Russia conducted a large military exercise that included plans for the rapid launch of military satellites to replace space assets lost in action.[19] A significant number of Russia's recent launches are of other nations' satellites; Russia struggles to maintain existing military systems in operational condition.

The United States has undertaken significant efforts to develop responsive space capabilities. A joint project of DARPA and USAF, the Force Application and Launch from the Continental U.S. (FALCON) program began in 2003 to develop and validate, in-flight, technologies for prompt global reach missions, while at the same time demonstrating affordable and responsive space lift.[20] SpaceX received funding for its Falcon-1 launch system under the FALCON Small Launch Vehicle program in 2004.[21] Falcon-1 delivered Malaysia's RazakSAT into LEO on 15 July 2009.[22]

In 2007, the DoD Operationally Responsive Space (ORS) Office opened to coordinate the development of hardware and doctrine in support of ORS across the various agencies.[23] ORS-1, a microsatellite designed to provide continuous battlefield ISR, was launched in 2011.[24] The ORS-3 mission centered on developing alternative launch technologies for CubeSats and delivered 28 CubeSats into orbit on 20 November 2013.[25] The USAF has attempted to close the office and fold its activities into its main space procurement shop in Los Angeles, but support from Congress kept the ORS open in 2014.[26]

The concept for a U.S. Space Maneuver Vehicle or military space plane first emerged in the 1990s as a small, powered, reusable space vehicle operating as an upper stage of a reusable launch vehicle.[27] The first technology demonstrators built were the X-40 (USAF) and the X-37A (NASA/DARPA).[28] A successor to the X-37A, the X-37B unmanned, reusable spacecraft was launched for the first time in April 2010 with significant secrecy. India has been working on a Reusable Launch Vehicle, with an experimental flight planned for late summer 2015.[29]

Constellations of smaller, less expensive spacecraft 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. Some experts see the replacement of traditional, large, multifunctional satellites with networked systems of distributed, cooperating, small satellites as an evolution similar to that of computers, as the large mainframe computers of the 1970s evolved into networks of small computers connected via the Internet.[30] The technology for these disaggregated mission architectures is currently being developed and utilized by both military and commercial actors.

Authorities are beginning to seek resilience measures other than replacement of satellites for the PNT provided by GNSS.

2014 Developments

Satellite servicing

NASA Robotic Refueling Mission completes ground test and delivers Phase 2 hardware

The Robotic Refueling Mission (RRM), managed by NASA's Satellite Servicing Capabilities Office, and the CSA continued work on remote-controlled robots that service satellites on-orbit. This mission provides an opportunity to reduce costs for satellite operations by eliminating the need to purchase new satellites when existing ones are out of fuel.[31] Building on the previous year's success, NASA's Satellite Servicing Capabilities Office performed the ground-based Remote Robotic Oxidizer Transfer Test on 28 February 2014 to test refueling processes and procedures.[32]

The delivery in August 2014 of Phase 2 RRM hardware, including a new taskboard and Visual Inspection Poseable Invertebrate Robot, was intended to demonstrate "how a space robot can complete intermediate tasks required to replenish croygen [sic] in the instruments of 'legacy' satellites: existing, orbiting spacecraft that were not designed to be serviced."[33] The Phase 2 hardware, however, was not installed on the RRM module in 2014, nor were any follow-on RRM activities scheduled for 2015.[34] NASA had hoped to demonstrate its satellite servicing technology by refueling NOAA's GOES-12 weather satellite, but the spacecraft was decommissioned in August 2013.[35]

In 2014, the White House sought to rename the Satellite Servicing Capabilities Office "In Space Robotic Servicing" and "give its activities a more general-purpose slant that could 'enable multiple NASA missions, including servicing potential science satellites, non-NASA users, and providing robotic tools for an Asteroid Redirect Mission, as well other applications for use and/or testing on ISS.'"[36]

DARPA continues to explore satellite servicing

DARPA has been experimenting with robotic satellite servicing technology for more than a decade. Brad Tousley, director of DARPA's tactical technology office, suggested in May 2014 that the Phoenix program, which focused on repurposing parts from inactive satellites in GEO, might have its mission broadened to include, inter alia, replacing failed components onboard a satellite.[37] On 3 September 2014, DARPA issued a request for information to guide creation of robotic satellite servicing capabilities in GEO[38] (see Indicator 2.5).

Commercial satellite servicing emerges

ViviSat, a joint venture of ATK and satellite communications company U.S. Space, has developed a concept called the Mission Extension Vehicle (MEV) that attaches to a satellite and takes over the attitude control and its propulsion needs, extending its life or allowing it to be moved to a different orbit.[39] According to Bryan McGuirk, COO of ViviSat, in June 2014, "three of our first MEVs are now booked with two clients, so we've seen that as early, positive evidence and validation from the market."[40]

Skycorp envisions a servicing spacecraft that attaches to a satellite in GEO that has exhausted all of its onboard propellant, and moves that satellite into a "graveyard" orbit several hundred kilometers above GEO.[41] Skycorp is working with NASA to fly the servicing spacecraft to the ISS on commercial cargo resupply spacecraft, testing the spacecraft at the station before deploying the servicing spacecraft to GEO.

Disaggregated architectures

USAF Space Command has defined space disaggregation as the dispersion of space-based missions, functions, or sensors across multiple systems spanning one or more orbital planes, platforms, hosts, or domains.[42] Platforms could include smaller satellites and commercial satellites with accommodations for military payloads. Disaggregated architectures include commercial constellations of small satellites, such as those operated by SkyBox (see Indicator 2.4); and constellations of CubeSats, such as those launched by Planet Labs (see Indicator 1.1).

U.S. GAO calls for more evidence to support disaggregated architectures in USAF

In 2014, the USAF obtained additional funding for disaggregation, focusing primarily on the AEHF, Space Based Infrared System, and Weather System Follow-On architectures.[43] However, the U.S. Government Accountability Office released a report in October that indicated the limitations of the approach: 1) "adversaries may be more likely to attack small tactical satellites because they may be viewed as lower risk with regard to escalating hostilities"; and 2) "with increased numbers of satellites, the space environment may become more congested, potentially creating additional sources of debris that can damage other assets in orbit."[44] The report stated the need for additional evidence in support of the practice[45] (see also Indicator 2.6).

Standardization of components for small satellites

The success of CubeSats is due, in part, to standardized hardware design. The Air Force Research Laboratory used a similar modular approach to standardize spacecraft components, based on "plug-and-play" technology.[46] Using these specifications, Russian private company Sputnix Ltd. developed a standard set of mechanical, electronic, and data interfaces and implemented them in its own microsatellite platform TableSat.[47] The plug-and-play approach allowed the company to create and launch its first Earth remote-sensing satellite, TabletSat-Aurora, in just nine months and with minimal financing. The satellite was launched in June 2014.[48]

DARPA's Phoenix program is also developing a new modular satellite architecture based on satlets.[49] A satlet is a small independent module, with dimensions of 20x20x10 cm, weighing about 7 kg. Each satlet is effectively a self-contained spacecraft, with its own computer, power, communications capabilities, and propulsion. Satlets are designed to be attached to each other in different combinations that would provide capabilities to accomplish a range of diverse space missions with any type, size, or shape of payload. In December 2014, DARPA contractor Novawurks signed an agreement with Spaceflight Inc. to launch eXCITe, a satlet demonstration mission, in 2015.[50]

Responsive launch capabilities

SpaceX continues testing reusable first-stage concept

In 2014, SpaceX continued flight tests of a planned reusable first-stage motor. The first test of the year on 18 April was the first successful water soft-touchdown of a liquid rocket engine orbital booster.[51] Planned testing for 2015 included landing on a floating platform.[52] Long-term objectives include returning a launch vehicle first stage to the launch site in minutes, and returning a second stage to the launch pad following orbital realignment with the launch site and atmospheric reentry in up to 24 hours.[53] SpaceX also conducted testing of the F9R development test vehicle, which was essentially a Falcon 9 first stage with landing legs, designed to test the precision landing techniques needed to return a rocket to Earth intact.[54] On its third flight in 2014, the F9R-Dev suffered an unexplained anomaly and exploded.[55] There were no injuries. Blue Origin is also working on reusable launch vehicles for both orbital and suborbital flights.[56]

USAF ORS delays rail-launched effort

The launch of the ORS-4 mission aboard the Super Strypi rocket, originally scheduled for October 2013, was delayed to November 2014, then January 2015, and then October 2015.[57] Based on designs developed by Sandia as part of nuclear-testing programs dating back to the 1960s, the Super Strypi will be launched from a 40-m rail.[58] The goal is to deliver payloads in the range of 300 kg to LEO.[59] Each mission is expected to cost approximately $16-million, although Tyler Evans, vice president of Aerojet Rocketdyne's new Rocket Shop Defense Advanced Programs unit, said that the cost of each mission could be as low as $12-million.[60]

New developments in U.S. air launch capability

In March 2014, Boeing won a Phase 2 contract to use a modified fighter jet to deliver microsatellites to orbit.[61] Boeing will use the F-15E Strike Eagle fighter to carry the Airborne Launch Assist Space Access (ALASA) rocket up to 12,000 m, then release the 7.3 m rocket to ignite and carry itself into orbit. Using an F-15E capability to launch the rocket would increase satellite launch sites from four locations (Cape Canaveral Air Force Station, Florida; Vandenberg Air Force Base, California; Wallops Flight Facility, Virginia; and Kodiak Island, Alaska) to any available runway. The cost to put a 45-kg microsatellite into orbit is targeted at $1-million, saving 66%. A demonstration launch was hoped for in FY2015.[62] Similar private air-launch ventures, not funded by DARPA, are being undertaken by Virgin Galactic and Generation Orbit.

The Experimental Spaceplane 1, announced in September 2013, is a program to develop "a reusable spaceplane that could ultimately fly 10 times in 10 days and boost payloads into LEO for less than $5-million per launch."[63] On 14 July 2014, DARPA announced that Phase 1 design contracts to develop a demonstration vehicle had been awarded to three companies: Boeing (working with Blue Origin), Masten Space Systems (working with XCOR Aerospace), and Northrop Grumman (working with Virgin Galactic).

On 17 October 2014, the USAF's X-37B spaceplane landed at Vandenberg Air Force Base after two years in orbit.[64] Details about its missions, including payloads carried to orbit, are classified. According to the USAF, the X-37B "is designed to demonstrate reusable spacecraft technologies for America's future in space and operating experiments which can be returned to, and examined, on Earth."[65] The USAF owns two X-37B planes, which were developed by

Boeing's Phantom Works and resemble the space shuttle.[66] They have flown three missions: Orbital Test Vehicle (OTV)-1, OTV-2, and OTV-3. The fourth X-37B mission is planned for 2015.[67]

Second demonstration of China's integrated system for rapid responsive launch capability

On 21 November 2014, China used its Kuaizhou ("quick vessel") system to launch Kuaizhou-2, a natural disaster monitoring satellite (see Indicator 2.1).[68] Developed by China Aerospace Science and Industry Corporation in collaboration with the Harbin Institute of Technology, Kuaizhou is an integrated launch vehicle system with the rapid ability to replace satellites in orbit. The Kuaizhou launcher is composed of three solid-fueled rocket stages and a liquid-fueled fourth stage that is part of the spacecraft it is launching.[69] Experts believe the Kuaizhou rocket can launch from a wheeled mobile transporter within days of call-up. The mobility of the system allows the rocket to launch from many locations. Kuaizhou-1 was launched using the same system on 25 September 2013.[70]

Resilience measures for PNT data provided by GNSS

DARPA's STOIC program seeks proposals for GPS-independent PNT

In June 2014, DARPA began soliciting proposals for the Spatial, Temporal and Orientation Information in Contested Environments (STOIC) program to develop PNT systems that provide GPS-independent PNT with GPS-level timing and positioning performance.[71] STOIC has three primary elements: 1) long-range robust reference signals, 2) ultra-stable tactical clocks, and 3) multifunctional systems that provide PNT information between cooperative users; when integrated they have the potential to provide global PNT independent of GPS.

United States seeks access to Galileo and other GNSS

In testimony to the Senate Armed Forces Committee on 12 March 2014, Deputy Assistant Secretary of Defense for Space Policy Douglas Loverro stated that the United States had begun negotiations with likeminded PNT owner/operators to ensure that the U.S. military has access to "the bulk" of the six independent satellite navigation systems it expects to be operational by 2020.[72] The statement was made in the context of the need for resilience; he noted that while it may be possible for an adversary to deny GPS signals through jamming, physical antisatellite attacks, or a cyberattack on a ground control network, it is much more difficult to eliminate multiple services at the same time. According to officials from the European Commission, the U.S. government has sent a request to access Galileo's Public Regulated Service signal, an encrypted and jam-resistant service reserved for European militaries and government public-security agencies.[73]

UK National Space Security Strategy calls for terrestrial alternative to space-based navigation

On 30 April 2014, the UK announced its first National Space Security Policy, which was signed by the government in December 2013. The policy indicates that a terrestrial alternative to space-based PNT systems should be developed to mitigate the potential effects of outages—intentional or due to space weather—of GPS and other satellite navigation systems. Many critical military, civil, and commercial infrastructures depend on GPS. The UK government believes that widespread investment in an enhanced version of the Long-Range Navigation (Loran) terrestrial radio network could not replace the services lost if GPS or similar satellite services went dark, but would allow for a minimal survivability of at least some systems (see also Indicator 4.1).

Indicator 3.3: Earth-based capabilities to attack satellites

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. Significant ASAT capabilities have been developed outside of dedicated ASAT programs. Launching a payload to coincide with the passage of a satellite in orbit is the fundamental requirement for a conventional anti-satellite capability. Tracking capabilities would allow a payload of metal pellets or gravel to be launched into the path of a satellite by rockets or missiles (such as a SCUD missile).[74] Kinetic hit-to-kill technology, which involves destruction of a target as a result of collision with an interceptor, requires more advanced sensors to reach the target. Targeting satellites from the ground using any of these methods has been described as more cost-effective and reliable than space-based options.[75]

The U.S. Army invested in ground-based kinetic energy ASAT technology in the late 1980s and early 1990s. The small, longstanding Kinetic Energy ASAT program was terminated in 1993, but later granted funding by Congress from FY1996 through FY2005.[76] For FY2005, Congress appropriated $14-million for the KE-ASAT program through the MDA Ballistic Missile Defense Products budget.[77] The KE-ASAT program was part of the Army Counterspace Technology testbed at Redstone Arsenal.[78]

The United States has also deployed a limited number of ground-based exoatmospheric kill vehicle (EKV) interceptors, including the Aegis (Sea-Based Midcourse) and Ground-Based Midcourse Defense Systems, for ballistic missile defense purposes.[79] EKVs use infrared sensors to detect ballistic missiles in midcourse and maneuver into the trajectory of the missile to ensure a hit to kill.[80] With limited modification, the EKV may be used against satellites in LEO.[81] Japan is an important international partner of the United States on ballistic missile defense and has its own Aegis system. In 2007, a Japanese destroyer successfully performed a sea-based midcourse intercept against an exoatmospheric ballistic missile target.[82]

Figure 3.1 Technologies required for the development of ground-based capabilities to attack satellites

Capabilities	Conventional			Directed energy			Nuclear
	Pellet cloud ASAT	Kinetic-kill ASAT	Explosive ASAT	Laser dazzling	Laser blinding	Laser heat-to-kill	HAND
Suborbital launch	■	■	■				■
Orbital launch	■	■	■				■
Precision position/ maneuverability		■					
Precision pointing				■	■	■	
Precision space tracking (uncooperative)	■	■			■	■	
Approximate space tracking (uncooperative)			■	■			■
Nuclear weapons							■
Lasers > 1 W				■			
Lasers > 1 KW					■		
Lasers > 100 KW						■	
Autonomous tracking/ homing		■					

Key: ■ = enabling capability

In 2008, the United States reconfigured an anti-missile system to destroy failing satellite USA-193 as it deorbited. Modifications were made to enable a Raytheon SM-3 missile to destroy the satellite before it reentered Earth's atmosphere. While this event demonstrated the ability to reconfigure a missile to use against a satellite, the United States has stressed that it was a "one-time event,"[83] not part of an ASAT development and testing program.

Between 1984 and 1989, the Soviet Union worked on development of an air-launched direct ascent ASAT system known as Kontakt.[84] Russia also developed a long-range (350-km) exoatmospheric missile, the Gorgon, for its A-135 anti-ballistic missile system.[85] In 2013, the Russian Duma reportedly called for the Russian military to restart the Kontakt program.[86] Russia has not tested an ASAT since 1982.

China has developed an advanced hit-to-kill capability, demonstrated by its intentional destruction of a Chinese weather satellite in 2007 using what is believed to be a vehicle based on a medium-range, two-stage, solid-fueled ballistic missile, possibly the DF-21.[87] However, China called the event an experiment, not an anti-satellite test.[88] The UK, Israel, and India have also explored techniques for exoatmospheric interceptors.[89]

A nuclear weapon detonated in space would generate an electromagnetic pulse that would be highly destructive to unprotected satellites, as demonstrated by the U.S. 1962 Starfish Prime test.[90] Given the current global dependence on satellites, such an attack could have a devastating and wide-ranging impact. Detonation of a nuclear weapon in space would also violate the Outer Space and Comprehensive Test Ban Treaties. Both the United States and USSR explored nuclear-tipped missiles as missile defense interceptors and ASAT weapons. The Russian Galosh ballistic missile defense system surrounding Moscow employed nuclear-tipped interceptors from the early 1960s through the 1990s.[91]

Low-powered lasers have been used to "dazzle" or degrade unhardened sensors on satellites in LEO.[92] In 1997, in preparation for a test of the megawatt U.S. Mid-Infrared Advanced Chemical Laser (MIRACL), a 30-watt laser was used for the alignment and tracking of a target satellite in a 420-km orbit, unexpectedly damaging the satellite's sensors.[93] This suggests that even a commercially available low-watt laser functioning from the ground could be used to "dazzle" or temporarily disrupt a satellite.[94]

Ground-based lasers, tracking systems and adaptive optics would allow laser energy to be accurately directed at a passing satellite. Low-power beams are useful for ranging and tracking satellites, while high-energy beams are known to cause equipment damage. Adaptive optics, which enable telescopes to rapidly adjust their optical components to compensate for distortions, could be used to produce detailed images of satellites. Ground- and aircraft-based lasers could also use the same technologies to maintain the cohesion of a laser beam as it travels through the atmosphere, enabling more energy to be delivered on target at a greater distance. Adaptive optics research and development have been conducted by Canada, China, Japan, the United States, Russia, and India.[95]

The Boeing YAL-1 Airborne Laser Test Bed (ALTB) system—formerly known as Airborne Laser—of the USAF was primarily designed as a missile defense system to destroy tactical ballistic missiles in boost phase.[96] This technology is believed by some experts to have potential ASAT capabilities, despite the significant technical and cost challenges it has faced.[97] The program was initiated in 1996 and developed over 12 years at a cost of $5-billion.[98] The first ballistic missile interception was planned for late 2009[99] and finally occurred in February 2010, when the ALTB system successfully shot down a test ballistic missile.[100] The program was cancelled in 2011[101] and the 747 airframe was dismantled at the "boneyard" at Davis-Monthan AFB in September 2014. In 2012, there were reports that Russia planned to modernize and refurbish their A-60 test bed aircraft to disable sensors and optical electronic systems by directed laser beam impulse.[102]

2014 Developments

Development of hit-to-kill technology continues

On 23 July 2014, China conducted what its Ministry of Defense called "a test of land-based anti-missile technologies."[103] The system tested, SC-19, was the same system used by China to destroy FY-1C in 2007. The 2014 test was nondestructive, with no known target or debris created; likely reached LEO; and was the third for the SC-19 system since 2007.[104] China's May 2013 launch of the Dong-Ning (DN-2) rocket, on the other hand, was a test of a different system, which is able to reach much higher altitudes.[105] The Chinese Academy of Sciences stated that the 2013 scientific experiment reached an altitude of more than 10,000 km; other estimates are as high as 30,000 km.[106]

In a structured test conducted by the U.S. Missile Defense Agency (MDA) on 22 June 2014, the Boeing-designed Ground-based Midcourse Defense (GMD) system successfully intercepted a target intended to represent an intermediate-range ballistic missile launched from Kwajalein Atoll in the Pacific Ocean. According to the MDA, the target was detected and tracked by a U.S. Navy destroyer with its Aegis Weapon System and by Sea-Based X-Band Radar before being intercepted by a second-generation Capability Enhancement II Exoatmospheric Kill Vehicle launched from Vandenberg Air Force Base, California. The time from target launch to interceptor launch was approximately six minutes, and the EKV was required to maneuver to target, discriminate, and intercept with "hit to kill" kinetic force[107] at a speed of approximately 10 km/sec.[108] On 4 March 2014, the MDA announced a request for $99.5-million to initiate the redesign of the EKV for GMD.[109]

While the U.S. Aegis SM-3 system used to destroy malfunctioning satellite USA-193 in 2008 has not since been used in an ASAT capacity, "there is no way to verify whether a particular Aegis ship has SM-3s with modified missiles on it or not."[110] In April 2014, SM-3 Block IB was operationally deployed with the U.S. Navy for the first time as part of the second stage of the Phased Adaptive Approach. Planned deployments include both U.S. naval vessels equipped with the Aegis Weapon System as well as an Aegis Ashore facility in Romania; this facility will host both the Block IB and the Block IIA, joint projects of the United States and Japan.[111] Aegis interceptors SM-3 Block IA/IB can reach only the relatively few satellites in orbits with perigees at or below 600 km altitude, while SM-3 Block IIA interceptors, attaining altitudes of 1,450 km, could reach the vast majority of satellites in LEO.[112]

The Israeli Ministry of Defense and the U.S. MDA jointly tested the Boeing and Israel Aerospace Industries Arrow-3 anti-ballistic missile system in January 2014. While the system was only tested against a virtual target, the interceptor vehicle successfully utilized separate stages of its engines to enter and maneuver in space. In a 2013 test, the Arrow-3 reached an altitude of 100 km; officials declared that it could climb higher and successfully maneuver in space.[113] While the system is slated for deployment in 2016, a test planned for December 2014 did not take place, as "conditions did not allow for launch," according to the Israeli defense ministry.[114]

On 27 April 2014, India's Defence Research and Development Organisation conducted a test of the Prithvi Defence Vehicle interceptor, in its efforts to expand the capabilities of India's ballistic missile defense system. During the test, the interceptor was intended to intercept a target missile launched from more than 2,000 km away at an altitude of approximately 120 km.[115] While the Indian Ministry of Defence declared the test a success, the target missile was not destroyed. According to Defense Ministry Scientific Advisor Avinash Chander, the primary purpose of the intercept was to test the PDV's infrared seeker and "the warhead in the missile was not meant to be exploded in this mission."[116]

Advances in laser technology

Although there have been no developments related specifically to ASAT applications for lasers, high-energy laser weapons have matured rapidly in the past several years.[117] In 2014, both the United States and Russia tested ship-based laser weapon systems.[118] General Atomics Aeronautical Systems, Inc. (GA ASI) was awarded a DARPA contract to develop the Demonstrator Laser Weapon System for the High Energy Liquid Laser Defense System (HELLADS) program in 2011.[119] The 150-kW Class HELLADS laser has been developed over a number of years to create electrically powered and efficient lasers that are small and light enough to allow deployment on a number of tactical platforms. Testing planned for 2014[120] was rescheduled for 2015.[121] Linden Blue, CEO of GA ASI said: "It is remarkable to see high-power laser technology mature into an extremely compact weapons system and be deployed for field tests."[122]

Indicator 3.4: Space-based negation-enabling capabilities

A space-based ASAT program using kinetic-kill, directed energy, or conventional explosive techniques would require foundational technologies including maneuverability, docking, and onboard optics. No hostile use of space-based ASATs has been recorded. Tests of space-based systems that could have residual ASAT capabilities must be distinguished from tests of weapons systems that are designed to provide specific, operationally useful military capabilities.

The Soviet Union developed a co-orbital ASAT system that used a space launch vehicle to place an interceptor into orbit; the interceptor could then maneuver to collide with or pass near the target.[123] For example, the Soviet Istrebitel Sputnikov system was tested in orbit several times between 1962 and 1980.[124] The Soviet Union/Russia has observed a voluntary moratorium on anti-satellite tests since its last test in 1982.

The U.S. Missile Defense Agency's Near-Field Infrared Experiment was a satellite designed to provide support to ballistic missile defense. At one point it was expected to employ a kill vehicle that would encounter a ballistic missile at close range. In 2005, MDA cancelled the kill vehicle experiment after the U.S. Congress expressed concerns about its applicability to ASAT development;[125] the kill vehicle was replaced with a laser communications payload.

Small satellites, particularly microsatellites (10-100 kg), could have ASAT applications. Space-based weapons targeting satellites with conventional explosives, referred to as "space mines," could 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. Moreover, a space-mine microsatellite can be hard to detect.

In 2000, the partnership between China and the UK's Surrey Satellite Technology Ltd. saw the launch of the Tsinghua-1 microsatellite and companion Surrey Nanosatellite

Application Platform to test on-orbit rendezvous capabilities.[126] This partnership caused much speculation about Chinese ASAT intentions, although there was no evidence of an official Chinese ASAT program.

The USAF Experimental Spacecraft System (XSS) employed microsatellites to test proximity operations, including autonomous rendezvous, maneuvering, and close-up inspection of a target. XSS-11 was launched in 2005 and flew successful repeat rendezvous maneuvers. In 2006, the United States launched a pair of Micro-satellite Technology Experiment (MiTEx) satellites into an unknown geostationary transfer orbit. A major goal of the MiTEx demonstrations was to assess the potential of small satellites in GEO for defense applications.[127] In January 2009, the Pentagon confirmed that the two MiTEx microsatellites had maneuvered into close proximity with a failing satellite in GEO.[128] This incident elicited concerns that the ability to achieve such proximity could be used for hostile actions.[129]

While microsatellites, maneuverability, and autonomous proximity operations are essential building blocks for a space-based negation system, they are also advantageous for a variety of civil, commercial, and non-negation military programs. Construction and manning of space stations involve both rendezvous and docking activities.[130] More recent applications include satellite formation flying, on-orbit satellite servicing and refuelling, and some of the proposed methods for actively removing space debris from orbit.[131] These activities, if not conducted transparently, may lead some actors to perceive additional threats to space security.

2014 Developments

The United States launches satellites with RPO capability

The two GSSAP satellites launched by the USAF on 28 July 2014 have the capability to perform RPO (see Indicator 1.4). As of May 2015, the United States had not released orbital elements for the GSSAP satellites.[132] Also launched on the same flight was a nanosatellite from the ANGELS program[133] which will test maneuvering concepts around its launch vehicle upper stage (see Indicator 2.6).[134]

Russian Kosmos 2499 demonstrates RPO

There was no official announcement when Russia's Kosmas 2499, a 50-kg satellite, was launched with three Rodnik military communication satellites in May 2014 (see Indicator 2.6).[135] Initially thought to be space debris and designated Object 2014-28E, Kosmos 2499 began a series of orbital maneuvers in August that culminated with the satellite's lowering its orbit in November to meet up with the Briz-KM upper stage that had launched it.[136] Kosmos 2499 also started transmitting radio messages under the call sign RS-47 and continued stationkeeping maneuvers with Briz-KM in the early months of 2015.[137]

A similar spacecraft, Kosmos 2491, was launched as undisclosed secondary payload and began transmitting amateur radio messages under the call sign RS-46 in December 2013.[138] In late 2014, the Russian Space Agency acknowledged the existence of Kosmos 2491 and 2499, stating that they were developed by Roscosmos and the Russian Academy of Sciences to advance research.[139]

Chinese satellites launched in 2013 continue maneuvers

Orbit data indicates multiple maneuvers during 2014 for both Shijian 15 and Shiyan 7 (SY 7), satellites launched by China in July 2013 along with Chuangxin 3 (CX 3).[140] In August 2013, following a series of maneuvers that kept it close to CX 3, SY 7 suddenly maneuvered to rendezvous with Shijian 7, a Chinese satellite launched in 2005.[141] These maneuvers suggested capabilities similar to those which China had previously demonstrated in 2008 and 2010.[142] At the time of the 2013 launch, the Chinese press focused on "space debris observation," "mechanical arm operations," and the testing of "space maintenance technologies," according to Gregory Kulacki of the Union of Concerned Scientists.[143] One of the three satellites is known to carry a robotic arm.[144]

Programs for active debris removal and satellite servicing continue to develop dual-use technologies

Many developing programs for active debris removal (see Indicator 1.1) and satellite servicing (see Indicator 3.2) involve RPO, maneuvering, and physically contacting target satellites in orbit.

THEME FOUR

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.

The 2010 U.S. National Space Policy "calls on all nations to work together to adopt approaches for responsible activity in space"[1] and affirms that the United States "renews its pledge of cooperation in the belief that with strengthened international collaboration and reinvigorated U.S. leadership, all nations and peoples—space-faring and space-benefiting—will find their horizons broadened, their knowledge enhanced, and their lives greatly improved."[2] Such cooperation is particularly linked to space exploration, space surveillance, and Earth observation.

Russia has been deeply engaged in cooperative space activities, is a major partner of the ESA,[3] and also cooperates with other key spacefaring nations, including China and India.[4] Russian space cooperation activities have tended to support broader access and use of space. At the same time, Russian policy aims to maintain Russia's status as a leading space power, as indicated in the Federal Space Program for 2006–2015, which significantly increased the resources of Roscosmos.[5]

China's 2011 White Paper on space[6] includes a commitment to the peaceful use of outer space in the interests of all mankind, linking this commitment to national development and security goals. While China actively promotes international exchanges and cooperation, it has also stated that such efforts must encourage independence and self-reliance in space capabilities.[7]

India is a growing space power that has pursued international cooperation from the inception of ISRO, although ISRO's mandate remains focused on national priorities. India has signed Memoranda of Understanding with almost 30 states and the ESA. India also provides international training on civil space applications at the Indian Institute of Remote Sensing and the Centre for Space Science and Technology Education in the Asia Pacific Region to support broader use of space data.[8]

ESA facilitates European space cooperation by providing a platform for discussion and policymaking for the European scientific and industrial community.[9] Many see this cooperation as one of the most visible achievements of European cooperation in science and technology. ESA has established strong links of cooperation with larger space powers, such as the United States and Russia.

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

On 7 February 2014, Canada announced its Space Policy Framework[10] in a 13-page document that outlines five core principles, along with its intention to publish a detailed implementation plan (as of July 2015 this plan had not been released).[11] The core principles are: (1) Canadian interests first, including security in space;[12] (2) positioning the private sector at the forefront of space activities; (3) progress through partnerships; (4) excellence in key capabilities; (5) inspiring Canadians.

In accord with the Policy Framework, in October the Minister for Industry announced the establishment of a new Space Advisory Council and its membership.[13] A Deputy Minister Governance Committee for Space was also established to oversee all future major space projects to enhance coordination and oversight.[14]

Japan drafts 10-year Basic Plan

In 2013, Japan announced adoption of a Basic Plan on Space Policy.[15] In late 2014, it began involving the business community in drafting a 10-year Basic Plan, which stipulates increased participation of industry and business, as well as increased cooperation with the United States.[16] The plan, which was approved in January 2015,[17] has a greater focus on space security, as a counter to China's rapidly growing space capabilities.[18]

In July, the government of Prime Minister Shinzo Abe authorized a reinterpretation of war-renouncing Article 9 of the Constitution, allowing Japan, for the first time since the end of World War II, to come to the aid of an ally under attack.[19] Prime Minister Abe has contended for many years that his country's constitution, which limits its military to self-defense, should be amended. In January, he had stated that a less restricted military policy could be in place by 2020.[20]

United Kingdom announces first National Space Security Policy

On 30 April 2014, the UK published its first National Space Security Policy, which had been approved by the government in December 2013.[21] Its core aims are: (1) "to make the United Kingdom more resilient to the risk of disruption to space services and capabilities, including from space weather" (see Indicator 3.2); (2) "to enhance the United Kingdom's national security interests through space"; (3) "to promote a safe and more secure space environment"; and (4) "to enable industry and academia to exploit science and grasp commercial opportunities in support of national space security interests."

U.S. Security Space Strategy shows change in rhetoric

In 2011, the U.S. government announced a new National Security Space Strategy, which emphasized preventing and deterring aggression on U.S. national security space systems.[22] A shift appeared in the language of the NDAA for the 2015 fiscal year, passed by the Senate on 19 December 2014.[23] While the Act describes the need for a "multi-faceted space security and defense program," the Secretary of Defense and the Director of National Intelligence were called on to produce a study on the role of *offensive* space operations.[24] It was specified that the majority of the budget for the Space Security and Defense Program for 2015 be used for "the development of offensive space control and active defensive strategies and capabilities."[25]

The Act states: "It is the Sense of Congress that: (1) critical United States national security space systems are facing a serious growing foreign threat; (2) the People's Republic of China and the Russian Federation are both developing capabilities to disrupt the use of space by the United States in a conflict, as recently outlined by the Director of National Intelligence in testimony before Congress; and (3) a fully developed multi-faceted space security and defense program is needed to deter and defeat any adversaries' acts of space aggression."[26]

The United States explores commercial rights to space resources

Commercial entities in the United States are developing technology and business models for asteroid mining. The Agreement Governing the Activities of States on the Moon and Other Celestial Bodies, also known as the Moon Treaty or Agreement, states that an international regime should be established to govern the exploitation of such resources when such exploitation is about to become feasible.[27] In the absence of an established international regime, companies Planetary Resources and Deep Space Industries are urging the U.S. government, which is not a signatory to the Moon Agreement, to begin considering a national policy on this type of activity. Bill H.R.5063 (the American Space Technology for Exploring Resource Opportunities in Deep Space or ASTEROIDS Act) was introduced in the 2nd session of the 113th Congress to "promote the development of a commercial asteroid resources industry for outer space in the United States and to increase the exploration and utilization of asteroid resources in outer space."[28] This bill would grant U.S. companies rights to resources they may extract from asteroids and allow legal action in the case of "harmful interference" in those licensed activities by other U.S. entities.[29] The bill was referred to the House Committee on Science, Space, and Technology and then to the Subcommittee on Space, where it died.[30] A similar bill, H.R.1508, Space Resource Exploration and Utilization Act of 2015, was introduced in 2015.[31]

Bigelow Aerospace is also seeking clarification from the FAA on whether licensed placement of a commercial Moon habitat would preclude interference from other licensed U.S. actors. The request includes a proposal to establish a zone of operation from which other U.S. entities would be excluded.[32] In a letter sent to Bigelow Aerospace in late December 2014, the FAA said that it intends to "leverage the FAA's existing launch licensing authority to encourage private sector investments in space systems by ensuring that commercial activities can be conducted on a non-interference basis." It noted that the national regulatory framework in the United States is ill-equipped to handle some of the challenges posed by such an endeavor.[33]

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 Inter-Agency Committee on Outer Space (UN-Space), the UN Committee on the Peaceful Uses of Outer Space, the International Telecommunication Union (see Indicator 1.2), the International Committee on Global Navigation Satellite Systems (see Indicator 2.3),[34] and the Conference on Disarmament (CD). Outside the UN, there is also an important European-led initiative to develop an International Code of Conduct for Outer Space.

UNGA

The UNGA has long held that preventing an arms race in outer space is a significant contribution to international peace and security. The UN Charter establishes the fundamental objective of peaceful relations among states. Article 2(4) prohibits the threat or use of force in international relations, while Article 51 codifies the right of self-defense in cases of aggression involving the illegal use of force.[35]

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.

In addition to treaties, six UN resolutions known as principles have been adopted by the UNGA for the regulation of special categories of space activities. Although these principles are not legally binding, they establish a code of conduct that reflects the position of the international community.

Figure 4.1 Key UN space principles

Declaration of Legal Principles Governing the Activities of States in the Exploration and Uses of Outer Space (1963)
Space exploration should be carried out for the benefit of all countries.
Outer space and celestial bodies are free for exploration and use by all states and are not subject to national appropriation by claim of sovereignty or by any other means.
States are liable for damage caused by spacecraft and bear international responsibility for national and nongovernmental activities in outer space.
Principles on Direct Broadcasting by Satellite (1982)
All states have the right to carry out direct television broadcasting and to access its technology, but states must take responsibility for the signals broadcasted by them or actors under their jurisdiction.
Principles on Remote Sensing (1986)
Remote sensing should be carried out for the benefit of all states, and remote sensing data should not be used against the legitimate rights and interests of the sensed state, which shall have access to the data and the analyzed information concerning its territory on a non-discriminatory basis and on reasonable cost terms.
Principles on Nuclear Power Sources (1992)
Nuclear power may be necessary for certain space missions, but safety and liability guidelines apply to its use.
Declaration on Outer Space Benefits (1996)
International cooperation in space should be carried out for the benefit and in the interest of all states, with particular attention to the needs of developing states.
Space Debris Mitigation Guidelines (2007)
These are voluntary guidelines for mission-planning, design, manufacture, and operational phases of spacecraft and launch vehicle orbital stages to minimize the amount of debris created.

In 2011, the UN Secretary-General established, on the basis of equitable geographical distribution, a Group of Governmental Experts (GGE) on Transparency and Confidence-building Measures in Outer Space Activities to conduct a study, which took place during 2012 and was reported to UNGA in 2013. The report 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 among space actors in encouraging security, safety, and sustainability in space.

UN Space

UN Space meets annually to coordinate future space-related plans and programs among UN agencies.

COPUOS

Reporting to the UNGA 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. By the end of 2014, there were 77 Member States of COPUOS,[36] which works by consensus. Some intergovernmental and nongovernmental organizations have permanent observer status in COPUOS and its subcommittees. Debate on revisiting the mandate of COPUOS to include all issues affecting the peaceful uses of outer space—namely those pertaining to militarization—has not reached consensus.

The five treaties that are considered to form the basis of international space law have been negotiated at COPUOS. They are:

Outer Space Treaty (1967)—A cornerstone of the existing space security regime, the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, commonly referred to as the Outer Space Treaty (OST), represents the primary basis for legal order in the space environment, establishing outer space as a domain to be used by all humankind for peaceful purposes. However important this treaty may be for international space law, there have been repeated calls from different quarters for an updated normative regime for space activities.

The implications of the OST's definition of "peaceful purposes" have been the subject of debate among spacefaring states. The interpretation initially favored by Soviet officials viewed peaceful purposes as wholly non-military.[37] However, space assets have been developed extensively to support terrestrial military operations; the position that "peaceful" in the context of the OST means "non-aggressive" has generally been supported by state practice.[38] While space actors have stopped short of actually deploying weapons in space or attacking the space assets of another nation from Earth, ASAT capabilities have been tested by some states against their own satellites—for example by China in 2007[39] and the United States in 2008.[40]

Astronaut Rescue Agreement (1968)—The Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space requires that assistance be rendered to astronauts in distress, whether on sovereign or foreign territory. The Agreement also requires that astronauts and their spacecraft be returned promptly to the responsible launching authority, should they land within the jurisdiction of another state party.

Liability Convention (1972)—The Convention on International Liability for Damage Caused by Space Objects establishes a liability system for activities in outer space, which is instrumental when addressing damage to space assets caused by manmade space debris and spacecraft. The Convention specifies that a launching state "is absolutely liable to pay compensation for damage caused by its space object on the surface of the Earth or to aircraft in flight."[41] When a launching state causes damage to a space asset belonging to another state, it is liable only if it is at fault for causing the damage. However, liability for damage caused by space debris is difficult to establish, as it may be difficult to determine the specific source of a piece of debris, particularly a small piece that has not been cataloged.

Registration Convention (1975)—The Convention on Registration of Objects Launched into Outer Space requires states to maintain national registries of objects launched into space and to provide information about their launches to the UN. The following information must be made available by launching states "as soon as practicable": name of launching state, an appropriate designator of the space object or its registration number, date and territory or location of launch, basic orbital parameters, and general function of the space object.[42] The amount, accuracy, and timeliness of data provided by states in registering orbital objects varies considerably and this limits the role of the Registration Convention as a TCBM.

Moon Agreement (1979)—The Agreement Governing the Activities of States on the Moon and Other Celestial Bodies generally echoes the language and spirit of the OST in terms of the prohibitions on aggressive behavior on and around the Moon, including the installation of weapons and military bases, as well as other non-peaceful activities.[43] It also prohibits the use of the Moon to threaten Earth. However, the Moon Agreement has not been widely ratified because of contentions related to lunar exploration.[44] States continue to object to provisions for an international regime to govern the exploitation of the Moon's natural resources and there are different interpretations of what it means for the Moon's natural resources to be the "common heritage of mankind." The right to inspect all space vehicles, equipment, facilities, stations, and installations belonging to any other party is also objectionable to some states.

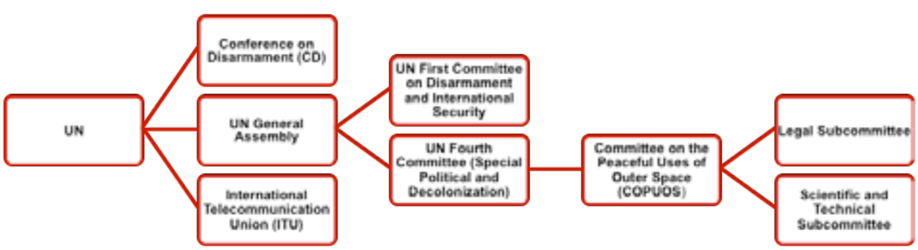
Figure 4.2: Status of major UN space treaties as of January 2015[45]

Treaty	Date	Total P*	Total S*
Outer Space Treaty	1967	103	25
Rescue Agreement	1968	94	24
Liability Convention	1972	92	21
Registration Convention	1975	62	4
Moon Agreement	1979	16	4

P*: Party S*: Signatory

Supported by secretariat services provided by the UN Office for Outer Space Affairs (UNOOSA), COPUOS and its two standing subcommittees—the Scientific and Technical Subcommittee and the Legal Subcommittee—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. The objective of this group is 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. A report of the working group and a set of voluntary guidelines to promote the long-term sustainability of outer space activities are forthcoming.

Figure 4.3 UN-related institutions relevant to international space security



Conference on Disarmament

The CD is the multilateral forum established by the United Nations to negotiate multilateral arms control and disarmament agreements. With 65 current Member States, the CD works by consensus under the chair of a rotating presidency. It has repeatedly attempted to address the issue of the weaponization of space, driven by perceived gaps in the OST, such as its lack of verification or enforcement provisions and its failure to expressly prohibit conventional weapons in outer space or ground-based ASATs. In 1985, a committee to negotiate a treaty to address these shortcomings was created and given a mandate "to examine, as a first step… the prevention of an arms race in outer space."[46] From 1985 to 1994 the PAROS committee met and, despite a wide disparity of views by key states, made several recommendations for space-related confidence-building measures.[47]

Efforts to extend the PAROS committee mandate faltered in 1995 over an agenda dispute that linked PAROS with other items discussed at the CD—in particular, a Fissile Material Cut-off Treaty (FMCT). CD agenda negotiations were stalled between 1996 and 2009, during which time the CD remained without a formal program of work. In 2009, the CD did adopt a program of work, but this advance was short-lived; the CD resumed its deadlock following objections from Pakistan over FMCT discussions. While at the end of 2014 the adoption of a Program of Work remained an elusive pursuit for the CD, overwhelming support for the resolution on PAROS in the UNGA indicates broad international support for consolidating and reinforcing the normative regime for space governance to enhance its effectiveness.

Other relevant initiatives include the International Code of Conduct for Outer Space Activities and the draft Treaty for the Prevention of Placement of Weapons in Outer Space. While these initiatives indicate the need for a new agreement, the way forward is not clear; global support for any one initiative has not emerged.

2014 Developments

UNGA passes resolution on No First Placement of Weapons in Outer Space

The UNGA adopted an important resolution, "No First Placement of Weapons in Outer Space," on 2 December 2014, with 126 in favor; Georgia, Israel, Ukraine, and the United States opposed; and 46 abstaining.[48] The resolution urged the CD to begin substantive work based on the Chinese-Russian proposal for a treaty on PPWT (see below) and added the item to its agenda for 2015.[49] It appeals to all states to make a political commitment to no first placement of arms in outer space. So far, such declarations have been made by Argentina, Armenia, Belarus, Brazil, Cuba, Indonesia, Kazakhstan, Kyrgyzstan, Russia, Sri Lanka, and Tajikistan.[50]

UNGA passes resolution on PAROS

Every year UNGA passes a resolution with nearly identical wording, expressing concern about a potential arms race in outer space and urging states, "in particular those with major space capabilities, to contribute actively to the goal of preventing an arms race in outer space, as an essential condition for the promotion of international cooperation in the exploration and use of outer space for peaceful purposes."[51] During its sixty-ninth session in December 2014, it passed this same resolution with 178 votes in favor, none against, and abstentions by Israel and the United States.[52]

UNGA calls for unprecedented meeting of First and Fourth Committees in 2015 to address possible challenges to space security and sustainability

The 2013 report on the study by the Group of Governmental Experts on TCBMs in Outer Space Activities recommended a joint ad hoc meeting of the First and Fourth Committees of the General Assembly.[53] In 2014, the General Assembly passed a resolution on transparency and confidence-building measures (TCBMs) in Outer Space Activities without a vote, calling for the unprecedented joint meeting of the two Committees. Bringing together the security and disarmament focus of the First Committee with the work on peaceful uses of outer space done at the fifty-seventh session of COPUOS (which reports to the Fourth Committee), the meeting is planned for October 2015. It will also take into account 2014 resolutions on No First Placement of Weapons in Outer Space passed by UNGA[54] and International Cooperation in the Peaceful Uses of Outer Space. The latter resolution was adopted by the Fourth Committee and drafted by Algeria, which stressed the need for COPUOS to continue to consider, "as a matter of priority, ways and means of maintaining use of outer space for peaceful purposes [and] urged States that had not yet become parties to the international treaties governing the uses of outer space to consider ratifying or acceding to them, as well as incorporating them into their national legislation."[55]

COPUOS extends work plan to complete the draft Guidelines on the Long-term Sustainability of Outer Space Activities for referral to UNGA in 2016

UN COPUOS held its fifty-seventh session from 11 to 20 June. It endorsed reports of the Legal and the Scientific and Technical Subcommittees—which included reports from new NEO-related networks International Asteroid Warning Network and Space Missions Planning Advisory Group (see Indicator 1.3)—as well as the reports of UN-Space; it also discussed the Draft Guidelines proposed by the Working Group on the Long-term Sustainability of Outer Space Activities, first submitted in 2013, with a revised draft presented to the STSC in February 2014.[56] The Chair of the Working Group submitted a proposal to consolidate many of the guidelines into a more concise document.[57] The Committee encouraged the interlinkage between the guidelines and the GGE's work on TCBMs.[58]

Some delegations proposed new guidelines and amendments.[59] Russia suggested the development of a unified center for information on near-Earth space monitoring under the auspices of the UN,[60] and requested an extension to 2015 for further proposals. The original work plan for the Working Group had called for finalizing the report and the set of best-practice guidelines for presentation to and review by the Committee in 2014.[61] The Committee agreed to a new work plan calling for the draft guidelines to be ready for approval by the Committee and referral to UNGA in 2016.[62] Given the substantial nature of the new proposals, there is some concern that the deadlines of the new work plan will not be met.

As in previous years, the Committee noted that there was "a self-induced lack of confidence in the potential of the Committee's work under this priority agenda item [space security] and that the Committee's work should go beyond mere reaffirmations of allegiance to peace in outer space."[63] Delegations continued to disagree on whether potential weaponization of space should be discussed by the Committee or left to the CD and other venues.[64] Several delegations indicated that "the Committee should begin to consider the legal basis for, and the modalities of, in a hypothetical case, the exercise of the right to self-defence in accordance with the Charter of the United Nations, as applied to outer space."[65]

Membership in COPUOS increased to 77 nations in 2014, with the addition of Luxembourg.[66] Ten intergovernmental organizations and 24 nongovernmental organizations have observer status.

Latest draft ICoC for Outer Space Activities released

Following two UNGA Resolutions on TCBMs in 2006 and 2007,[67] and in response to a request by the UN Secretary-General for "concrete proposals" for TCBMs, the EU prepared a proposal for an International Code of Conduct in 2008.[68] After it presented a revised draft in 2012, the EU responded to concerns that the process had not been sufficiently transparent and inclusive by holding three rounds of multilateral Open-ended Consultations, in Kiev (May 2013), Bangkok (November 2013), and Luxembourg (May 2014). Ninety-five UN Member States participated in the process.[69] To support more open consultations, the United Nations Institute for Disarmament Research (UNIDIR) organized regional seminars in Malaysia, Ethiopia, Mexico, and Kazakhstan, and helped with preparations for the Open-ended Consultations.[70]

On 31 March, the EU made public the latest draft of the ICoC.[71] Subscribing states are still asked to abide by the principle of freedom in outer space and recognize the right to self-defense in outer space, while refraining from the threat or use of force in outer space.[72] Subscribing states should refrain from damaging or destroying space objects; exceptions relate to "imperative safety considerations," reducing space debris, and exercising the "inherent right" to self-defense.[73] States are urged to implement the Space Debris Mitigation Guidelines.[74]

Responses to this new draft have been mixed. Many African and Latin American countries object to the emphasis on a right to self-defense and feel that accepting this code could restrict their future space activities.[75] Australia,[76] Canada,[77] Japan,[78] and the United States[79] support the ICoC. Brazil, Russia, India, China,[80] and the Union of South American Nations[81] question the development process,[82] even though they were involved in later consultations, and are concerned that a non-binding code could undermine the development of a binding treaty.

In its 27 October 2014 statement to the UNGA First Committee, the EU noted that the process had transitioned from consulting to multilateral negotiating.[83] With the assistance of the United Nations Office for Disarmament Affairs, the EU organized multilateral negotiations on the ICoC from 27-31 July 2015 in New York.[84]

Russia and China submit updated PPWT draft to the CD

The Chinese-Russian initiative on a treaty on the Prevention of Placement of Weapons in Outer Space has received mixed responses from other states since its launch in 2002[85] and the presentation of a first draft treaty to the CD in 2008.[86] On 12 June 2014, China and Russia submitted an updated treaty draft that took into account some of the criticism and concerns expressed.[87] Major changes in the 2014 draft included the removal of a definition of outer space; clarified definitions of "outer space object," "weapon in outer space," "use of force," and "threat of force"; the addition in Article II of the obligation to "not engage in outer space activities, as part of international cooperation, inconsistent with the subject matter and the purpose of this Treaty"; clarification that article 51 of the UN Charter includes both individual and collective self-defense; recognition of the need for compliance control mechanisms; and elaboration on a dispute resolution mechanism.[88]

Bangladesh,[89] Colombia,[90] Cuba,[91] the Democratic People's Republic of Korea,[92] and the Union of South American Nations are strong supports of the PPWT.[93]

Australia,[94] Canada, France,[95] and the United States are among the group of states with concerns about a PPWT, preferring a non-binding code. The United States indicated that the 2014 draft does not provide for an "effective verification regime to monitor compliance, and terrestrially-based anti-satellite systems posing the greatest and most imminent threat are not captured."[96] It stated that it will consider any space arms control proposals that are "equitable, effectively verifiable, and enhance the national security of the United States and its allies," but that it has not yet seen any such proposals.[97]

UN-Space discusses post-2015 Development Agenda

One of the main outcomes of the UN Conference on Sustainable Development (Rio+20), held in Rio de Janeiro in June 2012, was the agreement by Member States to launch a process to develop a set of sustainable development goals (SDGs).[98] Following the formulation of a set of SDGs in 2013,[99] UN-Space[100] took up the topic at its thirty-fourth session in June 2014, when it met in conjunction with the UN Geographical Information Working Group, a UN network of professionals working in the fields of cartography and geographic information science.[101] In its report to UN COPUOS, UN-Space identified four main themes: environmental sustainability, inclusive social development, inclusive economic development, and promotion of international cooperation in the peaceful uses of outer space.[102]

An open informal session on "Engaging space tools for development on Earth - contribution of space technology and applications to the post-2015 Development Agenda" was held on 14 May 2014.[103] The summary of the concluding discussion underlines the "need to enhance dialogue between the scientific community, the providers of data and added-value products, and the user community in order to bridge the existing gaps in knowledge on the access to and use of space-based technology."[104] The need for awareness raising, capacity-building and training, and institutional strengthening of informed decision-making at national, regional, and international levels was emphasized.[105]

When Simonetta Di Pippo was appointed the new director of UNOOSA in March 2014,[106] she spoke of the importance of interagency cooperation to achieve the post-2015 goals.[107]

Indicator 4.3: Other initiatives

Historically, the key 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 General Assembly 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 include the work of the Asia-Pacific Regional Space Agency Forum and discussions within the African Union to develop an African space agency. Nongovernmental organizations have also contributed to this dialogue on gaps in the international legal framework. For example, the Union of Concerned Scientists drafted a model treaty banning ASATs (1983).[108]

The UN Institute for Disarmament Research—an autonomous institute within the UN system—has also played a key role in facilitating dialogue among key space stakeholders. Every year since 2002, UNIDIR has partnered 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 addresses implementation and compliance

On 19 and 20 March, UNIDIR held its fourteenth annual Space Security Conference, on the theme "The Evolving Space Security Regime: Implementation, Compliance, and New Initiatives."[109] The focus was on the efforts to prevent an arms race in outer space: the Chinese-Russian initiative on a legally binding treaty and two "soft law" initiatives—the GGE project on TCBMs and the EU-driven ICoC.

Panelists outlined the benefits and challenges of each initiative, with preferences following regional political alignments. It was noted that the United States, the Russian Federation, and China have demonstrated ASAT capabilities, and that Israel and India are developing such systems.[110] There was agreement on the need for increased international dialogue to determine an effective response to these actions.[111] The challenge lay in aligning the different initiatives and states' policy perspectives. Switzerland joined Russia and China in seeking a legally binding treaty.[112] India has traditionally supported such an initiative but has been critical of the process and substance of the EU ICoC.[113] In the Middle East the chief concern is for increased intentional satellite interference.[114] Space debris was seen as a threat to the long-term sustainability of space; the United States emphasized that non-binding guidelines should be implemented domestically and bilateral cooperation should be increased.[115]

ARF holds second Space Security Workshop in Japan

On 9-10 October, Indonesia, Japan, and the United States co-hosted the second Association of Southeast Asian Nations (ASEAN) Regional Forum (ARF) Space Security Workshop in Tokyo, which was attended by representatives from all ARF participants except Brunei Darussalam, the Democratic People's Republic of Korea, and Papua New Guinea.[116] (The first workshop was co-hosted by Australia and Vietnam in 2012.) The meeting explored the benefits of space assets for ASEAN states, addressed current issues facing the space environment, and assessed approaches to space security to ensure benefits for future generations.[117] Support was expressed for the ICoC, which Japan viewed as an important mechanism,[118] while other states preferred a binding treaty.[119]

APSCO Workshop on Space Law held in China

From 17-20 November 2014, 133 participants attended the UNOOSA, CNSA, and APSCO Workshop on Space Law in Beijing.[120] Under the theme "Promoting National Space Legislation towards the Rule of Law," the workshop addressed, inter alia, the rule of law and global governance of space activities; the development of space policy, and transparency and confidence-building measures in outer space activities. Participants also discussed mechanisms for regional and interregional cooperation, including intergovernmental organizations such as ESA and APSCO.

ESA Council at Ministerial Level emphasizes independent European access to space

The ESA Council at Ministerial Level met in Luxembourg on 2 December. It adopted three resolutions. The first, on Europe's access to space, covered the development of Ariane 6 and Vega C, and emphasized independent European access to space. The second was on Europe's space exploration strategy, covering ESA's three destinations for exploration (LEO, the Moon, and Mars). The third envisioned the ESA's future until 2030.[121]

Montreal Declaration mandates study of global space governance

The 2nd Manfred Lachs International Conference on Global Space Governance, which was convened on 29-31 May 2014, by the McGill Institute of Air and Space Law, in Montreal, Canada, adopted the so-called Montreal Declaration by consensus. The Montreal

Declaration mandated the Institute to study the format and substance of a global space governance system to achieve, effectively and in practice, the goal of the sustainable use of space for peaceful purposes and for the benefit of all humankind.[122] This study is being carried out by an international and interdisciplinary team of more than 100 experts from various countries.

Space security: One step forward, two steps back?

Theresa Hitchens

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Humanity's endeavors in outer space largely have been driven by two competing realities: competition between nation states for prestige, economic/societal gain, and military advantage; and the requirement for cooperation among space actors to ensure a safe and peaceful operating environment for the use of spacecraft to improve life on Earth.

Some level of competition—both in the commercial sphere and among nation states—is desirable and healthy, driving technological innovation and economic development that benefit humanity as a whole. This is just as true in space as it is on Earth. Neither can the usefulness of space in ensuring national security be denied. At the same time, the physical realities of space as a limited and fragile resource demand cooperative approaches. Too much unregulated crowding of useful orbits, for example, would result in risks to satellites—such as potential collisions and radio frequency interference (hence the role of the ITU in managing orbit and RF access). Too much pollution (debris) raises the risks of satellite destruction from collision; and at a certain level, space debris could make certain useful orbits unusable, to the detriment of global society.

As the number of space actors has grown (from two major players, the United States and the Soviet Union, during the early days of the Cold War to more than 70 nations and independent organizations today), balancing between those two antipodal drivers has become more and more difficult. In particular, the growing diversity of space actors—ranging from major powers to developing countries to globalized commercial ventures to "space entrepreneurs" to universities—has resulted in a fracturing of priorities regarding needs versus requirements for protection of space as a global resource. This factor has complicated efforts at governance of space activities, both at a national and international level.

Over the past several years, progress toward a safer and more sustainable and secure space environment could be best characterized as a game of "two steps forward, one step back." International cooperation on mutual threats in space, such as the growth of the debris population and the lack of sufficient Space Situational Awareness capabilities, has steadily improved—although at a glacially slow pace. There has been widespread recognition and agreement among nation states that there is a need to improve transparency and confidence among space actors, and that norm setting, at least through voluntary measures, is needed to govern behavior in space—even if no agreements have yet been reached. At the same time, competition among nation states—especially in the military space sphere—has also been simmering. As the U.S. National Security Space Strategy of 2011 states, space has become more "congested, contested and competitive."

Unfortunately, as of late 2014 and early 2015, the growing national security tensions among the major space actors threaten to negate the painstaking efforts toward multilateral governance. That is, the situation is rapidly moving toward "one step forward, two steps back." As the geopolitical currents have become more turbulent (particularly, but not solely, due to the souring of relations between the Russian Federation and the West and the increasingly prickly relationship between the United States and China), the likelihood of more rapid development of a workable international governance model has decreased.

This chapter will review the developments in 2014 and early 2015 that highlight increased competition in space, as well as those developments that show the increasing recognition of the need for improved multilateral cooperation, despite the slow progress toward that goal. It will also put forward some suggestions on how to maintain a balance between the two poles during a politically tense time—and thus, at a minimum, prevent more backward steps.

Competition grows: For national economic benefit, military advantage, and access to space resources

More space actors, satellites—more problems

As of January 2015, there were more than 1,265 operational satellites on orbit, owned by some 80 countries; commercial ventures; and other entities, including universities.[1] Iraq,[2] Uruguay,[3] Belgium,[4] and Lithuania[5] are the latest countries to obtain their first satellites. Satellite-operating nations vary widely in their capabilities: some have built their own satellites, others have bought them from foreign manufacturers; some do operations through a domestic agency or company, others rent those services. In addition, there is wide disparity in capacity with regard to issues such as legal obligations. This disparity creates difficulties both for space safety and for multilateral governance efforts. In particular, the growing demand for orbital slot and RF allocations in Geosynchronous Orbit, the home of most communications satellites, has complicated the work of the ITU in coordinating access so as to avoid RF interference. And, as the competition for prime orbital real estate gets more intense, newcomers to space operations become frustrated and have fewer incentives to follow the rules.

Another key problem that is exacerbated by the growth in the number of space actors is debris creation. Space pollution has increased every year since the dawn of the space age, and has now reached worrying levels. For example, the International Space Station had to maneuver five times in 2014—a historical record.[6]

The debris problem has been recognized at the international level. In 2007, for example, UN COPUOS adopted a set of voluntary guidelines for space debris mitigation, based on technical guidelines developed by the Inter-Agency Space Debris Coordinating Committee and subsequently endorsed by the UN General Assembly in January 2008.[7] Unfortunately, not all states have moved to incorporate the Debris Mitigation Guidelines and, just as importantly, the IADC's technical guidelines that serve to flesh out the UN principles, into either their practices or their regulatory systems for space launch and satellite operations.

The European Space Agency, in its 2015 annual report on "Classification of Geosynchronous Objects," notes that, while 17 years after adoption of the guidelines for GEO operations "there is widespread compliance," there are also problems. In 2014, 18 satellites in GEO reached the end of their lives, but only 13 were moved to the graveyard orbit set by the IADC technical guidelines.[8] In addition, at least four rocket bodies were left adrift in orbits close to or crossing through GEO. A review of the past several years of the report reveals a common practice among even major spacefaring states to re-orbit non-operable satellites too low rather than the specified altitude above GEO for disposal in a so-called graveyard orbit, while, disconcertingly, satellites continue to be abandoned in GEO.[9]

In addition, a study by the French space agency CNES found that 40% of all satellites and rocket bodies launched into Low Earth Orbit between 2000 and 2012 were abandoned in orbits too high for them to re-enter Earth's atmosphere within the 25-year window specified in the Space Debris Mitigation Guidelines.[10] Part of the problem is that some developing space powers, such as India, do not see debris mitigation (which adds costs to space operations) as a priority—nor necessarily their problem, since most of the current debris was created by the United States, Russia, and China. New space actors may not be sufficiently aware of their obligations under the guidelines. Even countries like the United States, which has incorporated the guidelines into its satellite licensing procedures, sometimes grant waivers for the sake of expediency or national security.

The biggest population explosion in space, however, is that of commercially operated CubeSats. CubeSats were originally designed for research and educational purposes, but commercial ventures now have begun investment in operational systems. In 2014, 132 CubeSats were launched.[11] Planet Labs, Inc. successfully launched 67 CubeSats for Earth observation in 2014 (another 26 were lost in the October 2014 Antares rocket explosion[12]) and intends to deploy 100 in 2015,[13] and eventually a completed constellation of 150 to 200.[14] In 2014, OneWeb announced plans, with partial financing from Google, to launch 700 small satellites in LEO to deliver global Internet broadband services. Google also invested in early 2015 in a similar project by SpaceX, the company founded by entrepreneur Elon Musk.[15] Musk has proposed to put as many as 4,000 small satellites in orbit to create worldwide Internet access.[16] Skybox Imaging announced in 2014 a contract with Space Systems/Loral (SSL) to manufacture 13 small, high-resolution EO satellites, which, while bigger than most CubeSats, are based on a CubeSat design.[17]

While CubeSats are making low-cost access to space-based services more widely available, the advent of a much more crowded LEO environment carries risks. At the forefront of concerns for governments and experts is the issue of debris. The U.S. Space Surveillance Network currently tracks about 23,000 pieces of space debris 10 cm or larger, most of it in LEO. There are thousands and maybe millions of pieces of untrackable debris between 1 cm and 10 cm that can damage or destroy an active satellite in a collision.[18] Tracking CubeSats, especially those launched in large formations, is often difficult, as they are usually launched as secondary payloads. And because many have no propulsion systems onboard there is no ability for active de-orbiting; at the end of their lives they become debris.[19]

Unfortunately, CubeSats often fall between the regulatory cracks, both at a national and international level. Many are using amateur frequencies and so do not require ITU registration, raising questions of RF interference. In the United States they don't require licenses from the Federal Communications Commission and so they are not subject to debris mitigation requirements. Finally, because of their small size and the difficulty in tracking them, CubeSats have raised concerns at the U.S. Defense Department that they might house weapons.

Overcrowding in space can also lead to RF interference. The ITU's central role is to coordinate and regulate frequency use to avoid unintentional interference, through the Radio Regulations. Under Article 15 of the regulations, deliberate "harmful interference" is prohibited; certain measures must be taken by countries of the satellite operators to avoid interference (such as keeping their signals within the assigned RF bands); and, in cases where they have followed the proper procedures but interference still occurs, countries are to take appropriate steps to identify the cause and rectify it. Article 15 also includes dispute mechanisms for cases of interference.[20]

Because the ITU has no enforcement powers, it is up to member countries to "exercise the utmost good will and mutual assistance"[21] in dealing with cases of RF interference. The

Radio Regulations essentially lay out the methodology by which the involved parties are to work together to rectify the situation; only if they cannot come to an agreement should the ITU be brought in, but only to assist in identifying the source of harmful interference and facilitating communications. Even then, the ITU cannot force a party to "cease and desist" whatever is causing the interference.

Further, the ITU's response to complaints is limited because it lacks the means to verify claims. Information on the nature of the interference and where it emanates from is provided by the parties themselves. At the November 2014 ITU Plenipotentiary Conference in Busan, Korea, a resolution was passed to support ITU efforts to track reported cases of interference with satellite broadcasts.[22] The resolution, "Strengthening the role of ITU with regard to transparency and confidence-building measures in outer space activities," invites the ITU to enter into agreements with satellite-monitoring facilities to detect the sources of interference (a process known as "geo-location") and calls upon the ITU to create a database on interference.[23] This could give the ITU independent and neutral information about cases of interference.

Such a database would also allow the ITU to confidently "name and shame" perpetrators of deliberate interference. Despite the fact that deliberate interference is a violation of ITU treaty-based regulations, incidents of RF jamming—primarily by national governments for political purposes—have been on the rise since the early 2000s; this increase has led major space players to support the new resolution. In 2014, for example, Eutelsat and the BBC experienced jamming by Ethiopia and complained to the ITU.[24] Jamming by Iran has eluded a solution since 2010. Although Iran is a signatory to the ITU Convention, government officials remain unapologetic, even after the Iranian meteorological organization complained that the jamming made it impossible to forecast a major dust storm that hit Iran in June 2014.[25]

It remains unclear what will become of the resolution, as there is a question about whether such a proposal should instead come directly from a formal meeting of the ITU's governing council, known as the World Radio Conference. The next conference takes place in November 2015.

National security interests raise risks of antisatellite warfare

Jamming is not only a major concern for commercial space operators, but for the U.S. national security community. In a speech to the Atlantic Council in July 2014, Gen. William Shelton, then commander of U.S. Space Command, said that jamming was one of the top threats to U.S. military satellites.[26] While technologies, including jamming, to disrupt or destroy satellites have existed for many years, the zeitgeist regarding threats in space shifted from 2013 to 2014 and early 2015, particularly in the United States. While the Obama administration's watchword on national security space had been "strategic restraint," with an emphasis on diplomatic efforts to create norms of responsible behavior, harsher rhetoric has been emanating from the U.S. national security space community as relations with Russia have soured over the crisis in Ukraine, and both Russia and China have continued testing de facto ASAT capabilities.

U.S. military and intelligence officials have elevated their public concern over what is perceived as a dangerous increase over the past two years in threats to U.S. space assets. For example, U.S. Director of National Intelligence James Clapper raised the alarm about growing threats to U.S. satellites in his 29 January 2014 testimony to the Senate Intelligence Committee. "Threats to U.S. space services will increase during 2014 and beyond as potential adversaries pursue disruptive and destructive counterspace capabilities," Clapper said in written testimony. "Chinese and Russian military leaders understand the unique information advantages afforded by space systems and are developing capabilities to disrupt U.S. use of space in conflict."[27] "Strategic restraint has failed," one U.S. national security space official said bluntly. Indeed, U.S. government officials have said that concern about the possible need for a more aggressive counterspace strategy has risen all the way up to the White House.

Part of the edginess in U.S. national security circles stems from the fact that the U.S. lead in military space capabilities is starting to shrink. Over the past several decades, the United States has far outpaced all other nations in the use of satellites to achieve military advantage on the ground. That near-monopoly on space power as a force multiplier has begun to erode, however, as other nations—particularly China, which has a robust satellite development program—seek to gain similar military advantage. Russia, the European Union, India, and Israel also have significant military space capabilities and are pursuing further development. As space assets are becoming increasingly critical to successful military operations on the ground, sea, and air, they are increasingly seen by wary national militaries as potential targets in warfare.

Only three countries—the United States, Russia, and China—have tested ASAT capabilities overtly. But several other countries, including India and Israel, are also considering ASAT development. While there is still something of a taboo on overt ASAT testing—especially tests that create debris—ASAT capability is latent in ballistic missile defense systems. This fact was conclusively demonstrated by the 2008 U.S. shoot-down of the wayward USA-193 spy satellite with a modified SM-3 missile launched from an Aegis ballistic missile defense cruiser. All of the above nations have missile defense development programs that could serve as an acceptable "cover" for ASAT development.

Indeed, almost all space-related technologies are dual-use. For example, many countries are interested in developing small, maneuverable satellites for satellite servicing, especially refueling, which could save money by extending the life of large and expensive satellites. For example, NASA and the Canadian Space Agency are working on robotic satellite servicing systems and in February 2014 performed successful ground tests.[28] Such robotic spacecraft would be able to dock with an existing satellite not originally designed to be serviced—a so-called uncooperative satellite. While there are obvious benefits to satellite-servicing systems, they also could be used as ASATs, by either nudging the target satellite out of its useful orbit, or damaging or destroying it. The United States, China, Russia, Japan, and even Sweden have been testing and deploying satellites to perform such so-called "close proximity operations" on orbit. Similarly, some technologies for moving debris out of useful orbits—such as a grappling capability—could also be used as ASATs.

Again, while threats from counterspace technologies have long been recognized, the proliferation of capabilities as such technologies become more feasible and less expensive is worrying the U.S. national security community.

In particular, the Chinese test of a long-range Dong Ning-2 in an orbit near GEO—which the Chinese stated was a scientific experiment, but U.S. experts and government officials widely considered an ASAT test—threw the U.S. national security community into a tizzy. GEO is where many important national intelligence satellites reside.[29] While China has a declaratory policy of seeking only "peaceful purposes" in space, senior Chinese military officials (and Chinese military literature) have spoken openly about the "inevitability" of space warfare.[30]

While the 2007 test was overtly of a kinetic-energy, ground-based ASAT missile, the resulting international opprobrium has led Beijing to take a less publicly overt path toward developing ASAT capabilities and to refrain from debris-creating missile tests. On 23 July 2014, China conducted another missile test—described by Beijing as a ground-based missile defense test—in LEO, which led the U.S. State Department to take the rare step of publicly calling on China to cease and desist its ASAT testing. In a 20 February 2015 speech to the Federation of American Scientists, Frank Rose, State Department Assistant Secretary for the Bureau of Arms Control, Verification and Compliance, characterized the test as a "non-destruction test of a missile designed to destroy satellites in low-earth orbit." He said, "Despite China's claims that this was not an ASAT test, let me assure you the United States has high confidence in its assessment, that the event was indeed an ASAT test."[31] A State Department spokesman told *SpaceNews*: "We call on China to refrain from destabilizing actions—such as the continued development and testing of destructive anti-satellite systems—that threaten the long-term security and sustainability of the outer space environment, on which all nations depend."[32]

U.S. officials are almost as worried by recent Russian activities in space, especially as tensions between Moscow and Washington have escalated. While the U.S.-Russian relationship in space has long been isolated from geopolitics, the Ukraine crisis has infected almost every facet of the bilateral relationship. For example, in late 2013, CIA and Pentagon officials squashed State Department negotiations with Russia on civilian navigation and positioning that involved locating receiver stations for Russia's global navigation system, GLONASS, on U.S. soil. It was feared that these stations would improve Russian spying and military capabilities.[33] U.S. President Barak Obama then signed a 2014 national defense bill that bans foreign satellite stations on U.S. soil unless the Secretary of Defense and the Director of National Intelligence certify that these stations cannot be used to improve foreign weapons systems or be used for spying.[34] This ruling in effect banned GLONASS ground stations on U.S. soil. In response, Russia moved to prevent the use of the 11 International Global Navigation Satellite System Service ground stations on Russian territory (which are not U.S.-operated) for military purposes."[35]

U.S. national security officials are also concerned about Russian testing activities. In November 2014, Russian satellite Kosmos 2499 undertook a series of maneuvers on obit, including a very close approach to one of its own abandoned Briz-KM rocket stages. As Russia has been tight-lipped about the satellite's purpose, there has been growing speculation that it was a test of satellite-inspection capabilities or even the revival of the 1960s-era Soviet Istrebital Sputnikov co-orbital ASAT program.[36] There are now three maneuverable, refrigerator-sized Kosmos satellites in LEO—firmly on the radar of the U.S. military.[37]

While the United States is worried about the activities of Russia and China, it has also been testing and deploying technologies with latent ASAT capabilities. As noted earlier, kinetic-energy ballistic missiles designed for shooting down incoming missiles can be repurposed to attack satellites. For many years Russia has expressed concerns that the U.S. missile defense program (which includes ground- and sea-based systems) is designed to do just that. The 2008 U.S. shoot-down of USA 193 using a tweaked version of the Aegis missile defense system did nothing to dispel Russia's fears. The United States has also deployed maneuverable satellites, under the Geosynchronous Space Situational Awareness program, with two launched in July 2014. The Air Force has stated that the satellites are able to "maneuver near a resident space object of interest" to allow "more accurate tracking and characterization of man-made space objects."[38]

Renewed interest in offensive counterspace systems by the U.S. national security community is not just a reaction to the proliferation of ASAT capabilities, but also the growing capacities of other nations (particularly China) to use space in the same way that the U.S. military does to provide force projection.

The U.S. Congress has now ordered the Pentagon to focus on development of counterspace capabilities for both "active defense" and "offensive" operations. Active defense in Air Force parlance equates to weapon systems that target an enemy's counterspace systems; offensive counterspace refers to U.S. operations that target an adversary's satellites and space systems. The National Defense Authorization Act of 2015 (passed in December 2014, which sets guidelines for all U.S. military activities) orders the Secretary of Defense and the Director of National Intelligence to carry out a study on the role of offensive space operations in the National Security Space Strategy of 2011. It also mandates that the majority of the $32.3-million in the bill for the Space Security and Defense Program in 2015 must be used for "the development of offensive space control and active defensive strategies and capabilities."[39]

It must be acknowledged that the amount of money provided by Congress is not much by Pentagon standards. And it will be up to the White House and the Department of Defense to interpret the instructions and allocate the "majority" of resources between "offensive" and "active defense" programs. Still, the signaling is clear and reflects the intergovernmental discussions of strategic space policy ongoing within the Obama Administration. While many U.S. government officials have stated that the United States will not pursue debris-creating ASATs, it is now apparent that other options (such as jamming and laser weapons) are being reconsidered. There are also worrying signals that some within the U.S. government are ready to reconsider the use of debris-creating, and/or destructive, ASAT technologies.

Multilateral cooperative space governance efforts on a slow boat

With tensions among the big three players on military space at perhaps an all-time high, it is no wonder that multilateral efforts to build confidence and spur cooperation are beginning to sputter.

Between 2008 and mid-2013, three major multilateral initiatives aimed at building transparency and confidence and developing "rules of the road" for space were under way, giving cause for rising optimism. Each initiative addresses a slightly different aspect of multilateral governance, but all are interrelated, with overlapping concepts.

In 2008, the European Union released a draft code of conduct for outer space activities. The code, designed as a voluntary but politically binding instrument, is primarily a norm-setting exercise that looks to distinguish between responsible and irresponsible behavior in space. It thus straddles the somewhat blurry line between space security and space safety/stability, addressing both norms for behavior in peacetime and times of conflict. The latest EU revised draft was released in May 2015.[40]

In 2010, UN COPUOS established the Working Group on the Long-term Sustainability of Outer Space Activities under its Scientific and Technical Subcommittee to develop a set of voluntary "best practices" for space activities. The draft guidelines, which are more technical than political and focus on protecting the space environment, are now being negotiated.[41] While not officially aimed at dealing with space security or military uses of space, the guidelines, if accepted by states, would have an effect on the conduct of national security space activities.

In 2011, the UNGA First Committee, the body responsible for international security affairs, called upon the Secretary-General to establish a Group of Governmental Experts on transparency and confidence-building measures in space. The 15-member GGE began deliberations in 2012 and issued a report in July 2013, which was adopted by the General Assembly at its 68th session.[42] The work of the GGE is most directly related to space security, seeking to create mutual understanding and build trust among nations to reduce risks of misperceptions, miscalculations, and conflict. The report lays out basic TCBMs that could be undertaken by states unilaterally, bilaterally, or multilaterally.

The success of the GGE was seen as a milestone, since it is the first UN agreement in many years to focus directly on improving space security. It also raised hopes that the other two negotiation processes would also be successful; taken together, the initiatives could create a new governance framework for outer space. However, by August 2015, the multilateral climate had substantially soured.

The May version of the EU draft code was the basis of a meeting held in New York from 27-31 July 2015 under UN auspices. While initially designed as the first formal round of negotiations, the meeting was changed to a non-negotiating format. Participants debated both the substance of the draft code and the desired process for negotiations. According to the summary of the meeting prepared by Chair Sergio Marchisio of Italy, there were substantially divergent views on both the scope of the code (i.e., whether it should cover military activities) and the negotiation process (whether any negotiations could be held outside of the United Nations). The report states: "It was the assessment of the Chair that, based on the discussions and considering the importance afforded to the principles of openness, transparency, universality and inclusiveness, the most supported way forward would be the pursuit of negotiations within the framework of the United Nations through a mandate of the General Assembly."[43]

Essentially, the meeting brought to a head the division between a coalition of Russia, China, Brazil, India, South Africa and some Non-Aligned Movement states and the EU countries supported by the United States, Australia, and Japan. The objections of the first group to the draft code language on "self-defense" in space and their insistence that any negotiations on military space activities take place under a UN mandate were not surprising. However, it is now abundantly clear that the code proposal is either indefinitely stalled or will devolve into an agreement by a "coalition of the willing" Western states along the lines of the Hague Code of Conduct on ballistic missile proliferation.[44]

The COPUOS discussion has also bogged down. Many members had hoped to finalize the draft guidelines by 2016, after which they would be referred to the UNGA for adoption. However, those hopes were dashed during the 2-13 February 2015 STSC session in Vienna, due particularly to a complicated set of amendments and working papers proposed by Russia, which many saw as deliberate monkey wrenches. Particularly controversial is the Russian proposal to incorporate an official interpretation of "self-defense" in space, a task that has eluded space lawyers for nigh on 50 years.[45] The last meeting of the Working Group was in June 2015; participants generally left with feelings of frustration, especially at what many saw as a less-than-productive attitude by Moscow.

Not much has yet come of the GGE exercise. So far, no government has moved to take up substantial work to implement the recommendations, even though some activities could be taken up unilaterally, bilaterally, and regionally, as well as multilaterally. The one exception: in October 2015, the UNGA will hold the first ever joint meeting of the First Committee and the Fourth Committee (which deals with scientific issues and COPUOS) on challenges to space security and sustainability. It should be noted that the GGE specifically mentioned the importance of COPUOS work on long-term sustainability and the fact that the guidelines will have "characteristics similar to transparency and confidence-building measures."[46] As the agenda for this meeting has yet to be released, it remains to be seen whether the discussions will be shaped as a "stock taking" exercise or as an opportunity to discuss new approaches.

Running in place to avoid going backward

While at the moment it is hard to see how any major forward steps on space security can be taken, some initiatives provide opportunities to not lose gains made in the past several years.

Most immediately, the First-Fourth Committee meeting will provide an opportunity for states to present proposals on how to forward the work of the GGE. One idea would be for a joint resolution to call a meeting of States Parties to the 1967 Outer Space Treaty in 2017, when the treaty will turn 50. The goal would be to review implementation of the treaty, as well as other parts of the multilateral space regime. The GGE report recommends "universal participation in, implementation of, and full adherence to, the existing legal framework relating to outer space activities."[47] Such a meeting could, for example, discuss the problems highlighted by the GGE report, including compliance with the Registration Convention and the UN Debris Mitigation Guidelines. Some experts, however, are concerned that such a resolution could be taken as an opportunity to open the OST to amendments or reinterpretation. Nonetheless, if properly crafted, a review of the implementation of the current space governance instruments could provide a marker to keep the discussion of multilateral approaches on the table.

With regard to implementation of the GGE recommendations, one of the first, and relatively easy, steps that could be taken unilaterally by any number of states would be the creation of focal points and contacts for data exchange, particularly in the case of potential collisions. Similar recommendations are included in the draft COPUOS guidelines, which call for exchanges of information on spacecraft operators and entities performing conjunction analysis.[48] Likewise, the EU draft code calls for each subscribing state to establish a "central point of contact" responsible for reporting to the code's management organization of subscribing states. That state contact would not only provide notifications to the group, but would also be responsible for serving as a conduit for consultations.[49]

The articulation of contact nodes within organizations responsible for spacecraft management, including the private sector, would be useful for a number of reasons. It forces national governments to identify and create linkages to all stakeholders, and to develop channels for both internal and external communications. The identification of individuals as contact points creates ownership within stakeholder organizations. And the creation of an international "space phonebook" lays the foundation for the development of easily accessible dispute resolution methods. Once a network of contacts is developed at the national level, the information could be reported to various UN bodies, including the First and Fourth Committees, COPUOS, the Conference on Disarmament, the Office of Outer Space Affairs, and the ITU.

The GGE also recommends universal adherence to, and implementation of, the Registration Convention. Both the EU draft code and COPUOS draft guidelines note inadequate compliance, problems with harmonization of reporting data, and the need for more information (such as notification that a space object is no longer functional). The sketchiness of many countries' registration submissions has a negative effect on space security and safety. As compliance is a national responsibility, any one nation could launch its own effort or work with other states, not only to improve compliance, but to upgrade the types of information provided.

Cooperation could also be increased in the sharing of SSA data among governments and private-sector operators. The United States should be commended for continuing to expand its data-sharing program, primarily aimed at providing collision warning. In 2014, the United States signed agreements with France[50] (21 January; updated 16 April 2015 to include classified data exchange[51]), Japan[52] (12 May), EUMETSAT[53] (9 August), South Korea[54] (5 September), and the ESA[55] (31 October). The United States has an SSA-sharing agreement with Italy and, as of 28 January 2015, with Germany, plus agreements with 46 commercial entities in 16 countries.[56] In September 2014, the United States signed a Memorandum of Understanding for Combined Space Operations initiative with Australia, Canada, and the United Kingdom. The agreements include SSA sharing, as well as sharing of data on mitigation of interference, space weather, and GPS accuracy.[57] Finally, in a breakthrough of sorts, the United States and China agreed in December 2014 that USAF Space Command will provide collision warning data directly to Chinese space operators, rather than by the more circuitous route through the U.S. State Department to the Chinese Foreign Ministry and then to Chinese operators.[58]

Still, there is more that the United States could do to improve SSA data and data sharing, particularly with private sector actors. In addition, Russia, China, India, the EU, and other countries with SSA capabilities could work together to share their data more openly, including with the United States. Currently, the data flow is mostly a one-way street.

Russia submitted a proposal at the most recent meeting of the COPUOS Long-term Sustainability Working Group that a UN-managed space object database be seriously studied. The proposal states: "The Russian Federation, having proposed for consideration the basic elements of the concept of establishing a unified Centre for Information on Near-Earth Space Monitoring under the auspices of the United Nations…is of the view that an in-depth examination of the feasibility of a UN-centric information hub gathering information on objects and events in outer space from different sources as a tentatively promising means of meeting general needs and aspirations, in particular, the needs of emerging space-faring States, would be reasonable."[59] Russia foresees the database being managed by UN OOSA, which would initially gather data from states. A later stage might see OOSA providing conjunction analysis.

While the proposal faces opposition, from the United States in particular, there is widespread agreement that better access for all space operators to SSA data is a much needed transparency and safety measure. COPUOS too has emphasized this requirement, as well as the need for more accurate data and uniform standards of data collection and processing. In addition, the United States is considering a counter-proposal to create a new informal international group to discuss the challenges to space object data sharing; it would operate along the lines of the International Committee on Global Navigation Satellite Systems, created in 2005 under UN auspices to promote voluntary cooperation on commercial satellite navigation issues.[60] The creation of such a body would be welcome and help to increase "buy in" by a wide range of space actors, including commercial operators.

More cooperative activity could happen in the area of active debris removal and on-orbiting servicing. As mentioned earlier, the fact that these technologies have potential weapons applications is already putting national research and development efforts under a cloud of suspicion. COPUOS is considering whether to put ADR and on-orbiting servicing technologies on the agenda of the STSC—both as an information-sharing exercise on potential technological solutions and as a forum to discuss potential cooperative approaches.

There also are legal concerns about the compliance of ADR systems with the Outer Space Treaty and the Liability Convention, among other international legal instruments. One key problem is that there is no legal definition of space debris. Further, under the OST, it is illegal for a nation or commercial entity to remove a piece of debris without obtaining permission from the "owner" of that object, but identifying who owns what pieces of debris remains a problem.

As cooperation on ADR and on-orbit servicing technologies would help to dampen suspicions about the intent of such national development programs, a COPUOS STSC discussion of on-going efforts would be useful. COPUOS could at the same time create a working group under the Legal Subcommittee to examine the legal and political challenges to implementing ADR and on-orbit servicing systems, with an eye toward enabling and encouraging international cooperative development (or, at a minimum, establishing processes to ensure transparency regarding national developments).

Conclusion

Despite a situation that is unlikely to improve in the near term, multilateral efforts to restrain negative competition in space remain critical. It should be clear that if we fail to "hang together" in protecting the space environment, we will "all hang separately," as our ability to benefit from space resources diminishes over time. But short-term thinking about national advantage and profit from the use of space often prevails. There are opportunities for states—at the unilateral, regional, and multilateral levels—and for the nongovernmental and private sectors to take actions that will continue to move the ball toward a safer, more sustainable, and more secure environment in space. It would behoove all space actors to consider their options to ensure that progress made so far is not rolled back. Two steps forward, one step back is better than the alternative.

Space Security Working Group Meeting

Best Western Ville-Marie Hotel
Montreal, Canada
1-2 May, 2015

Invited Experts:

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Institute of Air and Space Law, McGill University

Laura Grego
Union of Concerned Scientists

Theresa Hitchens
Center for International and Security Studies at Maryland, University of Maryland (via Skype)

David Kendall
Canadian Space Agency (retired), International Space University, Incoming Chair UN COPUOS (2016-17)

Andrea Matte
Canadian Space Agency

Jonathan MacDowell
Harvard-Smithsonian Center for Astrophysics

Ryder McKeown
Department of National Defence, Canada

Audrey Schaffer
Department of Defense, United States

Erik Stenlund
Department of Foreign Affairs, Trade and Development

Lucy Stojak
École des Hautes Études Commerciales de Montréal (HEC)

Jinyuan Su
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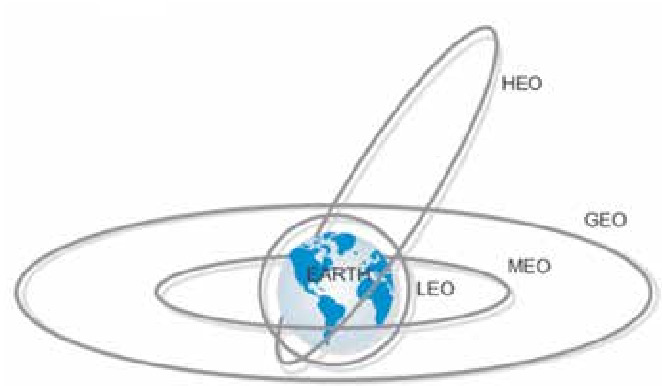
Types of Earth orbits*



Low Earth Orbit (LEO) is commonly accepted as below 2,000 km above the Earth's surface. Spacecraft in LEO make one complete revolution of the Earth in approximately 90 minutes.

Medium Earth Orbit (MEO) is the region of space around the Earth above LEO (2,000 km) and below GEO (36,000 km). The orbital period (time for one orbit) of MEO satellites ranges between two and 12 hours. The most common use for satellites in this region is navigation, as with the U.S. GPS.

Geostationary Orbit (GEO) is a region in which the satellite orbits at approximately 36,000 km above the Earth's equator. At this altitude GEO has a period equal to the period of rotation of the Earth. By orbiting at the same rate, in the same direction as Earth, the satellite appears stationary relative to the surface of the Earth. This is very useful for communications satellites. In addition, geostationary satellites provide a 'big picture' view of Earth, enabling coverage of weather events. This is especially useful for monitoring large, severe storms and tropical cyclones.

Sun Synchronous Orbit refers to an orbit at near-polar inclination and an altitude of between 200 and 1,200 km. The satellite passes over the equator and each latitude on the Earth's surface at the same local time each day, meaning that the satellite is overhead at essentially the same time throughout all seasons of the year. This feature enables collection of data at regular intervals and consistent times, which is especially useful for making long-term comparisons. **Polar orbit** is a more general term and includes all satellites with inclinations from approximately 70 degrees to 110 degrees at any altitude.

Highly Elliptical Orbits (HEO) are characterized by a relatively low-altitude perigee and an extremely high-altitude apogee. These extremely elongated orbits have the advantage of long dwell times at a point in the sky; visibility near apogee can exceed 12 hours. These elliptical orbits are useful for communications satellites. **Molniya orbit** is an example of HEO with excellent visibility of the Northern Hemisphere.

GEO transfer orbit (GTO) is an elliptical orbit of the Earth, with the perigee in LEO and the apogee in GEO. This orbit is generally a transfer path after launch to LEO by launch vehicles carrying a payload to GEO.

Apogee and **Perigee** refer to the distance from the Earth to the satellite. Apogee is the furthest distance from the Earth and perigee is the closest distance from the Earth.

* From the Space Foundation, *The Space Report 2008* (Colorado Springs: Space Foundation 2008), p. 52 with comments from Jonathan McDowell.

Reentries (over 1,000 kg) in 2014*

Object	COSPAR Number	Mass in kg	Launch Date	Reentry Date
EPC 572	2014-006	14500	6-Feb-14	6-Feb-14
EPC 571	2014-011	14500	22-Mar-14	22-Mar-14
EPC 593	2014-044	14500	29-Jul-14	30-Jul-14
EPC 573	2014-054	14500	11-Sep-14	11-Sep-14
EPC 574	2014-062	14500	16-Oct-14	16-Oct-14
EPC 575	2014-078	14500	6-Dec-14	6-Dec-14
ESC-A 556	2010-065C	5000	26-Nov-10	16-Aug-14
CZ-2C Stage 2	2011-072B	4006	29-Nov-11	19-Mar-14
CZ-2C Stage 2	2009-021B	4006	22-Apr-09	14-Dec-14
H-2A F22 Stage 2	2014-009J	4000	27-Feb-14	16-Jun-14
Angara URM-2	2014-085	4000	23-Dec-14	23-Dec-14
8S812	2014-007	3500	14-Feb-14	14-Feb-14
8S812	2014-010	3500	15-Mar-14	15-Mar-14
8S812	2014-023	3500	28-Apr-14	28-Apr-14
8S812	2014-058	3500	27-Sep-14	27-Sep-14
8S812	2014-064	3500	21-Oct-14	21-Oct-14
8S812	2014-082	3500	15-Dec-14	15-Dec-14
8S812	2014-089	3500	27-Dec-14	27-Dec-14
Kosmos-1220 main debris	1980-089A	3000	4-Nov-80	16-Feb-14
Falcon 9 stage 2	2013-071B	3000	3-Dec-13	30-Apr-14
Falcon 9 stage 2	2014-002B	3000	6-Jan-14	28-May-14
Falcon 9 stage 2	2014-052B	3000	7-Sep-14	28-Dec-14
CZ-3B Stage 3	2008-028B	2800	9-Jun-08	16-Jan-14
Yaogan Weixing 5	2008-064A	2700	15-Dec-08	2-Sep-14
GSLV-D5 CUS	2014-001B	2500	5-Jan-14	8-Jun-14
11S510	2014-005B	2350	5-Feb-14	7-Feb-14
Blok-I 14S54	2014-012	2350	23-Mar-14	23-Mar-14
11S510	2014-013B	2350	25-Mar-14	28-Mar-14
Blok-I 14S54/RD-0110	2014-016	2350	3-Apr-14	3-Apr-14
11S510	2014-018B	2350	9-Apr-14	11-Apr-14
Blok-I 14S54	2013-078D	2350	28-Dec-13	8-May-14
Blok-I 14S54/RD-0110	2014-025B	2350	6-May-14	10-May-14
11S510	2014-031B	2350	28-May-14	31-May-14
Blok-I 14S54	2014-032	2350	14-Jun-14	14-Jun-14
Blok-I 14S54	2014-037J	2350	8-Jul-14	10-Jul-14
Blok-I 374BL02B	2014-038	2350	10-Jul-14	10-Jul-14
11S510	2014-042B	2350	23-Jul-14	25-Jul-14
Blok-I 374BL02B	2014-050	2350	22-Aug-14	22-Aug-14
11S510	2014-057B	2350	25-Sep-14	28-Sep-14

Object	COSPAR Number	Mass in kg	Launch Date	Reentry Date
Blok-I 14S54/RD-0110	2014-069	2350	30-Oct-14	30-Oct-14
Blok-I 14S54/RD-0110	2014-067B	2350	29-Oct-14	30-Oct-14
Blok-I 14S54/RD-0110	2014-041B	2350	18-Jul-14	31-Oct-14
11S510	2014-074B	2350	23-Nov-14	26-Nov-14
Blok-I 14S54	2014-075	2350	30-Nov-14	30-Nov-14
Blok-I 374BL02B	2014-083	2350	18-Dec-14	18-Dec-14
Soyuz TMA-13M PAO	2014-031	2116	28-May-14	10-Nov-14
Centaur AC-166	2004-017B	2095	19-May-14	16-Jun-14
Soyuz TMA-10M PAO	2013-054	2049	25-Sep-13	11-Mar-14
Soyuz TMA-11M PAO	2013-061	2049	7-Nov-13	14-May-14
Soyuz TMA-12M PAO	2014-013	2049	25-Mar-14	11-Sep-14
Centaur AV-004	2005-009B	2020	11-Mar-05	1-Jul-14
Centaur AV-037	2013-011B	2020	19-Mar-13	22-Nov-14
Centaur AV-013	2007-006G	2020	9-Mar-07	22-Dec-14
Kosmos-1939	1988-032A	1900	20-Apr-88	29-Oct-14
Kosmos-1151	1980-005A	1888	23-Jan-80	4-Aug-14
Ariane H10-3 V118	1999-042B	1820	12-Aug-99	10-Mar-14
Ariane H10-3 V125	1999-071B	1820	22-Dec-99	11-Apr-14
Ariane H10 V47 main debris	1991-075B	1820	29-Oct-91	20-Oct-14
Kosmos-1242	1981-008A	1750	27-Jan-81	8-May-14
Kosmos-1400	1982-079A	1750	5-Aug-82	13-Sep-14
Kosmos-1441	1983-010A	1750	16-Feb-83	8-Nov-14
8A92ME	1980-069B	1440	15-Aug-80	22-May-14
8A92ME	1980-008B	1440	30-Jan-80	12-Oct-14
S3M	2006-060B	1434	19-Dec-06	30-Mar-14
S3M	2007-053B	1434	1-Nov-07	16-Apr-14
S3M	2008-036B	1434	22-Jul-08	1-May-14
S3M	2007-030B	1434	2-Jul-07	23-Sep-14
S3M	2008-014B	1434	27-Mar-08	23-Nov-14
Soyuz TMA-13M BO	2014-031	1311	28-May-14	10-Nov-14
Soyuz TMA-10M BO	2013-054	1273	25-Sep-13	11-Mar-14
Soyuz TMA-11M BO	2013-061	1273	7-Nov-13	14-May-14
Soyuz TMA-12M BO	2014-013	1273	25-Mar-14	11-Sep-14
Kosmos-903	1977-027A	1150	11-Apr-77	4-Aug-14
Kosmos-2097	1990-076A	1150	28-Aug-90	28-Dec-14
PSLV-C24 PS3	2014-017	1100	4-Apr-14	4-Apr-14
PSLV-C26 PS3	2014-061	1100	15-Oct-14	15-Oct-14
Antares Stage 2	2014-003B	1083	9-Jan-14	18-Jan-14
Antares Stage 2	2014-039B	1083	13-Jul-14	19-Jul-14
JSE reda-2 gouki	2007-005A	1000	24-Feb-07	13-Apr-14

Object	COSPAR Number	Mass in kg	Launch Date	Reentry Date
Dragon Trunk	2014-022	1000	18-Apr-14	18-May-14
JSE kougaku-1 gouki	2003-009A	1000	28-Mar-03	18-Jul-14
Briz-M DTB	2011-074D	1000	11-Dec-11	9-Sep-11
Briz-M DTB	2013-077C	1000	26-Dec-13	18-Oct-14
CZ-4B Stage 3	2014-053C	1000	8-Sep-14	23-Oct-14
Dragon Trunk	2014-056	1000	21-Sep-14	25-Oct-14

*Data provided by Jonathan McDowell, 2015.

Spacecraft launched in 2014*

Satellite name	Owner	Actor type	Primary function	Orbit	Mass (kg)	Launch Vehicle	Launch date
GSAT-14	India	Government	Communications	GEO	1,982	GSLV	5-Jan-14
Thaicom-6	Thailand	Commercial	Communications	GEO	3,325	Falcon 9	6-Jan-14
TDRS-12	USA	Government	Communications	GEO	3,454	Atlas 5	23-Jan-14
ABS-2 (Koreasat-8, ST-3)	Multinational	Commercial	Communications	GEO	6,330	Ariane 5 ECA	6-Feb-14
Athena-Fidus	France/Italy	Government/ Military	Communications	GEO	3,080	Ariane 5 ECA	6-Feb-14
Turksat 4A	Turkey	Commercial	Communications	GEO	4,869	Proton	14-Feb-14
Navstar GPS IIF-5	USA	Military/ Commercial	Navigation/Global Positioning	MEO	1,630	Delta 4	21-Feb-14
GPM Core Observatory	USA/Japan	Government	Earth Observation	LEO	3,850	H2A	27-Feb-14
Express-AT1	Russia	Commercial	Communications	GEO	1,726	Proton M	15-Mar-14
Express-AT2	Russia	Commercial	Communications	GEO	1,427	Proton M	15-Mar-14
Amazonas-4A	Spain	Commercial	Communications	GEO	2,938	Ariane 5 ECA	22-Mar-14
Astra 5B	Luxembourg	Commercial	Communications	GEO	5,724	Ariane 5 ECA	22-Mar-14
Glonass 754 (Kosmos 2494)	Russia	Military/ Commercial	Navigation/Global Positioning	MEO	1,415	Soyuz 2.1b	23-Mar-14
Shijian 11-06	China	Government	Technology Development	LEO		Long March 2C	31-Mar-14
DMSP 5D-3 F19	USA	Military	Earth Observation	LEO	1,230	Atlas 5	3-Apr-14
Sentinel 1A	ESA	Government	Earth Observation	LEO	2,300	Soyuz	3-Apr-14
IRNSS-1B	India	Government	Navigation/Regional Positioning	GEO	1,432	PSLV	4-Apr-14
Ofeq 10	Israel	Military	Earth Observation	LEO	300	Shavit	9-Apr-14
Mercury 3 (NROL 67)	USA	Military	Earth Observation	GEO	3,900	Atlas 5	10-Apr-14
Egyptsat-2 (Misrsat 2)	Egypt	Military	Earth Observation	LEO	1,050	Soyuz	16-Apr-14
KazSat-3	Kazakhstan	Commercial	Communications	GEO		Proton M	28-Apr-14
Luch 5V	Russia	Government	Communications	GEO	1,148	Proton M	28-Apr-14
KazEOSat-1	Kazakhstan	Government	Earth Observation	LEO	830	Vega	30-Apr-14
Navstar GPS IIF-6	USA	Military/ Commercial	Navigation/Global Positioning	MEO	1,630	Delta 4	17-May-14
SDS III-8 (NRO L-33)	USA	Military	Communications	GEO		Atlas 5	22-May-14
Rodnik (Kosmos 2496)	Russia	Military	Communications	LEO	280	Rokot	23-May-14
Rodnik (Kosmos 2497)	Russia	Military	Communications	LEO	280	Rokot	23-May-14

Satellite name	Owner	Actor type	Primary function	Orbit	Mass (kg)	Launch Vehicle	Launch date
Rodnik (Kosmos 2498)	Russia	Military	Communications	LEO	280	Rokot	23-May-14
RS-47 (Kosmos 2499)	Russia	Military	Technology Development	LEO		Rokot	23-May-14
Daichi-2 (ALOS 2)	Japan	Government	Earth Observation	LEO	2,120	H2A	24-May-14
Rising-2	Japan	Civil	Earth Observation	LEO	41	H2A	24-May-14
SOCRATES	Japan	Commercial	Technology Development	LEO	48	H2A	24-May-14
SPROUT	Japan	Civil	Technology Development	LEO	7	H2A	24-May-14
UNIFORM 1	Japan	Civil	Earth Observation	LEO	50	H2A	24-May-14
Eutelsat 3B	Multinational	Commercial	Communications	GEO	5,967	Zenit 3SL	26-May-14
Glonass 755 (Kosmos 2500)	Russia	Military/ Commercial	Navigation/Global Positioning	MEO	1,415	Soyuz 2.1b	14-Jun-14
Aerocube 6A	USA	Commercial	Technology Development	LEO	1	Dnepr	19-Jun-14
Aerocube 6B	USA	Commercial	Technology Development	LEO	1	Dnepr	19-Jun-14
AntelSat	Uruguay	Civil	Technology Development	LEO	2	Dnepr	19-Jun-14
AprizeSat 10	USA/ Argentina	Commercial	Communications/ Maritime Tracking	LEO	12	Dnepr	19-Jun-14
AprizeSat 9	Canada	Commercial	Communications/ Maritime Tracking	LEO	12	Dnepr	19-Jun-14
Aurora (Tabletsat-2U-EO)	Russia	Commercial	Technology Development	LEO	25	Dnepr	19-Jun-14
BRITE-CA-1	Canada	Civil	Space Science	LEO	10	Dnepr	19-Jun-14
Bugsat-1 (Tita)	Argentina	Commercial	Technology Development	LEO	25	Dnepr	19-Jun-14
Deimos 2	Spain	Government	Earth Observation	LEO	310	Dnepr	19-Jun-14
Dove 1C-1	USA	Commercial	Earth Observation	LEO	5	Dnepr	19-Jun-14
Dove 1C-10	USA	Commercial	Earth Observation	LEO	5	Dnepr	19-Jun-14
Dove 1C-11	USA	Commercial	Earth Observation	LEO	5	Dnepr	19-Jun-14
Dove 1C-2	USA	Commercial	Earth Observation	LEO	5	Dnepr	19-Jun-14
Dove 1C-3	USA	Commercial	Earth Observation	LEO	5	Dnepr	19-Jun-14
Dove 1C-4	USA	Commercial	Earth Observation	LEO	5	Dnepr	19-Jun-14
Dove 1C-5	USA	Commercial	Earth Observation	LEO	5	Dnepr	19-Jun-14
Dove 1C-6	USA	Commercial	Earth Observation	LEO	5	Dnepr	19-Jun-14
Dove 1C-7	USA	Commercial	Earth Observation	LEO	5	Dnepr	19-Jun-14
Dove 1C-8	USA	Commercial	Earth Observation	LEO	5	Dnepr	19-Jun-14
Dove 1C-9	USA	Commercial	Earth Observation	LEO	5	Dnepr	19-Jun-14
Hodoyoshi-3	Japan	Government	Technology Development	LEO	60	Dnepr	19-Jun-14

Satellite name	Owner	Actor type	Primary function	Orbit	Mass (kg)	Launch Vehicle	Launch date
Hodoyoshi-4	Japan	Government	Technology Development	LEO	60	Dnepr	19-Jun-14
KazEOSat-2	Kazakhstan	Government	Earth Observation	LEO	185	Dnepr	19-Jun-14
Lemur-1	USA	Commercial	Technology Development	LEO	4	Dnepr	19-Jun-14
NanosatC-Br1	Brazil	Civil	Earth Observation	LEO	1	Dnepr	19-Jun-14
Perseus M1	Russia/USA	Commercial	Communications	LEO	6	Dnepr	19-Jun-14
Perseus M2	Russia/USA	Commercial	Communications	LEO	6	Dnepr	19-Jun-14
PolyITAN-1	Ukraine	Civil	Technology Development	LEO	1	Dnepr	19-Jun-14
Popsat-HIP	Singapore	Commercial	Technology Development	LEO	3	Dnepr	19-Jun-14
QB50P1 (EO 79)	Belgium	Civil	Space Science	LEO	2	Dnepr	19-Jun-14
QB50P2 (EO 80)	Belgium	Civil	Space Science	LEO	2	Dnepr	19-Jun-14
Saudisat-4	Saudi Arabia	Government	Space Science	LEO	100	Dnepr	19-Jun-14
TIGRISat	Italy	Civil	Earth Observation	LEO	1	Dnepr	19-Jun-14
Unisat-6	Italy	Civil	Communications	LEO	12	Dnepr	19-Jun-14
AISat-1	Germany	Government	Communications	LEO	14	PSLV CA	30-Jun-14
Can-X4	Canada	Civil	Technology Development	LEO	15	PSLV CA	30-Jun-14
Can-X5	Canada	Civil	Technology Development	LEO	15	PSLV CA	30-Jun-14
Spot 7	France/ Belgium/ Sweden	Commercial	Earth Observation	LEO	714	PSLV CA	30-Jun-14
Velox 1	Singapore	Civil	Technology Development	LEO	4	PSLV CA	30-Jun-14
OCO 2	USA	Government	Earth Observation	LEO	454	Delta 2	2-Jul-14
Gonets M-18	Russia	Commercial/ Government	Communications	LEO	280	Rokot	3-Jul-14
Gonets M-19	Russia	Commercial/ Government	Communications	LEO	280	Rokot	3-Jul-14
Gonets M-20	Russia	Commercial/ Government	Communications	LEO	280	Rokot	3-Jul-14
AISSat-2	Norway	Government	Communications	LEO	6	Soyuz 2.1b	8-Jul-14
DX-1	Russia	Commercial	Communications	LEO	27	Soyuz 2.1b	8-Jul-14
Meteor-M N-2	Russia	Government	Earth Observation	LEO	2,778	Soyuz 2.1b	8-Jul-14
Relek (ICA-FC1)	Russia	Government	Earth Observation	LEO	253	Soyuz 2.1b	8-Jul-14
SkySat-2	USA	Commercial	Earth Observation	LEO	90	Soyuz 2.1b	8-Jul-14
TechDemoSat-1	United Kingdom	Government	Technology Development	LEO	150	Soyuz 2.1b	8-Jul-14
UKube-1	United Kingdom	Government	Technology Development	LEO	3	Soyuz 2.1b	8-Jul-14
O3b FM03	United Kingdom	Commercial	Communications	MEO	650	Soyuz-ST-B	10-Jul-14

Satellite name	Owner	Actor type	Primary function	Orbit	Mass (kg)	Launch Vehicle	Launch date
O3b FM06	United Kingdom	Commercial	Communications	MEO	650	Soyuz-ST-B	10-Jul-14
O3b FM07	United Kingdom	Commercial	Communications	MEO	650	Soyuz-ST-B	10-Jul-14
O3b FM08	United Kingdom	Commercial	Communications	MEO	650	Soyuz-ST-B	10-Jul-14
OG2 FM-103	USA	Commercial	Communications	LEO	172	Falcon 9	14-Jul-14
OG2 FM-104	USA	Commercial	Communications	LEO	172	Falcon 9	14-Jul-14
OG2 FM-106	USA	Commercial	Communications	LEO	172	Falcon 9	14-Jul-14
OG2 FM-107	USA	Commercial	Communications	LEO	172	Falcon 9	14-Jul-14
OG2 FM-109	USA	Commercial	Communications	LEO	172	Falcon 9	14-Jul-14
OG2 FM-111	USA	Commercial	Communications	LEO	172	Falcon 9	14-Jul-14
Angels	USA	Military	Technology Development	GEO	70	Delta 4M	28-Jul-14
GSSAP 1	USA	Military	Space Observation	GEO		Delta 4M	28-Jul-14
GSSAP 2	USA	Military	Space Observation	GEO		Delta 4M	28-Jul-14
Navstar GPS IIF-7	USA	Military/ Commercial	Navigation/Global Positioning	MEO	1,630	Atlas 5	2-Aug-14
AsiaSat-8	China	Commercial	Communications	GEO	4,500	Falcon 9	5-Aug-14
Yaogan 20A	China	Military	Earth Observation	LEO		Long March 4C	9-Aug-14
Yaogan 20B	China	Military	Earth Observation	LEO		Long March 4C	9-Aug-14
Yaogan 20C	China	Military	Earth Observation	LEO		Long March 4C	9-Aug-14
Worldview 3	USA	Commercial	Earth Observation	LEO	2,800	Atlas 5	13-Aug-14
BRITE-PL-2	Multinational	Government	Space Science	LEO	10	Long March 4B	19-Aug-14
Dove 1B-23	USA	Commercial	Earth Observation	LEO	5	Nanoracks Cubesat Deployer	19-Aug-14
Dove 1B-24	USA	Commercial	Earth Observation	LEO	5	Nanoracks Cubesat Deployer	19-Aug-14
Gaofen 2	China	Government	Earth Observation	LEO	1,000	Long March 4B	19-Aug-14
Dove 1B-2	USA	Commercial	Earth Observation	LEO	5	Nanoracks Cubesat Deployer	21-Aug-14
Galileo FOC FM1	ESA	Commercial	Navigation/Global Positioning	MEO	733	Soyuz-ST	22-Aug-14
Galileo FOC FM2	ESA	Commercial	Navigation/Global Positioning	MEO	733	Soyuz-ST	22-Aug-14
Dove 1B-8	USA	Commercial	Earth Observation	LEO	5	Nanoracks Cubesat Deployer	23-Aug-14

Satellite name	Owner	Actor type	Primary function	Orbit	Mass (kg)	Launch Vehicle	Launch date
Chuangxin 1-4	China	Government	Earth Observation	LEO	100	Long March 2D	4-Sep-14
Ling Qiao	China	Commercial	Technology Development	LEO	100	Long March 2D	4-Sep-14
Dove 1B-17	USA	Commercial	Earth Observation	LEO	5	Nanoracks Cubesat Deployer	5-Sep-14
AsiaSat-6 (Thaicom-7)	China	Commercial	Communications	GEO	3,700	Falcon 9	7-Sep-14
Tiantuo-2	China	Government	Earth Observation/ Communications	LEO	67	Long March 4B	8-Sep-14
Yaogan 21	China	Military	Earth Observation	LEO		Long March 4B	8-Sep-14
Measat 3B	Malaysia	Commercial	Communications	GEO	5,800	Ariane 5 ECA	11-Sep-14
Optus 10	Australia	Commercial	Communications	GEO	3,270	Ariane 5 ECA	11-Sep-14
CLIO	USA	Military	Communications	GEO		Atlas 5	16-Sep-14
Luch/Olympus	Russia	Military	Communications	GEO		Proton M	27-Sep-14
Shijian 11-07	China	Government	Technology Development	LEO		Long March 2C	28-Sep-14
Himawari 8	Japan	Government	Earth Observation	GEO	3,500	H2A	7-Oct-14
IRNSS-1C	India	Government	Navigation/Regional Positioning	GEO	1,425	PSLV XL	15-Oct-14
ArSat 1	Argentina	Commercial	Communications	GEO	3,000	Ariane 5 ECA	16-Oct-14
Intelsat 30/DLA 1	USA	Commercial	Communications	GEO	6,220	Ariane 5 ECA	16-Oct-14
Yaogan 22	China	Military	Earth Observation	LEO		Long March 4C	20-Oct-14
Express-AM6	Russia	Commercial	Communications	GEO	3,358	Proton M	21-Oct-14
Navstar GPS IIF-8	USA	Military/ Commercial	Navigation/Global Positioning	MEO	1,630	Atlas 5	29-Oct-14
Meridian-7	Russia	Military	Communications	Elliptical	2,500	Soyuz 2.1a	30-Oct-14
ASNARO 1	Japan	Government	Earth Observation	LEO	500	Dnepr	6-Nov-14
ChubuSat 1	Japan	Civil	Technology Development	LEO	50	Dnepr	6-Nov-14
Hodoyoshi-1	Japan	Government	Earth Observation	LEO	65	Dnepr	6-Nov-14
Qsat-EOS	Japan	Civil	Earth Observation	LEO	49	Dnepr	6-Nov-14
TSUBAME	Japan	Civil	Earth Observation	LEO	49	Dnepr	6-Nov-14
Yaogan 23	China	Military	Earth Observation	LEO		Long March 2C	14-Nov-14
Yaogan 24	China	Military	Earth Observation	LEO		Long March 2C	20-Nov-14
Kuaizhou-2 (KZ-2)	China	Government	Earth Observation	LEO		Kuaizhou	21-Nov-14

Satellite name	Owner	Actor type	Primary function	Orbit	Mass (kg)	Launch Vehicle	Launch date
SpinSat	USA	Military	Technology Development	LEO	50	Cyclops Deployer System	28-Nov-14
Glonass 702 (Kosmos 2501)	Russia	Military/ Commercial	Navigation/Global Positioning	MEO	935	Soyuz 2.1b	1-Dec-14
DirecTV-14	USA	Commercial	Communications	GEO	5,900	Ariane 5 ECA	6-Dec-14
GSAT-16	India	Government	Communications	GEO	3,181	Ariane 5 ECA	6-Dec-14
CBERS 4	China/Brazil	Government	Earth Observation	LEO	1,980	Long March 4B	7-Dec-14
Yaogan 25A	China	Military	Earth Observation	LEO		Long March 4C	10-Dec-14
Yaogan 25B	China	Military	Earth Observation	LEO		Long March 4C	10-Dec-14
Yaogan 25C	China	Military	Earth Observation	LEO		Long March 4C	10-Dec-14
Adv Trumpet 3 (NROL-35, SBIRS HEO-3)	USA	Military	Earth Observation	Elliptical	4,200	Atlas 5	13-Dec-14
Yamal-401	Russia	Commercial	Communications	GEO	2,976	Proton M	15-Dec-14
O3b FM09	United Kingdom	Commercial	Communications	MEO	650	Soyuz-ST-B	18-Dec-14
O3b FM10	United Kingdom	Commercial	Communications	MEO	650	Soyuz-ST-B	18-Dec-14
O3b FM11	United Kingdom	Commercial	Communications	MEO	650	Soyuz-ST-B	18-Dec-14
O3b FM12	United Kingdom	Commercial	Communications	MEO	650	Soyuz-ST-B	18-Dec-14
Kondor E2	South Africa	Military	Earth Observation	LEO		Strela	19-Dec-14
Lotos-S2	Russia	Military	Earth Observation	LEO	5,000	Soyuz 2.1b	23-Dec-14
Resurs-P2	Russia	Government/ Commercial	Earth Observation/ Communications/ Space Science	LEO	5,900	Soyuz 2.1b	26-Dec-14
Astra 2G	Luxembourg	Commercial	Communications	GEO	6,000	Proton M	27-Dec-14
Yaogan 26	China	Military	Earth Observation	LEO		Long March 4B	27-Dec-14
Fengyun 2G	China	Government	Earth Observation	GEO	1,390	Long March 3A	31-Dec-14

* Satellites listed were operational as of 31 January 2015. Data from Union of Concerned Scientists, "UCS Satellite Database," online: www.ucsusa.org/nuclear-weapons/space-weapons/satellite-database.html.

DRAFT International Code of Conduct for Outer Space Activities*

Annotations on the 31 March 2014 version of the draft Code are based on comments made in the context of the third round of Open-ended Consultations held in Luxembourg 27-28 May 2014.

	DRAFT **International Code of Conduct** **for Outer Space Activities**	Some participants called for the addition of "peaceful" in the title: "International Code of Conduct for Peaceful Uses of Outer Space ~~Activities~~." Other participants disagreed, expressing concern at a possible ambiguity that such a change might entail. According to those participants, the term "peaceful" uses required further clarification and should not limit the scope to civil and commercial uses. A comprehensive code was required that also covered military uses of outer space.
	Preamble	
	The Subscribing States	
1	• In order to safeguard the continued peaceful and sustainable use of outer space for current and future generations, and in a spirit of greater international cooperation, collaboration, openness and transparency;	It was proposed that box 1 starts with "Recognizing the common interest of humanity..."
2	• Considering that the activities of exploration and use of outer space for peaceful purposes play a key role in the social, economic, scientific and technological development of all nations, in the management of global issues such as the preservation of the environment and disaster management;	Some participants suggested the creation of a new paragraph (2bis): "In the management of global issues such as the preservation of the environment, disaster management and in maintaining international peace and security;"
3	• Further recognising that space activities and capabilities, including associated ground and space segments and supporting links, are vital to national security and to the maintenance of international peace and security;	Some participants expressed concern at the reference to "national security" and proposed to delete it.
4	• Noting that all States, both space-faring and non-spacefaring, should actively contribute to the promotion and strengthening of international cooperation relating to these activities;	
5	• Recognising the need for the widest possible adherence to relevant existing international instruments that promote the peaceful exploration and use of outer space;	
6	• Noting the importance of preventing an arms race in outer space;	The reference to PAROS was welcomed and the suggestion was made to reinforce it by adding "as well as refraining from actions that may lead to a militarization of outer space". Some participants further proposed the inclusion of language around legally binding arrangements. Some recommended to draw from the GGE report when referring to PAROS.
7	• Recalling the increasing importance of outer space transparency and confidence-building measures in light of the growing use of outer space by governmental and non-governmental entities;	

8	• Taking into account that space debris affects the sustainable use of outer space, constitutes a hazard to outer space activities and potentially limits the effective deployment and utilisation of associated outer space capabilities;	Some participants questioned the relevance of keeping this paragraph since the problem of space debris should be considered as one of many issues.
9	• Recognizing it is in the shared interest of all States to reinforce international norms for responsible behaviour in outer space;	
10	• Convinced that a multilateral code of conduct aimed at enhancing the safety, security, and sustainability of outer space activities could become a useful complement to international law as it applies to outer space, as recommended by the Report of the Group of Governmental Experts on Transparency and Confidence-Building Measures in Outer Space Activities established in response to the UN General Assembly Resolution 65/68;	Participants welcomed the reference to the GGE report and encouraged the introduction of specific language from the report.
11	• Considering that spacefaring States have acquired knowledge regarding general practices to enhance the safety, security and sustainability of outer space activities that could usefully be made available to other Subscribing States, for the benefit of all;	Some participants considered that the knowledge referred to in box 11 should be made available to all states, not only to subscribing states.
12	• Reaffirming existing commitments to resolve any dispute concerning activities in outer space by peaceful means;	
13	• Recognising the necessity of a comprehensive approach to safety, security, and sustainability in outer space;	
14	• Reaffirming their commitment to the Charter of the United Nations;	Some participants thought that this reference was redundant considering the obvious commitment of all countries to the UN charter, while others expressed the need to clarify the UN charter's comprehensiveness with this box. Some thought that the reference to the UN Charter should appear earlier in the text. The addition of a new box after box 14 was proposed that would read: "This Code does not prohibit or limit the use of space by all countries"
15	• Without prejudice to ongoing and future work in other appropriate international fora relevant to the peaceful exploration and use of outer space such as the United Nations Committee on the Peaceful Uses of Outer Space and the Conference on Disarmament;	One participant opposed the reference to the conference on disarmament in box 15.
16	Subscribe to the following International Code of Conduct for Outer Space Activities (hereinafter referred to as the "Code"):	
17	**I. Purpose, Scope and General Principles**	
18	**1. Purpose and Scope**	
19	1.1. The purpose of this Code is to enhance the safety, security, and sustainability of all outer space activities pertaining to space objects, as well as the space environment.	Some participants underlined the need to clarify the comprehensiveness of the Code, by introducing a reference to section 1.2, so that box 19 would read: "…of all outer space activities pertaining to space objects <u>**as described in para 1.2.**</u>, as well as the space environment." The suggestion was made by some participants to refer to the "…safety, security and sustainability of the <u>peaceful uses</u> of outer space activities". Other participants, however, considered that "<u>all</u>" outer space activities should be covered.

20	1.2. This Code addresses outer space activities involving all space objects launched into Earth orbit or beyond, conducted by a Subscribing State, or jointly with other States, or by non-governmental entities under the jurisdiction of a Subscribing State, including those activities conducted within the framework of international intergovernmental organisations.	Some participants proposed to delete "launched into Earth orbit or beyond", as well as "jointly with other states". Another proposal was to replace the existing text with "This Code addresses all outer space activities involving all space objects" or "launched to, and in, space". Yet another proposal was "This Code ~~addresses~~ **regulates** outer space activities ~~involving all space objects launched into Earth orbit or beyond~~, conducted by a Subscribing State, or jointly with other States, or by non-governmental entities under the jurisdiction of a Subscribing State, including those activities conducted within the framework of international intergovernmental organisations, **and excluding all weapon-related aspects, which are subject for a separate international legally-binding agreement**."
21	1.3. This Code establishes transparency and confidence-building measures, with the aim of enhancing mutual understanding and trust, helping both to prevent confrontation and foster national, regional and global security and stability, and is complementary to the international legal framework regulating outer space activities.	The suggestion was made to rephrase "confidence-building measures, **including** transparency". It was further proposed "This Code **enhances** ~~establishes~~ transparency and confidence-building measures, with the aim of enhancing mutual understanding and trust, helping both to prevent confrontation and foster national, regional and global security and stability, ~~and is complementary to the international legal framework regulating outer space activities~~." It was also proposed "This Code establishes **new and reinforced existing** transparency and confidence-building measures..."
22	1.4. Subscription to this Code is open to all States, on a voluntary basis. This Code is not legally binding, and is without prejudice to applicable international and national law.	
23	**2. General Principles**	
24	The Subscribing States decide to abide by the following principles:	
25	• the freedom for all States, in accordance with international law and obligations, to access, to explore, and to use outer space for peaceful purposes without harmful interference, fully respecting the security, safety and integrity of space objects, and consistent with internationally accepted practices, operating procedures, technical standards and policies associated with the long-term sustainability of outer space activities, including, inter alia, the safe conduct of outer space activities;	Some participants asked for further definition of "internationally accepted practices". Some participants proposed to replace "and obligations" with a reference to relevant UN Security Council Resolutions.
26	• the responsibility of states to refrain from the threat or use of force against the territorial integrity or political independence of any state, or in any manner inconsistent with the purposes of the Charter of the United Nations, and the inherent right of states to individual or collective self-defence as recognised in the Charter of the United Nations;	A number of participants suggested the removal of the reference to the right to self-defence, as recognised in the UN Charter, while others requested that it be retained. Some considered that a reference to the UN Charter alone should be sufficient and many proposals were made to try to accommodate both positions.

27	• the responsibility of States to take all appropriate measures and cooperate in good faith to avoid harmful interference with outer space activities; and	The proposal was made to adjust box 27 as follows: "the ~~responsibility of~~ States to take all appropriate measures and cooperate in good faith to avoid ~~harmful interference~~ **any discrimination** with outer space activities; and"
28	• the responsibility of States, in the conduct of scientific, civil, commercial and military activities, to promote the peaceful exploration and use of outer space for the benefit, and in the interest, of humankind and to take all appropriate measures to prevent outer space from becoming an arena of conflict.	The proposal was made to adjust box 28 as follows: "the ~~responsibility of~~ States, in the conduct of scientific, civil, commercial and military **support outer space** activities, to promote the peaceful exploration and use of outer space for the benefit, and in the interest, of humankind and to take all appropriate measures to prevent outer space from becoming an arena of conflict."
29	**3. Compliance with and Promotion of Treaties, Conventions and Other Commitments Relating to Outer Space Activities**	
30	3.1. The Subscribing States reaffirm their commitment to the Charter of the United Nations and existing treaties, principles and guidelines relating to outer space activities, to which they are parties or subscribe. They reiterate their support to encouraging efforts in order to promote universal adoption, implementation, and full adherence to such instruments:	A number of participants suggested the removal of the list of treaties and instruments (*) while others considered that it was important to retain it. It was suggested to modify section 3.1 as follows: "3.1. The Subscribing States ~~reaffirm their commitment to the Charter of the United Nations and existing treaties, principles and guidelines relating to outer space activities, to which they are parties or subscribe. They~~ reiterate their support to encouraging efforts in order to promote universal adoption, implementation, and full adherence to ~~such~~ **existing international legally-binding and non-legally-binding instruments in the field of peaceful uses of outer space**."
31	(a) Existing international legal instruments relevant to outer space activities, including:	* Delete text
32	• the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (1967);	* Delete text
33	• the Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space (1968);	* Delete text
34	• the Convention on International Liability for Damage Caused by Space Objects (1972);	* Delete text
35	• the Convention on Registration of Objects Launched into Outer Space (1975);	* Delete text
36	• the Constitution and Convention of the International Telecommunication Union and its Radio Regulations, as amended;	* Delete text
37	• the Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and under Water (1963) and the Comprehensive Nuclear Test Ban Treaty (1996).	A number of participants requested the deletion of the reference the CTBT. * Delete text
38	(b) Declarations, principles, recommendations and guidelines, including:	* Delete text
39	• International Co-operation in the Peaceful Uses of Outer Space as adopted by the United Nations General Assembly's (UNGA) Resolution 1721 (December 1961);	* Delete text
40	• the Declaration of Legal Principles Governing the Activities of States in the Exploration and Use of Outer Space as adopted by UNGA Resolution 1962 (XVIII) (1963);	* Delete text

41	• the Principles Relevant to the Use of Nuclear Power Sources in Outer Space as adopted by UNGA Resolution 47/68 (1992) and the Safety Framework for Nuclear Power Source Applications in Outer Space as endorsed by UNGA Resolution 64/86 (2010);	* Some proposed to delete the text in box 41, while the proposal was made to modify box 41 as follows: "**The safety Framework for Nuclear Power Source Applications in Outer Space, as endorsed by UNGA Resolution 64/86 (2010) and as informed by** the Principles Relevant to the Use of Nuclear Power Sources in Outer Space as adopted by UNGA Resolution 47/68 (1992) ~~and the Safety Framework for Nuclear Power Source Applications in Outer Space as endorsed by UNGA Resolution 64/86 (2010)~~;"
42	• the Declaration on International Cooperation in the Exploration and Use of Outer Space for the Benefit and in the Interest of All States, Taking into Particular Account the Needs of Developing Countries as adopted by UNGA Resolution 51/122 (1996);	* Delete text
43	• the International Code of Conduct against Ballistic Missile Proliferation (2002), as endorsed in UNGA Resolutions 59/91 (2004), 60/62 (2005), 63/64 (2008), 65/73 (2010) and 67/42 (2012);	* Delete text
44	• the Recommendations on Enhancing the Practice of States and International Intergovernmental Organisations in Registering Space Objects as endorsed by UNGA Resolution 62/101 (2007);	* Delete text
45	• the Space Debris Mitigation Guidelines of the United Nations Committee for the Peaceful Uses of Outer Space, as endorsed by UNGA Resolution 62/217 (2007).	* Delete text
46	3.2. The Subscribing States resolve to promote the development of guidelines for outer space operations within the appropriate international fora, such as the UN Committee on Peaceful Uses of Outer Space and the Conference on Disarmament, for the purpose of promoting the safety and security of outer space operations and the long-term sustainability of outer space activities.	Some participants proposed to modify section 3.2. as follows: "The Subscribing States resolve to promote the development of **a relevant international legally binding instrument and voluntary** guidelines for outer space operations within the appropriate international fora, **including the Conference on Disarmament and the United Nations Committee on the Peaceful Uses of Outer Space** ~~such as the UN Committee on Peaceful Uses of Outer Space and the Conference on Disarmament~~, for the purpose of promoting the safety and security of outer space operations and the long-term sustainability of outer space activities."
47	**II. Safety, Security and Sustainability of Outer Space Activities**	
48	**4. Measures on Outer Space Operations and Space Debris Mitigation**	
49	4.1. The Subscribing States resolve to establish and implement policies and procedures to minimise the risk of accidents in space, collisions between space objects, or any form of harmful interference with another State's peaceful exploration, and use, of outer space.	One participant pointed out that "*exploration and use of outer space*" was a quote from existing treaties and did not include any punctuation marks, therefore the commas had to be deleted. It was proposed to modify section 4.1. as follows: "The Subscribing States resolve to establish and implement policies and procedures to minimise the risk of accidents in space, collisions between space objects, or any form of ~~harmful interference~~ **discrimination** with another State's peaceful exploration, and use, of outer space." The question was raised by one participant about the need to tackle broader space security issues beyond space debris.

50	4.2. The Subscribing States resolve, in conducting outer space activities, to:	Some participants asked for more clarity on the scope of section 4.2.
51	• refrain from any action which brings about, directly or indirectly, damage, or destruction, of space objects unless such action is justified: ○ by imperative safety considerations, in particular if human life or health is at risk; or ○ in order to reduce the creation of space debris; or ○ by the Charter of the United Nations, including the inherent right of individual or collective self-defence. and where such exceptional action is necessary, that it be undertaken in a manner so as to minimise, to the greatest extent practicable, the creation of space debris;	Some participants questioned the appropriateness to allow for exceptions to the rejection of the destruction of space assets, while others considered them important. As for in the case of box 26, a number of participants called for removing the reference to the right to self-defence.
52	• take appropriate measures to minimize the risk of collision; and	Some participants suggested to introduce examples of "appropriate measures" and suggested the following: "take appropriate measures, **for example prior notification and consultations between countries, if applicable** to minimize the risk of collision; and"
53	• improve adherence to, and implementation of, International Telecommunication Union regulations on allocation of radio spectra and space services, and on addressing harmful radio-frequency interference.	The following proposals were made for a modification of box 53: • "radio spectra **for** space services" and • "~~improve adherence to, and implementation of~~, **fulfil obligations under the** International Telecommunication Union Radio ~~r~~**R**egulations **with respect to the use of the radio frequency spectrum by** ~~on allocation of radio spectra and~~ space services, **particularly with respect to preventing** and on addressing harmful ~~radio-frequency~~ interference."
54	4.3. In order to minimise the creation of space debris and to mitigate its impact in outer space, the Subscribing States resolve to limit, to the greatest extent practicable, any activities in the conduct of routine space operations, including during the launch and the entire orbital lifetime of a space object, which may generate long-lived space debris.	
55	4.4. To that purpose, they resolve to adopt and implement, in accordance with their own internal processes, the appropriate policies and procedures or other effective measures in order to implement the Space Debris Mitigation Guidelines of the United Nations Committee for the Peaceful Uses of Outer Space as endorsed by United Nations General Assembly Resolution 62/217 (2007).	
56	**III. Cooperation Mechanisms**	Some participants suggested to switch section 5 with section 6. Some participants stated that they would like to see more emphasis on the "equitable use of space" and references to the work of the GGE, as well as UNCOPUOS and LTSSA results.
57	**5. Notification of Outer Space Activities**	
58	5.1. The Subscribing States, guided by the principle of cooperation and mutual assistance, resolve to notify, in a timely manner, to the greatest extent practicable, all potentially affected States of any event related to the outer space activities they are conducting which are relevant for the purposes of this Code, including:	Some participants proposed the addition of the concept of voluntary basis : "to the greatest extent practicable, 'on voluntary basis,' all potentially affected States of any event related to the outer space activities" Other participants did not agree with this proposal.

59	• scheduled manoeuvres that could pose a risk to the safety of flight of the space objects of other States;	
60	• predicted conjunctions posing an apparent on-orbit collision risk, due to natural orbital motion, between space objects or between space objects and space debris;	
61	• pre-notification of launch of space objects;	Some participants questioned the usefulness of pre-launch notifications and call for the deletion of box 61. The following language was suggested as a possible compromise: "pre-notification of launch of space objects **intended to reach orbit or beyond**"
62	• collisions, break-ups in orbit, and any other destruction of a space object(s) which have taken place generating measurable orbital debris;	One participant questioned the accuracy of the term "***measurable***". Others proposed either to delete ***"which have taken place generating measurable orbital debris"*** or to introduce a comma before it.
63	• predicted high-risk re-entry events in which the re-entering space object or residual material from the re-entering space object potentially could cause significant damage or radioactive contamination;	The suggestion was made to modify box 63 as follows: "**human casualtie**s, significant damage or radioactive contamination"
64	• malfunctioning of space objects or loss of control that could result in a significantly increased probability of a high risk re-entry event or a collision between space objects.	
65	5.2. The Subscribing States resolve to provide the notifications on any event related to the outer space activities described above to all potentially affected States:	
66	• through the Central Point of Contact to be established under section 9; or	
67	• through diplomatic channels; or	The suggestion was made to modify box 67 as follows: "through diplomatic **or existing multilateral** channels".
68	• by any other method as may be mutually determined by the Subscribing States.	
69	In notifying the Central Point of Contact, the Subscribing States should identify, if applicable, the potentially affected States.	One participant proposed to number this provision as "**5.3**", while another suggested the removal of the word "should".
70	The Central Point of Contact should ensure the timely distribution of the notifications received.	One participant proposed to number this provision as "**5.4**", while another suggested the removal of the word "should".
71	**6. Information on Outer Space Activities**	
72	6.1. The Subscribing States resolve to share, on an annual basis, where available and appropriate, information with the other Subscribing States on:	One country was reluctant to include the preparation of such a report which could touch national security matters. Some participants proposed to substitute "on an annual basis" with "on a voluntary basis".
73	• their space strategies and policies, including those which are security-related, in all aspects which could affect the safety, security, and sustainability in outer space;	Some participants proposed deletion of this provision (and box 74), because of possible national security implications, while other participants supported to retain it.
74	• their major outer space research and space applications programmes;	
75	• their space policies and procedures to prevent and minimise the possibility of accidents, collisions or other forms of harmful interference and the creation of space debris; and	
76	• efforts taken in order to promote universal adoption and adherence to legal and political regulatory instruments concerning outer space activities.	

77	6.2. The Subscribing States may also consider providing timely information on outer space environmental conditions and forecasts collected through their space situational awareness capabilities, including in particular on natural phenomena that may pose a hazard to spacecraft, to relevant governmental and non-governmental entities of other Subscribing States.	The suggestion was made to replace "*spacecraft*" with "space objects" as mentioned in the GGE report.
78	6.3. Subscribing States, particularly those with relevant space capabilities and with programmes for the exploration and use of outer space, should contribute to promoting and fostering international cooperation in outer space activities, giving particular attention to the benefit for and the interests of developing countries. Each Subscribing State is free to determine the nature of its participation in international space cooperation on an equitable and mutually acceptable basis with regard to the legitimate rights and interests of parties concerned, for example, appropriate technology safeguard arrangements, multilateral commitments and relevant standards and practices.	Some linguistic modifications were proposed: • to replace "should" with "shall" (some participants spoke out against this suggestion); • to add "**The**" at the very beginning of section 6.3.
79	6.4. The Subscribing States endeavour to organise on a voluntary basis, to the extent feasible and practicable, and consistent with national and international law, and obligations, including non-proliferation commitments, activities to familiarize other Subscribing States with their programs, policies, and procedures related to the exploration and use of outer space, including: • familiarisation visits to improve understanding of a State's policies and procedures for outer space activities; • expert visits to space launch sites, flight control centres, and other outer space infrastructure facilities; • observations of launches of space objects; • demonstrations of rocket and other space-related technologies, in line with existing multilateral commitments and export control regulations; • dialogues to clarify information on outer space activities; and • thematic workshops and conferences on the exploration and use of outer space.	Some participants proposed to: • replace "endeavour to" by "shall" • to substitute "*international law and obligations*" with "international law, **including relevant UN Security Council resolutions**".
80	**7. Consultation Mechanism**	
81	7.1. Without prejudice to existing consultation mechanisms provided for in Article IX of the Outer Space Treaty of 1967 and in the relevant provisions of the ITU Constitution and Radio Regulations, the Subscribing States resolve to implement the following consultation mechanism:	It was proposed to add "**Convention**" after "ITU Constitution".
82	• A Subscribing State or States that may be directly affected by certain outer space activities conducted by another Subscribing State or States and has reason to believe that those activities are, or may be contrary to this Code may request consultations with a view to achieving mutually acceptable solutions regarding measures to be adopted in order to prevent or minimise the potential significant risks of damage to persons or property, or of harmful interference to a Subscribing State's outer space activities.	Some participants maintained that the Subscribing State requesting consultations should be required to provide "credible evidence". The following modifications to box 82 were proposed: "A Subscribing State or States that may be directly affected by certain outer space activities conducted by ~~another~~ Subscribing State or States and ~~has reason~~ provide credible evidence to prove ~~believe~~ that those activities are, or may be contrary to this Code may request consultations with a view to achieving mutually acceptable solutions regarding measures to be adopted in order to prevent or minimise the potential significant risks of damage to persons or property, or of ~~harmful interference~~ **any discrimination** to a Subscribing State's outer space activities."

83	• The Subscribing States involved in a consultation process resolve to:	Some participants proposed to modify box 83 as follows: "The Subscribing States involved **<u>upon agreement</u>** in a consultation process resolve to:"
84	○ consult through diplomatic channels or by other methods as may be mutually determined; and	
85	○ work jointly and cooperatively in a timeframe sufficiently urgent to mitigate or eliminate the identified risk initially triggering the consultations.	
86	• Any other Subscribing State or States which has or have reason to believe that its or their outer space activities would be directly affected by the identified risk may take part in the consultations if it or they request so, with the consent of the Subscribing State or States which requested consultations and the Subscribing State or States which received the request.	
87	• The Subscribing States participating in the consultations resolve to seek mutually acceptable solutions in accordance with international law.	
88	7.2. In addition, Subscribing States may propose to create, on a voluntary and case-by-case basis, missions to analyse specific incidents affecting space objects, based on objective information, with a view to draw lessons for the future. These missions, to be established by consensus by the Meeting of the Subscribing States and carried out by a geographically representative group of experts, endorsed by the involved Subscribing States, should utilise information provided on a voluntary basis by the Subscribing States, subject to applicable laws and regulations. The findings and any recommendations would be of an advisory nature and could be shared, with the consent of the Subscribing States involved, with other Subscribing States.	Some participants suggested the removal of lessons-learnt missions (deletion of all paragraph), while others asked for its retention. One participant suggested to limit the number of experts to no more than 5.
89	**IV. Organisational Aspects**	
90	**8. Meeting of Subscribing States**	It was proposed that the 1st meeting of Subscribing States should take place in Vienna prior to a COPUOS meeting. defining call was made for a better definition of the role of the Central Point of Contact (POC), financial support to the POC and the term for the Chair.
91	8.1. The Subscribing States decide to hold regular meetings annually to define, review and further develop this Code and facilitate its implementation. Additional meetings may be held if decided by consensus of the Subscribing States at previous meetings or as communicated through the Central Point of Contact. The agenda of such meetings could include: • review of the implementation of the Code; • modification of the Code; • discussion of additional measures which may be necessary, including those due to advances in the development of space technologies and their application; and • establishing procedures regarding the exchange of notifications and other information in the framework of the Code.	Some participants asked for deletion of the agenda item on establishing procedures regarding the exchange of notifications and other information in the framework of the Code.
92	8.2. The decisions at such meetings, both substantive and procedural, are to be taken by consensus of the Subscribing States present. Decisions with regard to any modification of the Code taken at such meetings are to apply after written consent is received by the Central point of Contact via diplomatic note from all Subscribing States.	The suggestion was made to replace "*are to be taken*" with "**<u>should</u>** be taken". Some participants proposed the following modification : "…by consensus of the Subscribing States ~~present~~." or "…by **<u>all</u>** Subscribing States."

93	8.3. At the end of each regular meeting the Subscribing States are to elect by consensus their Chair for the period until the end of the next regular meeting. The chair of the first meeting is to be elected at the beginning of this meeting.	
94	8.4. The Subscribing States may decide to submit the outcomes of the Meeting of Subscribing States to the attention of relevant international fora including the United Nations General Assembly, the Committee on Peaceful Uses of Outer Space and the Conference on Disarmament, according to their rules of procedure.	
95	**9. Central Point of Contact**	Some participants called for a more elaborate definition of the procedural role of the Central Point of Contact.
96	9.1. A Central Point of Contact is to be designated by the Subscribing States at the first Meeting of the Subscribing States and tasked with:	
97	• receiving and communicating notifications that a State subscribes to the Code;	
98	• serving as a mechanism to facilitate communication of information exchanged under the Code to all Subscribing States;	
99	• serving as secretariat at the Meetings of Subscribing States;	
100	• maintaining an electronic database and communications system;	
101	• exercising organisational functions in connection with the preparation and implementation of familiarisation activities referred to in section 6.4., if and to the extent requested by Subscribing States involved; and	
102	• carrying out other tasks as decided by the Meeting of the Subscribing States.	
103	9.2. The Subscribing States resolve to create an electronic database and communications system, which would be used to:	
104	• collect and disseminate notifications and information submitted in accordance with this Code; and	
105	• serve as a mechanism to channel requests for consultations.	Some participants proposed to delete this box.
106	9.3. The electronic database is to be used exclusively in the interests of the Subscribing States.	Some participants proposed to replace "*is to be*" by "should be".
107	9.4. In implementing the Code of Conduct, the Subscribing States and the Central Point of Contact shall endeavour to make the best use of existing facilities and available services.	
108	**10. Participation by Regional Integration Organisations and International Intergovernmental Organisations**	
109	In this Code, references to Subscribing States are intended to apply, upon their subscription to the Code:	
110	• To any regional integration organisation which has competences over matters covered by this Code, without prejudice to the competences of its member States.	Some participants expressed reservation to a special status for Regional Integration Organisations (RIOs), notably the possibility that RIOs might be allowed to vote in addition to/instead of their Member States. One participant considered that there should be only a single category of international organisations.
111	• With the exception of Sections 8.2 and 8.3: To any international intergovernmental organisation which conducts outer space activities if a majority of the States members of the organisation are Subscribing States to this Code.	

* "Multilateral Negotiations on an International Code of Conduct for Outer Space Activities," 27 July 2015, online: https://papersmart.unmeetings.org/secretariat/unoda/wmd/codeofconductforouterspace/documents.

DRAFT Treaty on the Prevention of the Placement of Weapons in Outer Space, the Threat or Use of Force against Outer Space Objects*

Conference on Disarmament – 10 June 2014

The States Parties to this Treaty,

Reaffirming that further exploration and use of outer space plays an ever-increasing role in the development of humankind,

Willing that outer space would not turn into a new area of weapon placement and an arena for military confrontation to avert a grave danger to international peace and security,

Reaffirming the importance of strict compliance with the existing multilateral agreements related to outer space activities and recognizing that the observance of principles and rules of international space law in outer space activities contributes to building confidence in peaceful intentions of States,

Noting that the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies of January 27, 1967 (hereinafter referred to as the 1967 Outer Space Treaty), obliges the States Parties not to place in orbit around the Earth any objects carrying nuclear weapons or any other kinds of weapons of mass destruction, not to install such weapons on celestial bodies, or station such weapons in outer space in any other manner,

Recognizing that while the existing international agreements related to outer space and the legal regime thereof play a positive role in regulating outer space activities, however they are unable to fully prevent the placement of weapons in outer space,

Recalling the resolutions of the United Nations General Assembly "Prevention of an arms race in outer space" which *inter alia* emphasize the need to examine further measures in the search for effective and verifiable bilateral and multilateral agreements in order to prevent an arms race in outer space,

Have agreed as follows:

Article I

For the purpose of this Treaty:

a) the term "outer space object" means any device placed in outer space and designed for operating therein.

b) the term "weapon in outer space" means any outer space object or its component produced or converted to eliminate, damage or disrupt normal functioning of objects in outer space, on the Earth's surface or in the air, as well as to eliminate population, components of biosphere important to human existence, or to inflict damage to them by using any principles of physics.

c) a device is considered as "placed in outer space" when it orbits the Earth at least once, or follows a section of such an orbit before leaving this orbit, or is placed at any location in outer space or on any celestial bodies other than the Earth.

d) the terms "use of force" or "threat of force" mean, respectively, any intended action to inflict damage to outer space object under the jurisdiction and/or control of other States, or clearly expressed in written, oral or any other form intention of such action. Actions subject to special agreements with those States providing for actions, upon request, to discontinue uncontrolled flight of outer space objects under the jurisdiction and/or control of the requesting States shall not be regarded as use of force or threat of force.

Article II

States Parties to this Treaty shall:

– not place any weapons in outer space;

– not resort to the threat or use of force against outer space objects of States Parties;

– not engage in outer space activities, as part of international cooperation, inconsistent with the subject matter and the purpose of this Treaty;

– not assist or incite other States, groups of States, international, intergovernmental and any non-governmental organizations, including nongovernmental legal entities established, registered or located in the territory under their jurisdiction and/or control to participate in activities inconsistent with the subject matter and the purpose of this Treaty.

Article III

Nothing in this Treaty can be interpreted as preventing the States Parties from exploring and using outer space for peaceful purposes in accordance with international law, including the Charter of the United Nations and the Outer Space Treaty of 1967.

Article IV

This Treaty shall by no means affect the States Parties' inherent right to individual or collective self-defense, as recognized by Article 51 of the UN Charter.

Article V

States Parties recognize the need for measures to control compliance with the provisions of this Treaty, which may be the subject of an additional protocol.

In order to enhance confidence in compliance with the provisions of this Treaty States Parties can implement on a voluntary basis, unless agreed otherwise, agreed transparency and confidence-building measures.

Article VI

To promote the implementation of the purposes and provisions of the Treaty, the States Parties shall establish the Executive Organization of the Treaty, which shall:

a) consider matters related to the operation and implementation of the Treaty;

b) receive for consideration inquiries by a State Party or a group of States Parties related to an alleged violation of the Treaty;

c) organize and conduct consultations with the States Parties in order to address the situation related to the alleged violation of the Treaty;

d) refer the dispute to the United Nations General Assembly or the United Nations Security Council if the problem related to the alleged violation of this Treaty remains unresolved;

e) organize and hold meetings to discuss and accept the proposed amendments to this Treaty;

f) develop procedures for collective data sharing and information analysis;

g) collect and distribute information provided as part of transparency and confidence-building measures;

h) receive notifications on the accession of new States to this Treaty and submit them to the Secretary-General of the United Nations;

i) consider, upon agreement with the States Parties, other procedural and substantive matters.

The procedure of formation, the composition of the working bodies, operating procedures and provision of work of the Executive Organization of this Treaty shall be subject of an additional protocol.

States Parties shall cooperate with the Executive Organization of this Treaty to facilitate its performance of the functions entrusted to it.

Article VII

A State Party which has reasons to believe that another State Party fails to fulfill the obligations imposed by this Treaty may request this State Party to clarify the related situation. The requested State Patty shall provide the clarification as soon as possible.

If the requesting State Party deems the clarification unable to solve its concerns, it may request consultations with the requested State Party. The requested State Party shall immediately enter into such consultations. The information concerning the outcome of consultations shall be sent to the Executive Organization of this Treaty, which shares the information received with all States Parties.

If the consultations do not lead to a mutual settlement with due regard to the interests of all States Parties, any State Party or a group of States Parties shall seek assistance of the Executive Organization of the Treaty and provide the relevant evidence for further consideration of such a dispute. The Executive Organization may convene a meeting among States Parties to review such a dispute, make decisions identifying a violation of this Treaty and prepare recommendations based on States Parties' proposals to settle the dispute and eliminate the violation. The Executive Organization may, in case it is not able to settle the dispute or eliminate the violation, bring the issue, including relevant information and conclusions, to the attention of the United Nations General Assembly or the United Nations Security Council.

In cases subject to the Convention on International Liability for Damage Caused by Space Objects of 1972, the relevant provisions of the Convention shall be used.

Article VIII

In this Treaty references to the States, except those contained in Article IX-XIII, shall imply any international intergovernmental organization, which operates in outer space, if such organization declares that it assumes the obligations provided by this Treaty and if the majority of its member States are States Parties to this Treaty. Member States of such organization, which are Parties to this Treaty, shall take all necessary measures to ensure that the organization make such declaration in accordance with the provisions of this Article.

Article IX

This Treaty shall be opened for signature by all States at the United Nations Headquarters in New York. Any State which did not sign the Treaty before its entry into force may accede to it at any time.

This Treaty shall be subject to ratification by signatory States in accordance with their internal procedures.

Instruments of ratification or accession shall be deposited with the Secretary-General of the United Nations, who is hereby designated the Depositor of this Treaty.

Article X

This Treaty shall enter into force upon the deposit of instruments of ratification by twenty States, including all Permanent Member States of the United Nations Security Council.

For States whose instruments of ratification or accession are deposited after the entry into force of this Treaty, it shall enter into force on the date of the deposit of their instruments of ratification or accession.

The Secretary-General of the United Nations shall inform all signatory or acceding States of the date of each signature, the date of the deposit of each instrument of ratification or accession, the date of the entry into force of this Treaty, the proposals for amending this Treaty, of the arising disputes and their settlement, as well as of other notifications, if necessary.

Article XI

Any State Party may propose amendments to this Treaty. The text of a proposed amendment shall be submitted to the Secretary-General of the United Nations for circulation to all States Parties. An amendment conference shall be convened if at least one third of the States Parties agree to do so.

Amendments shall enter into force upon their acceptance by consensus.

Article XII

This Treaty shall be of unlimited duration.

Each State Party shall in exercising its national sovereignty have the right to withdraw from this Treaty if it decides that extraordinary events, related to the subject matter of this Treaty, have jeopardized its supreme interests. It shall notify the Secretary-General of the United Nations in the written form of the decision taken six months in advance of the withdrawal from the Treaty. Such notification shall include a statement of the extraordinary events that the notifying State Party regards as having jeopardized its supreme interests.

Article XIII

This Treaty, of which the Arabic, Chinese, English, French, Russian and Spanish texts are equally authentic, shall be deposited with the Secretary-General of the United Nations, who shall send duly certified copies thereof to all signatory and acceding States.

* Draft updated PPWT, 10 June 2014, online:
http://reachingcriticalwill.org/images/documents/Disarmament-fora/cd/2014/documents/PPWT2014.pdf.

Endnotes

Theme One Endnotes

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3 Secure World Foundation, p. 8.

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5 Ibid.

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14 UNGA, *Report of the Committee on the Peaceful Uses of Outer Space, Sixty-Second Session*, A/62/20, 2007, p. 17, online: www.oosa.unvienna.org/oosa/Reports/gadocs/coprepidx.html.

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16 Working group 2 of the IADC Coordination Committee, "Stability of the Future LEO Environment," January 2012, online: www.iadc-online.org/index.cgi?item=docs_pub.

17 Union of Concerned Scientists, "UCS Satellite Database," 11 March 2015, online: www.ucsusa.org/nuclear_weapons_and_global_security/solutions/space-weapons/ucs-satellite-database.html.

Note that the number of active satellites varies slightly depending on the methodology used. See Laura Grego, "Three Reasons the UCS Satellite Database is Different from Other Satellite Catalogs," All Things Nuclear – Blog, 2 April 2015, online: http://allthingsnuclear.org/three-reasons-the-ucs-satellite-database-is-different-from-other-satellite-catalogs. Jonathan McDowell reports a similar increase from slightly different totals: 1,324 active satellites at the end of 2014, up from 1,200 in 2013. Jonathan McDowell, "Space Activities in 2014," online: http://planet4589.org/space/papers/space14.pdf.

18 Cesar Jaramillo, ed., *Space Security Index 2014*, 2014, p. 23, online: http://spacesecurityindex.org/wp-content/uploads/2014/11/Space-Security-Index-2014.pdf.

19 J.-C. Liou, "USA Space Debris Environment, Operations, and Measurement Updates," presentation at UN COPUOS Scientific and Technical Committee meeting in Vienna, Austria, 6 February 2015, online: www.unoosa.org/pdf/pres/stsc2015/tech-28E.pdf. Jonathan McDowell (see note 17) gives the total mass of cataloged objects in 2014 as 8,200 metric tons and suggests the two values illustrate the uncertainty due to different methodologies.

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24 Ibid.

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