SPACE SECURITY INDEX 2014

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Featuring a global assessment of space security by James Clay Moltz

SPACE SECURITY INDEX

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

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ACRONYMS AND ABBREVIATIONS

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

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

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

INTRODUCTION

Space Security Index 2014 is the eleventh annual report on developments related to safety, sustainability, and security in outer space, covering the period January-December 2013. It is part of the broader Space Security Index (SSI) project, which aims to improve transparency on space activities and provide a common, comprehensive, objective knowledge base to support the development of national and international policies that contribute to the security and sustainability of outer space.

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

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

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

From search-and-rescue operations to weather forecasting, from banking to arms control treaty verification, the world has become increasingly reliant on space applications. The primary goals of the SSI are to improve transparency on space activities and to provide a common, comprehensive knowledge base to support the development of national and international policies that contribute to the security and sustainability of outer space.

The information in the report is organized under four broad Themes, with each divided into various indicators of space security. This arrangement is intended to reflect the increasing interdependence, mutual vulnerabilities, and synergies of outer space activities. In this context, issues such as the threat posed by space debris, the priorities of national civil space programs, the growing importance of the commercial space industry, efforts to develop a robust normative regime for outer space activities, and concerns about the militarization and potential weaponization of space are critical.

The structure of the 2014 report is as follows:

- **Theme 1: Condition and knowledge of the space environment**
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  Indicator 1.2: *Radio frequency (RF) spectrum and orbital positions*
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Indicator 4.2: *Multilateral forums for space governance*
Indicator 4.3: *Other initiatives*

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

Today the U.S. Department of Defense (DoD) is using the Space Surveillance Network to track more than 20,000 pieces of debris 10 centimeters (cm) in diameter or larger. Experts estimate that there are over 300,000 objects with a diameter larger than one centimeter and several million that are smaller.

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

In recent years, awareness of the space debris problem has grown considerably and significant efforts have been made to mitigate the production of new debris through compliance with national and international guidelines. The future development and deployment of technology to remove debris promises to ensure the sustainability of outer space if and when it becomes operational. It is incumbent upon the international community to proactively address the myriad technical, political, and financial challenges that will inevitably be associated with Active Debris Removal.

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

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

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

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

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

The military space sector is an important driver in the advancement of capabilities to access and use space. Many of today's common space applications, such as satellite-based navigation, were first developed for military use. Space systems have augmented the military capabilities of a number of states by enhancing battlefield awareness, offering precise navigation and targeting support, providing early warning of missile launch, and supporting real-time communications. Furthermore, remote sensing satellites have served as a technical means for nations to verify compliance with international nonproliferation, arms control, and disarmament regimes.

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

The security dynamics of space systems protection and negation are closely related and space security cannot be divorced from terrestrial security. Further, under some conditions protective measures can motivate adversaries to develop weapons to overcome them.

In this context, it is important to highlight that offensive and defensive space capabilities are not only related to systems that are physically in orbit, but include orbiting satellites, ground stations, and data and communications links.

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

No hostile anti-satellite (ASAT) attacks have been carried out against an adversary; however, recent incidents testify to the availability and effectiveness of missiles to destroy an adversary's satellite. Satellite resiliency measures include system redundancy, distributed architectures, and interoperability, which have become characteristics of, for example, some satellite navigation systems.

The ability to rapidly rebuild space systems after an attack could reduce vulnerabilities in space. The capabilities to refit space systems by launching new satellites into orbit in a timely manner to replace satellites damaged or destroyed by an attack are critical resilience measures. Smaller spacecraft that may be fractionated or distributed on hosts can improve continuity of capability and enhance security through redundancy and rapid replacement of assets. While these characteristics may make attack against space assets less attractive, they can also make assets more difficult to track and could potentially hinder transparency in space activities.

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

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

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

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

As in the 2013 edition, *Space Security Index 2014* includes a brief Global Assessment analysis, which is intended to provide a broad assessment of the trends, priorities, highlights, breaking points, and dynamics that are shaping current space security discussions.

The Global Assessment will be assigned to a different space security expert every year to encourage a range of perspectives. The inaugural essay was written by Claire Jolly, senior policy analyst at the Organisation for Economic Co-operation and Development (OECD). The author of the current assessment is James Clay Moltz, professor at the Naval Postgraduate School in Monterey, California.

The information in *Space Security Index 2014* is from open sources. Great effort is made to ensure a complete and factually accurate description of events, based on a critical appraisal of the available information and consultation with international experts. Project partners and sponsors trust that this publication will continue to serve as both a reference source and a tool for policymaking, with the ultimate goal of enhancing the sustainability of outer space for all users.

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

For further information about the Space Security Index, its methodology, project partners, and sponsors, please visit the website **www.spacesecurityindex.org**, where the publication is also available free of any charge in PDF format. Comments and suggestions are welcome.

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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 to catalog more than 16,000 objects approximately 10 centimeters (cm) in diameter or larger. Roughly 23,000 pieces of debris of this size are being tracked, but not cataloged; the U.S. military only catalogs objects with known owners. Experts estimate that there are over 300,000 objects with a diameter larger than one centimeter and several million that are smaller. The annual rate of new tracked debris began to decrease in the 1990s, largely because of national debris mitigation efforts, but accelerated in recent years as a result of events such as the Chinese intentional destruction of one of its satellites in 2007 and the accidental 2009 collision of a U.S. Iridium active satellite and a Russian Cosmos defunct satellite.

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

2013 Developments

Space object population

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

Debris-related risks and incidents

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

International awareness of debris problem increases as progress made toward solutions

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

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

More satellites are locating in GEO, using frequency bands in common and increasing the likelihood of frequency interference.

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

Research has also been conducted on the use of lasers for communications, particularly by the military. Lasers transmit information at very high bit rates and have very tight beams, which could allow for tighter placement of satellites, thus alleviating some of the current congestion and concern about interference. Newer receivers have a higher tolerance for interference than those created decades ago. The increased competition for orbital slot assignments, particularly in GEO, where most communications satellites operate, has caused occasional disputes between satellite operators. The International Telecommunication Union (ITU) has been pursuing reforms to address slot allocation backlogs and other related challenges.

2013 Developments

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

INDICATOR 1.3: Near-Earth Objects — Near-Earth Objects (NEOs) are asteroids and comets in orbits that bring them into close proximity to the Earth. NEOs are subdivided into Near-Earth Asteroids (NEAs) and Near-Earth Comets (NECs). Within both groupings are Potentially Hazardous Objects (PHOs), those NEOs whose orbits intersect that of Earth and have a relatively high chance of impacting the Earth itself. As comets represent a very small portion of the overall collision threat in terms of probability, most NEO researchers commonly focus on Potentially Hazardous Asteroids (PHAs). A PHA is defined as an asteroid whose orbit comes within 0.05 astronomical units of the Earth's orbit and has a brightness magnitude greater than 22 (approximately 150 meters in diameter). By the end of 2013 there were 10,482 known NEAs, 858 of which were one km in diameter or larger.

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

2013 Developments

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

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

The Space Surveillance Network (SSN) puts the United States far in advance of the rest of the world in space situational awareness capability. Russia has relatively extensive capabilities in this area; it maintains a Space Surveillance System using early-warning radars and monitors objects (mostly in LEO), although it does not widely disseminate data. China and India have significant satellite tracking, telemetry, and control assets essential to their civil space programs. The EU, Canada, France, Germany, and Japan are all developing space surveillance capabilities for various purposes, although none of these states is close to developing a global system on its own.

Sharing SSA data could benefit all space actors, allowing them to supplement their own data at little if any additional cost. But there is currently no operational global system for space surveillance, in part because of the sensitive nature of surveillance data. Since the 2009 Cosmos-Iridium satellite collision there has been an increased push in the United States to boost conjunction analysis—the ability to accurately predict high-speed collisions between two orbiting objects—and to undertake collaborative agreements with international partners that will allow for an increase in data sharing, As the importance of space situational awareness is acknowledged, more states are pursuing national space surveillance systems and engaging in discussions over international SSA data sharing.

2013 Developments

Capabilities

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

SSA sharing

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

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

INDICATOR 2.1: Space-based global capabilities — The use of space-based global utilities has grown substantially over the last decade. Millions of individuals rely on space applications on a daily basis for functions as diverse as weather forecasting, navigation, communications, and search-and-rescue operations. Global utilities are important for space security because they broaden the community of actors that have a direct interest in maintaining space for peaceful uses.

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

Remote sensing satellites are used extensively for a variety of Earth observation (EO) functions, including weather forecasting; surveillance of borders and coastal waters; monitoring of crops, fisheries, and forests; and monitoring of natural disasters such as hurricanes, droughts, floods, volcanic eruptions, earthquakes, tsunamis, and avalanches. Space has also become critical for disaster relief. COSPAS-SARSAT, the International Satellite System for Search and Rescue, was founded by Canada, France, the USSR, and the United States to coordinate satellite-based search-and-rescue. COSPAS-SARSAT is basically a distress alert detection and information distribution system that provides alert and location data to national search-and-rescue authorities worldwide, with no discrimination, independent of country participation in the management of the program. Similarly, in 2006 the UN General Assembly (UNGA) agreed to establish the UN Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER).

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

2013 Developments

Navigation systems

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

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

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

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

2013 Developments

- Changing budgetary allotments in civil space programs

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

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

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

By allowing states to pool resources and expertise, international civil space cooperation has played a key role in the proliferation of the technical capabilities needed by states to access space. Cooperation agreements on space activities have proven to be especially helpful for emerging spacefaring states that currently lack the technological means for independent space access. Cooperation agreements also enable established spacefaring countries to tackle high-cost, complex missions as collaborative endeavors with international partners.

The high costs and remarkable technical challenges associated with human spaceflight are likely to make collaborative efforts in this area increasingly common. In 2007 the 14 largest space agencies agreed to coordinate future space missions in the document *The Global Exploration Strategy: The Framework for Coordination*, which highlights a shared vision of space exploration, focused on the Moon and Mars. It calls for a voluntary forum to assist coordination and collaboration for sustainable space exploration, although it does not establish a global space program.

2013 Developments

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

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

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

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

2013 Developments

Growth in satellite market

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

Space tourism

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

Commercial spaceports

- Various commercial spaceports under development

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

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

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

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

2013 Developments

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

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

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

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

The Indian National Satellite System is one of the most extensive domestic satellite communications networks in Asia. To enhance its use of GPS, the country has been developing GAGAN, the Indian satellite-based augmentation system. This will be followed by the Indian Regional Navigation Satellite System (IRNSS), which is to provide an independent satellite navigation capability. Although these are civilian-developed and -controlled technologies, they are used by the Indian military for its applications.

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

2013 Developments

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

Theme 3: Security of space systems

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

The vulnerability of civil and commercial space systems raises security concerns, since a number of military space actors are becoming increasingly dependent on commercial space assets for a variety of applications. Satellite communications links require specific electronic protective measures to safeguard their utility. Although unclassified information on these capabilities is difficult to obtain, it can be assumed that most space actors are able to take advantage of simple but reasonably robust electronic protective measures. Sophisticated electronic protective measures were traditionally unique to the military communications systems of technologically advanced states, but they are slowly being expanded to commercial satellites.

While many actors employ passive electronic protection capabilities, such as shielding and directional antennas, more advanced measures, such as burst transmissions, are generally confined to military systems and the capabilities of more technically advanced states. Because the vast majority of space assets depend on cyber networks, the link between cyberspace and outer space constitutes a critical vulnerability. Satellite communications links require specific electronic protective measures to safeguard their utility.

2013 Developments

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

2013 Developments

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

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

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

2013 Developments

Satellite servicing

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

Distributed architectures

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

INDICATOR 3.3: Earth-based capabilities to attack satellites — Some spacefaring nations possess the means to inflict intentional damage on an adversary's space assets. Ground-based anti-satellite weapons employing conventional, nuclear, and directed energy capabilities date back to the Cold War, but no hostile use of them has been recorded.

Conventional anti-satellite weapons include precision-guided kinetic-intercept vehicles, conventional explosives, and specialized systems designed to spread lethal clouds of metal pellets in the orbital path of a targeted satellite.

A space launch vehicle with a nuclear weapon would be capable of producing a High Altitude Nuclear Detonation (HAND), causing widespread and immediate electronic damage to satellites, combined with the long-term effects of false radiation belts, which would have an adverse impact on many satellites. The application of some destructive space negation capabilities, such as kinetic-intercept vehicles, would also generate space debris that could potentially inflict widespread damage on other space systems and undermine the sustainability of outer space.

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

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

2013 Developments

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

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

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

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

2013 Developments

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

Theme 4: Outer space governance

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

However, the military doctrines of a growing number of states emphasize the use of space systems to support national security. Major space powers and emerging spacefaring nations increasingly view space assets such as multiuse space systems as integral elements of their national security infrastructure. As well, more states have come to view their national space industries as fundamental drivers and components of their space policies.

Bilateral cooperation agreements on space activities are increasingly common among spacefaring actors. A number of nations, including the United Kingdom, Germany, Australia, and the United States, have made innovation and development of industrial space sectors a key priority of their national space strategies.

2013 Developments

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

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

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

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

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

While at the end of 2013 the adoption of a Program of Work remained an elusive pursuit for the Conference on Disarmament, overwhelming support for the resolution on the Prevention of an Arms Race in Outer Space (PAROS) at UNGA indicates broad international consensus in support of consolidating and reinforcing the normative regime for space governance to enhance its effectiveness.

2013 Developments

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

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

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

A growing number of diplomatic initiatives relate to bilateral or regional collaborations in space activities. Examples of this include the work of the Asia-Pacific Regional Space Agency Forum and discussions within the African Union to develop an African space agency. The UN Institute for Disarmament Research (UNIDIR)—an autonomous institute within the UN system—has also played a key role to facilitate dialogue among key space stakeholders. Every year UNIDIR partners with civil society actors and some governments to bring together space security experts and government representatives at a conference on emerging security threats to outer space.

2013 Developments

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

THEME ONE

Condition and knowledge of the space environment

Indicator 1.1: Orbital debris

Space debris—predominantly objects generated by human activity in space—represent 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.

The U.S. Space Surveillance Network (SSN) offers the most comprehensive tracking and cataloging of space debris. Technological constraints restrict it to spot checks rather than continuous surveillance and limit the size of cataloged objects to those greater than 10 cm in Low Earth Orbit (LEO) and even larger in Geostationary Earth Orbit (GEO). The current catalog contains more than 16,000 objects.[1] It is estimated that there are more than 300,000 objects with a diameter larger than 1 cm and millions smaller.[2]

Figure 1.1: Unintentional collisions between space objects

Year	Event
1991	Inactive Cosmos-1934 satellite hit by cataloged debris from Cosmos 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 Cosmos-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 Cosmos 2251 collides with U.S. satellite Iridium 33
2013	Ecuadorean satellite Pegasus collides with debris from S14 Soviet rocket launched in 1985

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 8 October 1997 and 30 June 2004 only 603 new pieces of debris were cataloged—a noteworthy decrease, particularly given the increased ability of 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 major debris-creating events. In January 2007 China destroyed its weather satellite FY-1C with an Anti-Satellite Weapon (ASAT) and in February 2009 the Russian satellite Cosmos 2251 and the U.S. satellite Iridium 33 collided. There were no major debris-generating events in 2013.

Collisions between such space assets as the International Space Station (ISS) and very small pieces of untracked debris are frequent but manageable.[3] 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 Scientific and Technical Subcommittee 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 Inter-Agency Space Debris Coordination Committee (IADC) to develop a set of international debris mitigation guidelines, on which it based its own draft guidelines in 2005.[4] In 2007 these guidelines were adopted by UN COPUOS and endorsed by the UN General Assembly as voluntary measures with which all states should comply.[5] The draft International Code of Conduct for Outer Space Activities also calls on signatories to reaffirm their commitments to the UN COPUOS space debris mitigation guidelines.

The IADC was formed in 1993 as an international forum to harmonize efforts of various space agencies to address the problem posed by orbital debris. By the end of 2013 the IADC comprised ASI (Agenzia Spaziale Italiana [Italy]), CNES (Centre national d'études spatiales [France]), CNSA (China National Space Administration), CSA (Canadian Space Agency), DLR (German Aerospace Center), ESA (European Space Agency), ISRO (Indian Space Research Organisation), JAXA (Japan Aerospace Exploration Agency), NASA (National Aeronautics and Space Administration [United States]), NSAU (National Space Agency of Ukraine), Roscosmos (Russian Federal Space Agency), and the United Kingdom Space Agency.

Figure 1.2: Top 10 breakups of on-orbit objects[6]

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
Cosmos 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
Cosmos 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 progressive development of international and national debris mitigation guidelines has been complemented by research on technologies to physically remove debris. To date, no active debris removal (ADR) mechanisms have been implemented, although research continues.

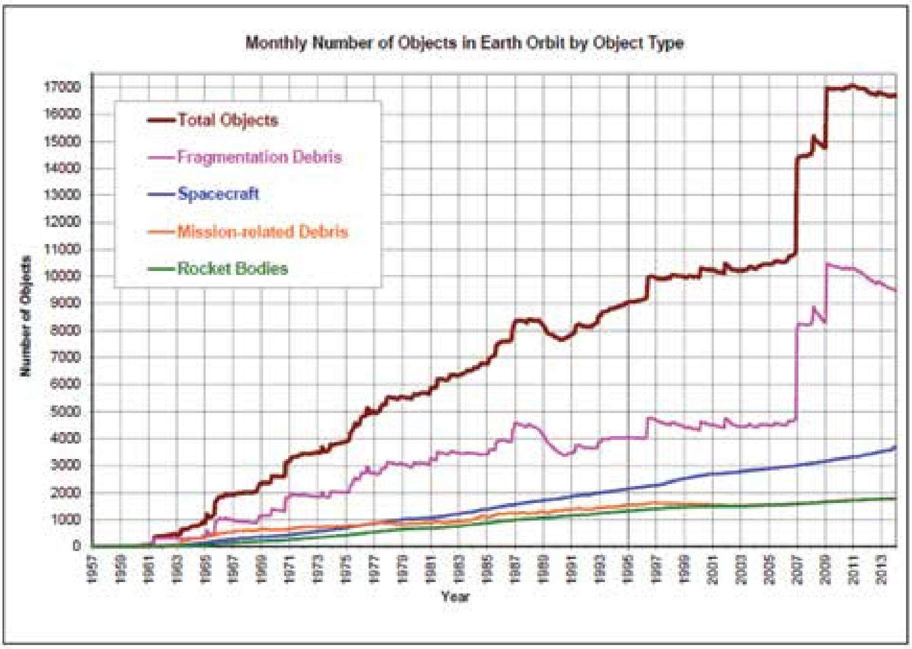
2013 Developments

Space object population

Cataloged debris population remains virtually unchanged; number of active objects in orbit continues to grow

The number of active satellites in orbit increased in 2013 to a total of 1,167.[7] This represents an increase of 11.6% over the 2012 total of 1,046.[8] The number of cataloged objects at the end of 2013 was 16,655, a decrease of 0.2% from 16,686 at the end of 2012.[9]

Figure 1.3: Growth in on-orbit population by category[10]



The reduction in cataloged objects was largely the result of fragmentation debris reentering the atmosphere, and an absence of any significant breakup events. In 2013 more than 400 cataloged objects reentered Earth's atmosphere and there were only two minor fragmentations. A Falcon 9 second-stage malfunction created 15 debris fragments, but only one remained in orbit by the end of the year. Also, an anomaly with the Ball Lens in the Space (BLITS) satellite produced one fragment.[11]

U.S. Space Surveillance Network continues to update satellite catalog

The U.S. Space Surveillance Network (SSN) continues to track more than 23,000 objects in Earth orbit,[12] including fragments from the 2007 Chinese ASAT weapons test. Seven years after the test, which destroyed the defunct Fenyun-1 satellite, more than 90% of the 3,400 fragments created by this event remained in orbit.[13] NASA estimates that 50% of the fragments could still be in orbit in 2027.[14]

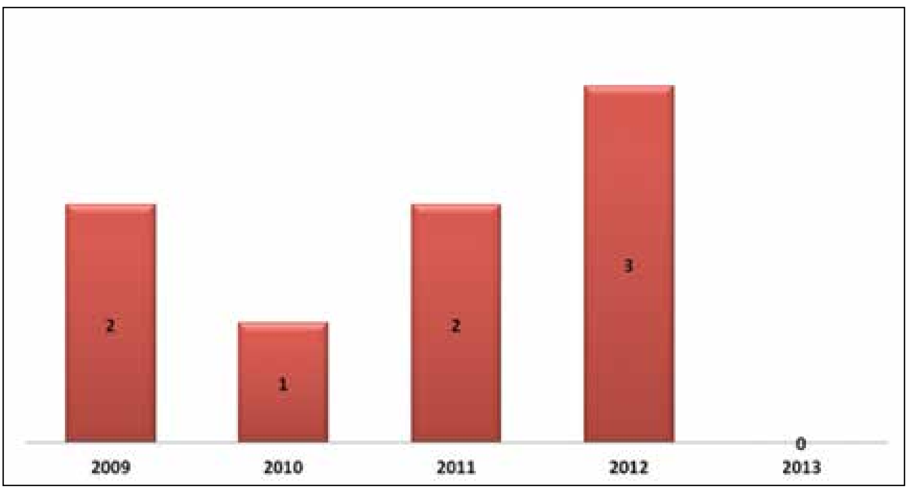
Debris-related risks and incidents

Orbital debris continues to threaten safe space operations of both satellites and the International Space Station

Orbital debris continues to impact operational spacecraft and the International Space Station (ISS). During 2013 three satellites suffered anomalies consistent with a collision with small micro-meteoroids or untracked pieces of debris. In January Russia's BLITS satellite was disturbed and shed a debris fragment.[15] On 22 May NOAA's GOES 13 experienced a sudden attitude drift of at least two degrees per hour, which would indicate an impact on one of the satellite's solar arrays. The following day Ecuador's one-month-old Pegaso satellite began to tumble shortly after a close conjunction with a 28-year-old Soviet rocket body. Although it was determined that the rocket body passed below Pegaso at a safe distance, an impact with an object in the rocket body's debris wake could not be ruled out.[16]

Although the ISS did not perform any debris avoidance maneuvers in 2013,[17] satellites in LEO performed numerous collision avoidance maneuvers, especially as a result of conjunctions with debris fragments from the 2007 Chinese ASAT test and the 2009 collision between Iridium 33 and Cosmos 2251. NASA executed or assisted in a record 29 debris-avoidance maneuvers. Six involved debris from the Fenyun-1 and six more from conjunctions with Iridium/Cosmos debris.[18] During 2013 European Space Agency satellites performed two avoidance maneuvers and experienced 17 conjunctions of 300 m or less. Of these conjunctions, 24-58% involved fragments from Fenyun-1, Iridium 33, or Cosmos 5521.[19] France's Centre national d'études spatiales performed or assisted in 19 debris avoidance maneuvers, up from 13 the previous year.[20]

Figure 1.4: ISS collision-avoidance maneuvers 2009-2013

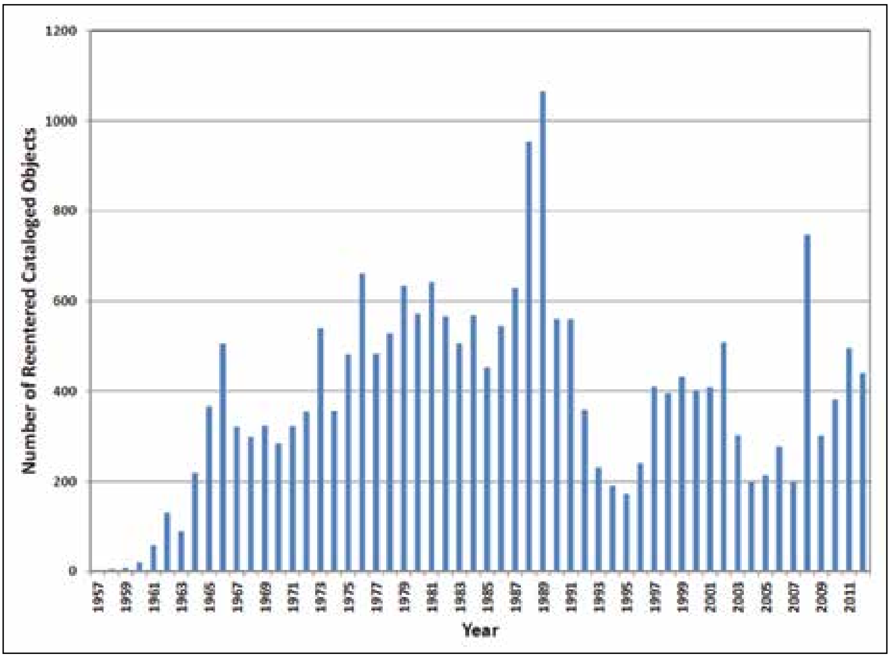


The risk posed by debris and satellite reentries remained in 2013

Not all debris-related risks occur in outer space. Controlled reentries of 19 spacecraft and rocket-bodies were executed in 2013.[21] (There were 25 reentries in 2012 and eight in 2011.[22]) There were 66 uncontrolled spacecraft and rocket-body reentries in 2013.[23] In total more than 400 cataloged objects reentered during the year.[24]

Notable reentries included that of the 1.2-ton Gravity field and steady-state Ocean Circulation Explorer (GOCE), ESA's first uncontrolled reentry in 25 years.[25] GOCE reentered over the South Atlantic, west of the Falkland Islands early on the morning of 11 November 2013, with no reported impacts.[26] On 14 July the second stage from a Delta 1 launched in 1975 reentered the atmosphere over the Atlantic. The propellant tank and two smaller spheres survived reentry and hit ground in central Zimbabwe. No one was injured and no property was damaged.[27]

Figure 1.5: Number of reentered cataloged objects[28]



International awareness of debris problem increases as progress made toward solutions

Compliance with international debris mitigation guidelines has improved in recent years, particularly at GEO

Compliance with the Inter-Agency Space Debris Coordination Committee (IADC) debris mitigation guidelines to re-orbit satellites a sufficient distance above GEO has improved 25% since 2004. Thirty per cent fewer satellites in GEO have been abandoned. Twenty-six objects were added to GEO in 2013 (25 spacecraft and one rocket-body), while 20 satellites were retired. Fifteen satellites were successfully re-orbited at least 250 km above GEO. Three others were re-orbited, but with perigees less than 250 km above GEO. Two satellites were retired without attempting to comply with IADC guidelines.[29]

Figure 1.6: GEO satellite retirements in 2013*

Spacecraft	Owner	Re-orbit	IADC Guideline compliance*
ZX 5B (ChinaSat 5B)	China	278 x 342 km	YES
NileSat 101	Egypt	731 x 923 km	YES
Hot Bird 5	EUTELSAT	491 x 543 km	YES
Inmarsat 2-F1	INMARSAT	385 x 408 km	YES
Intelsat VII F-1	INTELSAT	280 x 337 km	YES
Intelsat VIII F-1	INTELSAT	394 x 480 km	YES
Intelsat VIII F-2**	INTELSAT	224 x 795 km	NO
ST-1	INTELSAT	411 x 455 km	YES
BSAT-1B	Japan	313 x 340 km	YES
BSAT-2C	Japan	283 x 325 km	YES
MEASAT 1	Malaysia	336 x 350 km	YES
Solidaridad 2	Mexico	280 x 515 km	YES
Thor II	Norway	359 x 379 km	YES
Cosmos-2434/Raduga-1M1**	Russia	238 x 256 km	NO
Ekspress AM-1	Russia	281 x 328 km	YES
Ekspress MD-1	Russia	306 x 352 km	YES
Arabsat 2B**	Saudi Arabia	227 x 259 km	NO
GOES 12	USA	297 x 346 km	YES
USA 8**	USA	-434 x 696 km	NO
USA 48**	USA	-1305 x 1050 km	NO

* 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.

** These spacecraft were re-orbited too low; did not comply with end-of-life disposal requirements.

Several actions were taken in LEO to comply with IADC debris mitigation guidelines. On 21 June 2013 JASON-1, a joint NASA-CNES mission, was moved to an orbit above LEO and passivated following completion of its mission.[30] Four Globalstar commercial communications satellites also reached the ends of their operational lives and were maneuvered to orbits well above LEO.[31] SPOT 4 and PARASOL (CNES)[32] and Landsat 5 (NASA),[33] with lifetimes of less than 25 years, were all moved to disposal orbits. ATV-4 "Albert Einstein" executed a controlled reentry over the South Pacific on 2 November after delivering its cargo to the ISS.[34]

Figure 1.7: UN COPUOS Space Debris Mitigation Guidelines[35]

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 low-Earth orbit (LEO) region after the end of their mission.
7. Limit the long-term interference of spacecraft and launch vehicle orbital stages with the geosynchronous Earth orbit (GEO) region after the end of their mission.

NASA also launched 16 small satellites under its Educational Launch of Nanosatellites program. Because they were inserted into low orbits they will reenter Earth's atmosphere within 25 years. Eight primary NASA or NASA-sponsored spacecraft and nine upper stages were launched in 2013. All spacecraft and eight of the rocket-bodies have reentered or will reenter within 25 years. The ninth upper stage will likely remain in orbit for approximately 30 years.[36] In deep space, ESA's Herschel and Planck spacecraft, which had been performing astronomy missions from a Sun-Earth L2 Lissajous orbit, executed final insertion maneuvers into heliocentric disposal orbits.[37]

International dialogue on debris problems, active debris removal, and other solutions continues in 2013

Following the 2012 release of the documentary *Space Junk 3D*,[38] the 2013 release of the Oscar-winning motion picture film *Gravity* further heightened global awareness[39] of the issues surrounding orbital debris, despite numerous inaccuracies related to physics and orbital mechanics.[40] A number of scientific meetings and conferences were held in which space debris was either discussed or was the central issue. In April more than 355 participants from 25 countries attended 115 presentations at the 6th European Conference on Space Debris in Darmstadt, Germany. The 31st IADC meeting was held the same month.

Earlier in the year, the IADC reported on the stability of the future LEO environment to the Scientific and Technical Subcommittee of the United Nations Committee on the Peaceful Uses of Outer Space. Six IADC members, each a national space agency, presented models; all showed a steady increase in the population of debris 10 cm and larger, despite the assumption that post-mission disposal guidelines were followed 90% of the time.

On average the models predicted a catastrophic collision every five to nine years, with most predicted to occur near the highly congested 800 km and 1,000 km altitudes. Most of the debris population increase occurred above 800 km, due to the relative lack of atmospheric drag at those altitudes. The IADC report concluded that existing debris mitigation standards are insufficient to constrain the future LEO debris population and that more aggressive measures, especially the removal of massive non-functioning spacecraft and launch vehicle stages, should be considered and implemented in a cost-effective manner.[41]

At the same session of the UN COPUOS Scientific and Technical Subcommittee, the Working Group on the Long-term Sustainability of Outer Space Activities outlined proposed candidate guidelines from each of its four expert groups, including Expert Group B: Space debris, space operations and tools to support collaborative space situational awareness. Group B recommended that nations should implement UN COPUOS Space Debris Mitigation Guidelines through relevant national mechanisms.[42]

The 3rd European workshop on Space Debris Modeling and Remediation and a satellite's end-of-life workshop were held in Paris, in June and January respectively.[43] Space debris was also a topic at the 6th International Association for the Advancement of Space Safety Conference in Montreal, Canada and the 64th International Astronautical Congress in Beijing, China.[44]

Research and development in active debris removal continue in 2013

Many projects are currently exploring potential methods to remove existing debris from orbit. As discussed above, the IADC has reported that active debris removal (ADR) is required to constrain the growing debris population in LEO. The UN COPUOS Scientific and Technical Subcommittee began its 50th session with a half-day symposium on an "Overview of Studies and Concepts for Active Orbital Debris Removal," sponsored by the International Astronautical Federation and with presentations by the United States, France, Japan, the Russian Federation, Germany, Switzerland, ESA, and the Secure World Foundation.

ESA's new Clean Space initiative focuses on four areas of space sustainability, including space debris mitigation and technologies for space debris remediation. Several Phase-A industrial studies for active removal of an ESA satellite are in progress.[45] The e.Deorbit project is a Clean Space debris remediation initiative, intended to assess the feasibility, risk, and cost for the controlled de-orbiting and reentry of a large, massive, uncooperative target in sun-synchronous orbit.[46]

ESA posted a 16-minute video on its website in April 2013 that describes the problems posed by space debris, as well as some of the removal methods being considered, such as attaching a solid rocket motor to the debris, using a sail to increase atmospheric drag of debris, or eradiating debris with an ion engine to reduce its orbital velocity. Several methods for dealing with tumbling debris—such as clamps, robotic arms, and nets[47]—were described.

The Swiss Space Center, which designed the CleanSpace One mission, announced in September their intention to engage Swiss Space Systems (S3) to launch the 30-kg CleanSpace One satellite in 2018. S3's new launch system will consist of an A300 jetliner as the first stage, a Suborbital Reusable Shuttle as the second stage, and a conventional upper stage. The satellite is to rendezvous with, grapple, and de-orbit the defunct SwissCube nanosatellite. By removing the satellite, the Swiss will avoid many legal problems.[48]

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

Radio frequencies

The radio frequency spectrum is the part of the electromagnetic spectrum that allows the transmission of radio signals. 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 the frequency. Higher frequencies (shorter wavelengths) are capable of transmitting more information than lower frequencies (longer wavelengths), but require more power to travel longer distances.

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.[49]

Originally adopted in 1994, the International Telecommunication Union Constitution[50] governs international sharing of the finite radio spectrum and orbital slots used by satellites in GEO. Article 45 of the 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."[51] 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,"[52] as military demand for bandwidth grows.

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. Frequency hopping, lower power output, digital signal processing, frequency-agile transceivers, and software-managed spectrum have the potential to significantly improve bandwidth use and alleviate conflicts over bandwidth allocation.

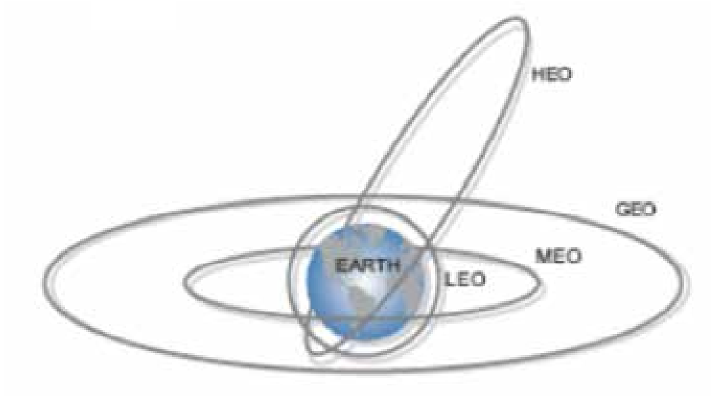
Issues of interference arise primarily when two spacecraft require the same frequencies at the same time and their fields of view overlap or when they are transmitting in close proximity to each other. While interference is not epidemic, it is a growing concern for satellite operators, particularly in crowded space segments.

Orbital slots

Today's satellites operate mainly in three basic orbital regions: LEO, MEO (Medium Earth Orbit), and GEO (see Figure 1.8). As of 31 May 2013 there were 1,071 operating satellites: 523 in LEO, 75 in MEO, 435 in GEO, and 38 in Highly Elliptical Orbit (HEO).[53] 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 the 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 the 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;[54] these slots are also optimal for the rest of the Americas. Similarly desirable spots exist over Africa for Europe and over Indonesia for Asia.

Figure 1.8: Types of Earth orbits*



* See Annex 1 for a description of each orbit's attributes.

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.[55] 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.[56] 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.[57] 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. The ITU requires that the operational frequencies for these constellations be registered, but does not stipulate specific orbital slots. 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.

2013 Developments

Pressure on the radio frequency (RF) spectrum continues to grow

Growing demand for and crowding of terrestrial RF spectrum with potential impacts on space RF spectrum

Demand for radio frequency spectrum continued to grow in 2013, as did concerns about crowding and interference, which come with increased demand. As part of the National Broadband Plan, which calls for making 500 MHz of spectrum newly available by 2020 for mobile and fixed wireless broadband use, the U.S. Federal Communications Commission

(FCC) confirmed its intention to license the 1755-1780 MHz and 1695-1710 MHz bands, which had previously been reserved for federal use.[58] Of particular interest is the 1695-1710 band, which is used by National Oceanic and Atmospheric Administration (NOAA) meteorological satellites.[59] Continued use of this band by NOAA will result in spectrum sharing by federal and non-federal entities.

Optical or laser communications are being explored in attempts to use a broader portion of the RF spectrum more efficiently. Laser communications allow the transmission of information at data rates 10-100 times faster than traditional RF systems of similar mass and power.[60] Laser communications also provide a much smaller beam width, which should help to prevent unintentional interference.[61] As part of the Laser Communications Project, in January 2013 the ISS crew transferred 400 Mb of data from the ISS to the ground at 125 Mbps.[62] In December the Lunar Laser Communication Demonstration (LLCD) mission aboard the Lunar Atmosphere and Dust Environment Explorer (LADEE) demonstrated record-breaking data download and upload speeds to the moon of 622 Mbps and 30 Mbps, respectively.[63]

The follow-on long-term Laser Communications Relay Demonstration payload is expected to launch in 2017. It will be placed in a geostationary orbit; its mission is expected to last two years.[64] In July 2013 ESA launched laser communications technology demonstration payload Alphasat into a geostationary orbit.[65] Alphasat is a precursor to the European Data Relay System (EDRS).[66]

Increased efforts to reduce unintentional radio frequency interference

Interference is a costly threat to commercial satellite communications operators. Significant attempts have been made to prevent RF interference, including training 10,000 technicians through global certification programs over the past seven years; doubling the global footprint of industry test agencies that ensure Earth station equipment performs within acceptable industry limits to avoid causing interference; and achieving widespread support for Carrier ID, with the Digital Video Broadcasters Forum adopting an open, spread-spectrum standard for Carrier ID.[67]

The World Broadcasting Unions International Satellite Operations Group (WBU-ISOG) issued a resolution in support of the adopted Carrier ID standards issued by the European Telecommunications Standards Institute.[68] The UN International Committee on Global Navigation Satellite Systems (ICG), which promotes voluntary cooperation on matters related to civil positioning, navigation, and timing, expressed concern in November about ITU plans to discuss new spectrum allocations for international mobile communications at the World Radio Conference in 2015. The ICG wants to ensure that this action won't harm Global Navigation Satellite System (GNSS) operations[69] and declared its intent to develop materials to educate the public on potential sources of interference to GNSS.[70]

Indicator 1.3: Near-Earth Objects (NEOs)

NEOs are asteroids and comets whose orbits bring them in close proximity to the Earth or intersect the Earth's orbit. NEOs are subdivided into Near-Earth Asteroids (NEAs) and Near-Earth Comets (NECs). Within both groupings are Potentially Hazardous Objects (PHOs), those NEOs whose orbits intersect that of Earth and have a relatively high potential 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) instead. 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).[71] By the end of 2013 there were 10,841 known NEAs, 855 of which were 1 km in diameter or larger—the so-called "civilization-killer" class.[72]

Initial efforts to find threatening NEOs focused on these destroyers of worlds. If any were to strike the Earth they could wipe out regions of the Earth's surface. 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.

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. Mitigation methods are divided into two categories, which are valid depending on the amount of warning time before a potential impact event. 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, certain kinetic methods could potentially be applied.

Kinetic deflection methods could include ramming the NEO with a series of kinetic projectiles, but 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 and would have complex technical challenges and policy implications.

The increasing international awareness of the potential threat posed by NEOs has prompted discussions at various multilateral forums on the technical and policy challenges related to mitigation, as described below.

2013 Developments

International awareness of NEO threat and progress in international response continues

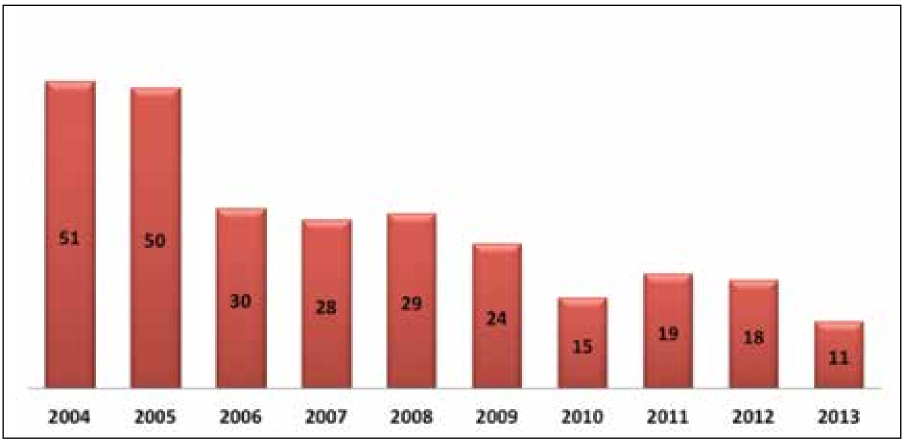
On 15 February 2013 an undetected meteor exploded over the city of Chelyabinsk, Russia, causing almost 1,200 injuries[73] and property damage calculated at $33-million.[74] When the asteroid entered Earth's atmosphere, it was approximately 17 m long, weighed 12,000 tons, and released energy equal to 440 kilotons of TNT.[75] The explosion resulted in a shower of meteorites.[76] The largest piece of the asteroid (650 kg) was recovered from the bed of Lake Chebarkul by Ural Federal University.[77] Infrasound generated by the blast was the largest ever recorded by the Comprehensive Nuclear-Test-Ban Treaty Organization's International Monitoring System.[78] Signals from the explosion were also detected by a network of U.S. seismographic stations.[79]

Insurance market Lloyd's noted that insurers take into account the risks posed by so-called "city-killers" in their risk assessment.[80] The dimensions of the potential harm attributable to NEO impact can be found in the report produced in 2009 by a group of specialists from Risk Management Solutions (RMS). In the report, RMS modeled the 1908 Tunguska event scenario over New York, a city with a population of approximately 10 million. Such an explosion would result in 3.2 million fatalities and 3.76 million injuries.[81] The Chelyabinsk event, "unprecedented in modern times,"[82] focused global attention on the risk associated with NEOs, confirmed growing concerns of the international space community, and prompted a series of asteroid mitigation initiatives. Russia called for the creation of "a joint system of asteroid defence."[83]

In a completely unrelated event, but also on 15 February, near-Earth asteroid (NEA) 2012 DA14 safely passed the Earth. This "closest-ever predicted"[84] approach, expected since 2012, provided an unusual opportunity for researchers to examine a NEO.[85] From 16-20 February the asteroid was observed by Goldstone radar in the Mojave Desert, a part of NASA's Deep Space Network.[86]

In 2013 NASA announced a series of initiatives that contribute to NEO detection and mitigation efforts. In February NASA gave $5-million to the Asteroid Terrestrial-Impact Last Alert System (ATLAS), which is being developed by the University of Hawaii.[87] On 10 April NASA presented the FY2014 Asteroid Strategy,[88] which includes a plan to "robotically capture a small near-Earth asteroid and redirect it safely to a stable orbit in the Earth-moon system where astronauts can visit and explore it."[89]

Figure 1.9: Number of large* NEAs discovered by year (2004-2013)[90]



* 1 kilometer in diameter or larger

A crucial part of the plan is the Origins-Spectral Interpretation-Resource Identification-Security-Regolith Explorer (OSIRIS-REx) mission, with a planned launch in 2016. The OSIRIS-REx spacecraft will be designed and built by Lockheed Martin.[91] The primary objective is to reach NEA 1999 RQ36, study it for up to 505 days, and return in 2023 with a sample.[92] In May 2013 OSIRIS-REx passed a confirmation review and the development stage has been authorized.[93]

During the 50th session of the UN COPUOS Scientific and Technical Subcommittee in February, Action Team 14 presented its final report on NEOs and recommendations for an international response to the NEO threat.[94] "The Committee noted with satisfaction that implementation of the recommendations would ensure increased awareness, coordination of protection and mitigation activities and further international collaboration with regard to NEOs."[95] As recommended by Action Team 14, the International Asteroid Warning Network (IAWN) and the Space Missions Planning Advisory Group (SMPAG) were formally established by the Committee at its 56th session in June 2013 and by the resolution adopted on 11 December 2013 at the 68th session of the General Assembly.[96] They are dedicated to research on, and the mitigation of, the NEO threat.

Space agencies, amateur observers produce increasingly accurate assessment of NEO population

By the end of 2013 there were 10,482 known NEAs, 858 of which were 1 km in diameter or larger[97] and 153 identified as potentially hazardous asteroids (PHAs).[98]

Partnerships and collaboration among space agencies, the private sector, amateur observers, and academics developed in 2013. In January the European Space Agency enlisted researchers to help guide the development of the Asteroid Impact and Deflection Assessment (AIDA) mission. ESA sought ideas "for both ground- and space-based investigations, seeking improved understanding of the physics of very high-speed collisions involving both man-made and natural objects in space."[99]

Searching for new ways to detect, redirect, and explore an asteroid, in June NASA issued a Grand Challenge to government agencies, industry, and academics. It "focused on finding all asteroid threats to human populations and knowing what to do about them,"[100] complementing NASA's mission to capture and redirect an asteroid.[101]

Russian officials contemplate space-based solutions to asteroids

In February Deputy Prime Minister Rogozin backed calls for a new system to identify and eliminate threats from space. Responding to a disaster caused when a meteorite crashed in central Russia, injuring more than 1,000 people and producing $33-million damage, Rogozin pledged to develop proposals to deal with future incidents.[102] He suggested that the world should establish a defense system against space objects, while acknowledging that such an anti-asteroid system could become a pretext for the deployment of nuclear weapons in space.[103]

In March Russian officials proposed ideas ranging from planting beacon transmitters on asteroids to megaton-sized nuclear strikes to avert meteor collisions with Earth.[104] In June Russia and the United States pledged to work together to improve protection against meteorites and other space threats. Russia's Emergencies Minister Vladimir Puchkov indicated that the U.S. Federal Emergency Management Agency and Russia's Emergencies Ministry would cooperate on this matter.[105] In October Roscosmos chief Oleg Ostapenko announced that his organization was working with the Russian Academy of Sciences on this issue.[106]

Indicator 1.4: Space Situational Awareness

Space Situational Awareness (SSA) refers to the technical ability of spacefaring actors "to monitor and understand the changing environment in space."[107] This includes 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.[108] Critical to the usefulness of SSA are growing international efforts to improve the predictability of space operations through data sharing.

Improved SSA capabilities can have a positive impact on the security of outer space, as they can be used to predict and/or prevent harmful interference with the assets of spacefaring states and private satellite operators. 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. Additionally, increasing the amount of SSA data available to all states can help increase the transparency and confidence of all actors in space activities, which can reinforce the overall stability of the outer space regime.

As well as helping to prevent accidental collisions and otherwise harmful interference with space objects, SSA capabilities can be used for the protection and potential negation of satellites. At the same time, 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. It bears noting that, to avoid collisions, the operator of a space asset needs to know that there is an object it could hit, but not the exact nature of that object.

The sharing of SSA data affords benefits to all space actors, as they can supplement the data collected by national assets at little or no additional expense. Still, there is currently no operational global system for space surveillance, in part because of the sensitive nature of surveillance data. In addition, technical and policy challenges put constraints on data sharing, although efforts among 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. SSN, the most advanced system for tracking and cataloging space objects, is a network of radar and optical sensors strategically located at more than two dozen sites worldwide. The SSN can reliably track objects in LEO with a radar cross-section of 10 cm or greater and 1 m or greater in GEO. Because it uses a tasked sensor approach—not all orbital space is searched at all times—objects are only periodically spot checked.

The sensors that currently make up the SSN can be grouped into three categories:[109]

Dedicated: The primary mission of these United States Air Force (USAF) Space Command sensors is space surveillance.

Collateral: These USAF Space Command sensors contribute to the SSN, but have a primary mission other than space surveillance, such as missile warning.

Contributing: These sensors belong to private contractors or other government agencies and provide some data under contract to the SSN.

Data from all SSN sensors is used to maintain positions on as many as 23,000 manmade objects in Earth orbit. Objects that can be tracked repeatedly and whose sources have been identified are recorded in the satellite catalog, which currently has more than 16,000 entries. A low-accuracy version of this catalog is publicly available at the Space Track website,[110] but the data is not sufficiently precise to adequately support collision avoidance. The USAF uses a private high-accuracy catalog for a number of data products.

Operators outside the U.S. government can also request surveillance information through the Commercial and Foreign Entities (CFE) program, a pilot initiative started in 2004 that allows satellite operators to access space surveillance data through a website. Initially, the USAF Space Command oversaw the CFE pilot program and its website, Space-Track.org. In 2009, however, responsibility for CFE, renamed SSA Sharing Program, was transferred to the U.S. Strategic Command (USSTRATCOM)—specifically, to the Joint Functional Component Command for Space.

Nongovernmental actors have also recognized the increased importance of data sharing. Three major commercial satellite operators—Intelsat, SES, and Inmarsat—announced in 2009 that they had established the non-profit Space Data Association (SDA) on the Isle of Man. SDA serves as a central hub for sharing data among participants. Initial operations began in July 2010 and full capabilities were online by April 2011. The SDA's main functions are to share data on the positions of members' satellites and information to prevent electromagnetic interference.

2013 Developments

Capabilities

U.S. efforts to build the new-generation S-Band Space Fence continue

In a memo sent to Five Rivers Services in August 2013, the operator of the Air Force Space Surveillance System (Space Fence), the USAF indicated that it was not exercising its contractual option for a fifth year of management and logistical support for the nine field stations.[111] Budget constraints due to sequestration are understood to have played a key role in this decision.[112] The Air Force expected to save approximately $14-million a year by shutting down the space fence.[113]

On 12 August Gen. William Shelton, commander of Air Force Space Command, indicated that shutting down the Space Fence would not compromise its overall space surveillance capabilities and pointed to the improved capabilities of the next-generation system. On 15 August Shelton directed that the Fence be closed and all sites vacated effective 1 October 2013.[114]

Some experts have cautioned about a weakening of U.S. space surveillance. "It will be more difficult and take longer to detect and catalog new pieces of debris, especially those from large breakups," said Brian Weeden, technical adviser at Secure World Foundation. "And the loss of capacity likely means that we have less accurate orbits for a good portion of the space debris."[115]

There have been some delays in the planning and contracting for the new-generation S-Band Space Fence,[116] aimed at tracking more and smaller objects in space while also relieving legacy SSA systems.[117] Costing $6.1-billion over its expected lifetime, the Space Fence is to employ two or three geographically distributed ground-based radar.

In February 2012 Lockheed Martin's preliminary system prototype received final approval from the USAF.[118] A few months later, Raytheon's preliminary design review with the USAF was also completed.[119] Lockheed Martin then submitted its final contract proposal to build the Space Fence in mid-November.[120] In September 2012 the USAF announced that its first S-Band Space Fence facility would be placed on Kwajalein Island in the Republic of the Marshall Islands.[121]

Initially anticipated to be as early as 2015, the inauguration date of the Fence has been repeatedly postponed. In an August 2013 memorandum posted on the Federal Business Opportunities website, the Air Force said that "due to budgetary constraints" the government would amend its original solicitation for the next-generation Space Fence program to reflect a new funding profile and target date for initial operational capability.[122] Shelton said that a Pentagon review of its major acquisition programs was delaying the project. In an email sent on 22 August 2013 to SpaceNews, Shelton indicated that new capability would not be available before fall 2018.[123] "When combined with the new Joint Space Operations Center's high performance computing environment, the new Fence will truly represent a quantum leap forward in space situational awareness for the nation," said Shelton.[124]

NASA conducted works on an infrared sensor, which in April passed a design test. The Near Earth Object Camera (NEOCam) sensor is a critical step on the way to a proposed new space-based asteroid-hunting telescope and can contribute significantly to the detection and tracking of asteroids and comets.[125]

Canada's Sapphire satellite becomes newest element of Space Surveillance Network

On 25 February Canada's first "dedicated operational military satellite"[126] was launched from Sriharikota, India, by the Indian Space Research Organisation aboard a Polar Satellite Launch Vehicle.[127] The launch had been planned for late 2012, but had been postponed.[128] Less than a year after launch, on 30 January 2014, the Sapphire satellite was declared fully operational.[129] It will contribute to the existing U.S. Space Surveillance Network.[130] Also launched was the Near-Earth Object Surveillance Satellite (NEOSSat),[131] a suitcase-sized satellite that orbits approximately 800 km above Earth, searching for near-Earth asteroids that are difficult to spot using ground-based telescopes.[132]

According to a press release by the Canadian Armed Forces, Sapphire can monitor "space objects orbiting between 6,000 and 40,000 kilometres above the Earth's surface on a 24-hour basis."

Unlike land-based sensors, Sapphire is not affected by weather conditions and cloud cover."[133] Sapphire and its ground infrastructure were developed by MDA Corp. of Richmond, British Columbia and Surrey Satellite Technology Ltd. of Britain at a cost of approximately $94.6-million (Cdn) and below initial projections.[134] Sapphire is scheduled to operate for five years.[135]

Phase II of ESA SSA program begins

In 2013 Phase II of the European Space Agency Space Situational Awareness program began, funded at €46.5-million for the period 2013–2016.[136] It has three main objectives:[137]

- Monitoring conditions at the Sun and in the solar wind and in Earth's magnetosphere, ionosphere, and thermosphere, which can affect space-borne and ground-based infrastructure or endanger human life or health;
- Detecting natural NEOs that can potentially impact Earth and cause damage;
- Watching for active and inactive satellites, discarded launch stages, and fragmentation debris orbiting Earth.

Phase II, which follows a Preparatory Phase that covered the period 2009–2012, was voted on at the November 2012 Ministerial Council of the ESA.[138] Specific activities to be pursued during Phase II include the establishment of data and coordination centers; the development of sensors, applications, and user interfaces; the deployment of hosted payloads, such as placing space weather sensors on host missions; and the utilization of data from satellites in orbit.[139] The Ministerial Council also decided to continue support for the buildup of an SSA capability, in close cooperation with ESA Member States and European partners, with a focus on activities related to space weather. Research and development into NEO and space surveillance and tracking (SST) will also be pursued. Fourteen SSA Participating States contribute to space weather activities and nine to activities related to NEO and SST.

To improve its SSA capabilities, ESA created the Space Situational Awareness Space Weather Coordination Centre in April 2013[140] and NEO Coordination Centre in May 2013. Nicolas Bobrinsky, head of ESA's SSA program, revealed that ESA is working "on a prototype 'fly's eye' telescope, with specially designed wide vision, to help surveillance of the cosmos."

SSA sharing

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

Global Space Situational Awareness capabilities have been enhanced through international cooperation and data-sharing agreements. On 26 December 2013 it was announced that the U.S. Strategic Command and the Canadian Department of National Defence had signed an updated accord permitting the exchange of advanced SSA data.[141] The agreement is expected to streamline the process by which the Canadian military requests SSA data from Strategic Command's Joint Space Operations Center for, inter alia, satellite maneuver planning, collision avoidance, and anomaly resolution.[142] A similar agreement with Australia, signed on 24 April,[143] was intended to streamline the process for Australians to make specific requests about space data gathered by U.S. Strategic Command (Stratcom).[144]

On 21 January 2014 Stratcom and the French Ministry of Defense signed another data-sharing accord that "will enable Stratcom to provide data from the Joint Space Operations Center at Vandenberg Air Force Base, Calif., directly to the French military upon request."[145] The agreement with France is Stratcom's fifth since it was granted the authority to negotiate such agreements by the White House. Stratcom has similar deals with Italy and Japan.[146]

By the end of 2013 the United States had entered into SSA sharing agreements with 41 commercial firms and five nations.[147] These formal agreements are in addition to some 85,000 Space-Track.org accounts with 185 countries.[148]

Access to and use of space by various actors

Indicator 2.1: Space-based global capabilities

The use of space-based global capabilities, including navigation, weather, and search-and-rescue systems, has grown dramatically over the last decade. While key global capabilities such as 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 global satellite navigation systems: the U.S. GPS and the 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.

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] Although the first GLONASS satellite was orbited in 1982, various satellite malfunctions kept the system below operational levels, retaining only some capability.[2] In 2011 the system was declared fully operational.[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 development of Galileo gained traction in 2002 with the allocation of $577-million by the European Council of Transport Ministers under a public-private partnership.[6] After a five-year delay, European governments agreed in 2007 to provide the necessary $5-billion to continue work on the system[7] and in 2011 again revised cost estimates upwards by approximately $2.4-billion.[8] In October 2012 two Galileo satellites, launched into orbit from Kourou Spaceport in French Guiana, joined the first pair of satellites launched a year earlier.[9] The 30-satellite system is expected to be fully deployed by 2020.[10] 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.[11]

The Chinese Beidou system is currently limited to regional uses. It works on a different principle from that of the GPS or GLONASS, operating four satellites in GEO.[12] In 2006 China announced that it would extend Beidou into a global system called Compass or Beidou-2 for military, civilian, and commercial use.[13] The planned global system will include five satellites in GEO and 30 in MEO. While Beidou will initially provide only regional coverage, it is expected to evolve into a global navigation system by 2020.[14]

India has also proposed an independent, regional system—the Indian Regional Navigation Satellite System (IRNSS)—intended to consist of a seven-satellite constellation.[15] Japan is developing the Quazi-Zenith Satellite System (QZSS), which is to consist of four satellites interoperable with GPS in HEO to enhance regional navigation over Japan, but operating separately from GPS, providing guaranteed service.[16] Neither system was fully operational by the end of 2013.

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 development of competing independent satellite navigation systems, although conceivably interoperable and able to extend the reliability of this global utility, may face problems related to proper intersystem coordination and lead to disagreements over the use of signal frequencies. Another concern is orbital crowding as states seek to duplicate global services, particularly in MEO.

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.[17]

The European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) provides meteorological data for Europeans, while the National Oceanic and Atmospheric Administration (NOAA) provides the United States with meteorological services.[18] Satellite operators from China, Europe, India, Japan, 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.[19]

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."[20] By the end of 2013 the Group on Earth Observation had members from 88 state governments and the European Commission.[21] In addition, 67 intergovernmental, international, and regional organizations are recognized as Participating Organizations.[22] Established in 2005 GEOSS has a 10-year implementation plan. Benefits will include reduction of the impact of disasters, resource monitoring and management, sustainable land use and management, better development of energy resources, and adaptation to climate variability and change.[23] The European Global Monitoring for Environment and Security (GMES) initiative is an example of a centralized database of Earth observation data made available to users around the world.[24]

Disaster relief & search-and-rescue

Space has also become critical for disaster relief. The International Charter Space and Major Disasters was initiated by ESA and CNES in 1999 to provide "a unified system of space data acquisition and delivery to those affected by natural or man-made disasters through Authorized Users."[25] Other member organizations include the CSA, NOAA, ISRO, the Argentine Space Agency, the U.S. Geological Survey, the British National Space Centre, CNSA, and DMC International Imaging, which bring together resources from over 20 spacecraft.[26]

In 1979 COSPAS-SARSAT, the International Satellite System for Search and Rescue, was founded by Canada, France, the USSR, and the United States to coordinate satellite-based search-and-rescue. COSPAS-SARSAT is essentially 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.[27]

On 14 December 2006 the UNGA agreed to establish the United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER). 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."

2013 Developments

Navigation systems

Global Positioning System (GPS)

On 30 August 2013 Lockheed Martin and Raytheon successfully concluded compatibility and integration tests on the prototype of the next-generation GPS III satellite and GPS Next Generation Operational Control System (GPS OCX).

According to Matthew Gilligan, Raytheon GPS OCX program manager, this experiment is "an invaluable early opportunity to demonstrate command and control of the GPS III satellite with Launch and Check Out System, proving the end-to-end system capabilities well before putting an actual GPS III in orbit. The positive results tell us that we are right on track for the first GPS III launch."[28]

The new GPS III satellites will be three times more accurate and have as much as eight times more powerful anti-jamming capabilities. The GPS OCX is intended to "revolutionize GPS command and control and mission management capabilities, controlling all legacy and new military and civil signals, providing protection against evolving cyber threats and ensuring continuity of operations during cyber-attacks, and reducing operation and sustainment costs through efficient software architecture, automation and performance-based logistics."[29]

Galileo

On 12 March 2013 ESA celebrated "a historic milestone" of the Galileo satellite navigation system.[30] Using four in-orbit Galileo satellites, launched in pairs in 2011 and 2012, and the accompanying European ground infrastructure, the system made its "first position fix of longitude, latitude and altitude."[31] ESA reported that the determination was made with accuracy between 10 and 15 m[32]; accuracy will increase as more satellites are launched.

ESA Galileo Project Manager Javier Benedicto emphasized the historic and technical importance of this achievement. He observed that, "from the technical perspective, generation of the Galileo navigation messages is an essential step for beginning the full validation activities, before starting the full deployment of the system by the end of this year."[33] At present, the Galileo constellation comprises only four of 30 planned satellites.[34]

GLONASS

On 19 February 2013 Russian Space Systems opened a ground station for differential corrections and monitoring of GLONASS in Brazil.[35] The station, situated on the campus of the University of Brasilia, is the first such installation outside of Russia.[36] It will enhance the accuracy of GLONASS in the Western Hemisphere.[37] Pursuant to the agreement between Russian Space Systems and the Brazilian National Institute of Technology, Russia pledged to launch a second GLONASS correction station in Brazil by the end of the year.[38] According to Sergey Savelyev, Deputy Head of Roscosmos, Russia concluded similar agreements for the installation of ground correction stations with South Africa, Nicaragua, and Cuba.[39]

On 26 April 2013 Russia launched the second-generation GLONASS-M satellite (Uragan-M)[40] onboard a Soyuz 2-1b rocket from the Plesetsk Cosmodrome in Mirny.[41] Its projected lifespan is four years longer than that of first-generation Uragan spacecraft.[42] Following its commissioning and testing phases, the satellite will join the GLONASS satellite constellation, which currently comprises 23 operational satellites.[43]

Beidou

The global outreach of Beidou, China's navigation and positioning system, is growing. In March 2013 China and Thailand signed an agreement to extend Beidou's coverage to Thailand, which will become the first foreign country to use the system.[44] The main objective is to promote the use of Beidou by Thailand's public sector in, inter alia, disaster relief, power distribution, and transportation.[45] In exchange, China will bear the cost of establishing Thailand's geospatial system and constructing a satellite ground station based on Beidou.[46] The estimated value of the agreement is $319-million.[47]

Beidou will begin operating in Thailand in 2014 and for now remains limited to the Asia-Pacific region.[48] According to Deputy Director of the Wuhan Information Technology Outsourcing Service and Research Centre Liu Junyi, however, "the Beidou will be able to provide global service by 2015."[49]

Remote sensing capabilities continue to advance

On 11 February 2013 NASA launched the eighth satellite in its Landsat program, a collaboration between NASA and the United States Geological Survey.[50] Landsat, which in 2012 celebrated the fortieth anniversary of its first satellite launch, is the world's longest-running Earth observation program.[51] According to NASA Administrator Charles Bolden, data collected by Landsat satellites "is a key tool for monitoring climate change and has led to the improvement of human and biodiversity health, energy and water management, urban planning, disaster recovery and agriculture monitoring."[52]

Most recently the Landsat Data Continuity Mission (Landsat 8) was launched on an Atlas V rocket from Vandenberg Air Force Base in California.[53] It officially began operations on 30 May 2013.[54] Landsat 8 joins Landsat 7, the only remaining operational spacecraft in the Landsat series, after Landsat 5 was retired on 5 June 2013.[55] The new satellite has a five-year design life and is equipped with the Operational Land Imager, which "collects image data for nine shortwave spectral bands"[56] and the Thermal Infrared Sensor, which "collects image data for two thermal bands."[57] All data gathered by Landsat 8 will be available online and free of charge.[58]

South Korean Korea Multi-Purpose Satellite-5 (KOMPSAT-5 or Arirang-5) was launched onboard a Dnepr-1 rocket on 22 August 2013 from the Dombarovsky launch site near Yasny, Russia. KOMPSAT-5 is the first synthetic-aperture radar (SAR) satellite developed and operated by the Korea Aerospace Research Institute (KARI) and fourth satellite in the

Korea Multi-Purpose Satellite (Arirang) program, following three optical satellites.[59] With a design life of five years, KOMPSAT-5 will provide all-weather day-and-night SAR images for Geographical Information Systems, ocean monitoring, land management, disaster monitoring, and environment monitoring (GOLDEN mission).[60]

KOMPSAT-5's secondary payload, the Atmospheric Occultation and Precision Orbit Determination system, will provide data for its radio occultation mission.[61] KARI is planning to further expand its KOMPSAT constellation by launching an infrared and optical imaging satellite, KOMPSAT-3A, in 2014.[62]

On 6 May 2013 ESA successfully launched Proba-V (Project for Onboard Autonomy-Vegetation), a lightweight Earth observation satellite[63] and the fourth in the Proba minisatellite series.[64] It was launched from the Guiana Space Center, French Guiana, onboard the second flight of the Vega launcher,[65] ESA's new launch vehicle.[66] Using a smaller version of the Vegetation imaging instruments onboard French Spot-4 and Spot-5 satellites, Proba-V will "map land cover and vegetation growth across the entire planet every two days."[67]

In particular, data gathered by Proba-V will assist in "day-by-day tracking of extreme weather, alerting authorities to crop failures, monitoring inland water resources and tracing the steady spread of deserts and deforestation."[68] The Vegetation sensors on Proba-V and its predecessor, Spot-5, have been cross-calibrated to ensure continuity in the provision of data once the French satellite has reached the end of its mission.[69]

On 26 April 2013 the China National Space Administration launched Gaofen-1, a high-resolution optical remote sensing satellite.[70] The spacecraft, launched using a Long March 2D (Chang Zheng 2D) rocket, is the first in the constellation of small Gaofen civilian satellites in the China High-resolution Earth Observation System (CHEOS).[71] Gaofen-1, which became operational on 30 December 2013, will provide Near-Real-Time images for climate change and disaster monitoring, geographic and resources surveys, and precision agriculture.[72] High-resolution panchromatic, multi-spectral, and wide-field cameras on board the spacecraft allow observation of objects as small as a car or a bicycle.[73] The second Gaofen satellite is scheduled for launch in 2014, followed by the launch of three more satellites by 2016.[74] China is planning to complete the implementation of the CHEOS program by 2020.[75]

Azerbaijan launches its first telecommunications satellite

Azerbaijan's first communications satellite, Azerspace-1/Africasat-1a, was launched aboard the Ariane 5 rocket from the Guiana Space Center near Kourou in French Guiana on 8 February 2013.[76] Azerspace-1/Africasat-1a was designed and manufactured by Orbital Sciences Corporation, a U.S. company.[77]

The satellite will be operated jointly by Azercosmos, the Azerbaijani state-owned satellite operator, and Measat Satellite Systems, a Malaysian communications satellite operator.[78] Over a period of 15 years the satellite will provide telecommunications and broadcasting services to Azerbaijan, Europe, Africa, the Middle East, and Central Asia.[79]

In August 2013 Azercosmos received a grant of $500,000 from the U.S. Trade and Development Agency to assess the feasibility of launching a second telecommunications satellite.[80] The feasibility study will be conducted by a U.S.-based contractor, selected by both parties.[81] Azercosmos is planning to launch the Azerspace-2 communications satellite in 2018.[82]

Figure 2.1: Countries with independent orbital launch capability*

*Dark grey indicates an independent orbital launch capability and dots indicate launch sites.

Figure 2.2: Countries' first orbital launches

State/actor	Year of first orbital launch	Launch vehicle	Satellite
USSR/Russia	1957	R-7 rocket	Sputnik 1
United States	1958	Juniper-C	Explorer 1
France	1965	Diamant	Astérix
Japan	1970	Lambda	Osumi
China	1970	Long March	Dong Fang Hong I
United Kingdom	1971	Black Arrow	Prospero X-3
India	1980	SLV	Rohini
Israel	1988	Shavit	Ofeq 1
Iran	2009	Safir-2	Omid

Indicator 2.2: Priorities and funding levels in civil space programs

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. NASA's work is carried out through four interdependent directorates:[83] Aeronautics develops and tests new flight technologies; Exploration Systems creates capabilities for human and robotic explorations; Science undertakes scientific exploration of the Earth and Solar System; and Space Operations provides critical enabling technologies as well as support for spaceflight. While much of the operational work is carried out by NASA itself, major commercial contractors such as Boeing and Lockheed Martin are often involved in the development of technologies for new space exploration projects.

During the Cold War civil space efforts in the Soviet Union were largely decentralized and led by "design bureaus"—state-owned companies headed by top scientists. Russian launch capabilities were developed by Strategic Rocket Forces and cosmonaut training was managed by the Russian Air Force. Formal coordination of efforts came through the Ministry for

General Machine Building.[84] A Russian space agency (Rossiyskoe Kosmicheskoye Agentstvo) was established in 1992, and has since been reshaped into Roscosmos. While Roscosmos is more centralized, most work is still completed by design bureaus, now integrated into "Science and Production Associations" (NPOs) such as NPO Energia, NPO Energomash, and NPO Lavochkin.

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, both formed in 1962, 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.

Civil space activities began to grow in China when they were allocated to the China Great Wall Industry Corporation in 1986. The China Aerospace Corporation was established in 1993, followed by the development of the China National Space Administration. CNSA remains the central civil space agency in China and reports through the Commission of Science, Technology and Industry for National Defense to the State Council.

In Japan civil space was initially coordinated by the National Space Activities Council formed in 1960. Most of the work was performed by the Institute of Space and Aeronautical Science of the University of Tokyo, the National Aerospace Laboratory, and, most importantly, the National Space Development Agency. In 2003 all this work was assumed by the Japanese Aerospace Exploration Agency (JAXA).[85] India's civil space agency ISRO was founded in 1969. The Israel Space Agency was formed in 1982, the Canadian Space Agency in 1989, and Brazil's Agência Espacial Brasileira in 1994.

Human spaceflight

On 12 April 1961 Yuri Gagarin became the first human to travel into space onboard a Soviet Vostok 1 spacecraft. The early years of human spaceflight were dominated by the USSR, which succeeded in fielding the first woman in space, the first human spacewalk, the first multiple-person space flights, and the longest-duration spaceflight. Following the Vostok series rockets, the Soyuz became the workhorse of the Soviet and then Russian human spaceflight program and has since carried out more than 100 missions, with a capacity load of three humans on each flight. The 2006-2015 Federal Space Program maintains an emphasis on human spaceflight, featuring ongoing development of a reusable spacecraft to replace the Soyuz vehicle and completion of the Russian segment of the ISS.[86]

The first U.S. human mission was completed on 5 May 1961 with the suborbital flight of the Mercury capsule, launched on an Atlas-Mercury rocket. The Gemini flight series and then the Apollo flight series followed, ultimately taking humans to the Moon. The United States went on to develop the Skylab human space laboratories in 1973 and the USSR developed the Mir space station, which operated from 1986 to 2001. The first Space Shuttle, Columbia, was launched in 1981 and, by the time the program was terminated in 2011, a total of 135 Space Shuttle launches had been conducted.[87] Recent developments described in this volume suggest an increased reliance on commercial providers for space transport services.

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.[88] Future plans include a permanent human presence on the lunar surface.[89] 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. In its final report, the Committee proposed three basic options for exploration beyond low Earth orbit:[90]

- Mars First, with a Mars landing, perhaps after a brief test of equipment and procedures on the Moon;
- Moon First, with lunar surface exploration focused on developing the capability to explore Mars;
- A Flexible Path to inner solar system locations, such as lunar orbit, Lagrange points, near-Earth objects, and the moons of Mars, followed by exploration of the lunar surface and/or Martian surface.

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.[91] A second mission was successfully completed in 2005, and the third and latest in 2008.

2013 Developments

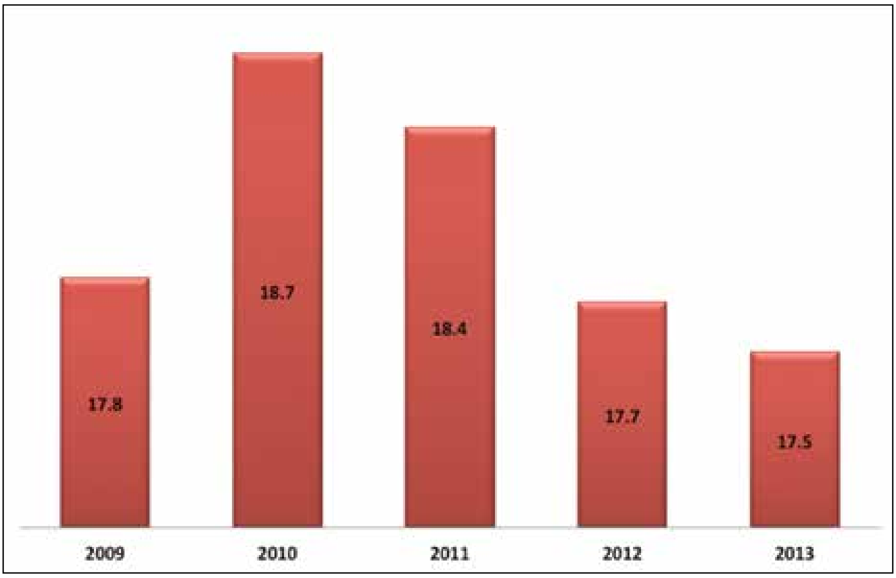
Budgetary allotments in civil space programs

On 10 April 2013 NASA Administrator Charles Bolden announced the proposed agency budget of $17.7-billion for fiscal year 2014.[92] Following a long debate and a 16-day federal government shutdown in October, the U.S. Congress approved a $17.67-billion budget for NASA.[93] It provides $5.2-billion for science, including $658.2-million for the James Webb Space Telescope.[94] It allocates $4.1-billion for exploration, including $1.9-billion for development of the Space Launch System, a heavy-lift launch vehicle, and $1.2-billion for the Orion Multi-Purpose crew capsule.[95]

The Commercial Crew Program will receive $696-million to further the objective of launching a manned mission from the United States by 2017.[96] Space operations are the third largest spending area, but most of the $3.8-billion will fund NASA's continuing participation in the International Space Station.[97] A sum of $105-million was allocated for the new Asteroid Redirect Mission, "a first-ever mission to identify, capture and relocate an asteroid," with a further prospect of a manned mission to an asteroid by 2025.[98]

Russia began a major reorganization of its space industry. Following the fifth major launch failure of the Russian Proton-M rocket on 1 July 2013, Prime Minister Dmitry Medvedev tasked Deputy PM Dmitry Rogozin with drafting a proposal for the restructuring of the Russian space sector.[99] Pursuant to a decree proposed by Rogozin and signed by the President on 2 December 2013, the Russian space industry, in particular hardware developers and manufacturers, will be consolidated under a single government-owned open joint-stock company.[100] According to Rogozin, the "consolidation will help the government pursue a 'unified technical policy' in the space sector as well as remove current redundancies and avoid potential ones."[101] Two primary goals of the newly created United Rocket and Space Corporation are "to diminish the reliance on imported equipment" and "to eliminate excess manufacturing capacity."[102]

Figure 2.3: NASA 2009-2013 budget (in $USB)



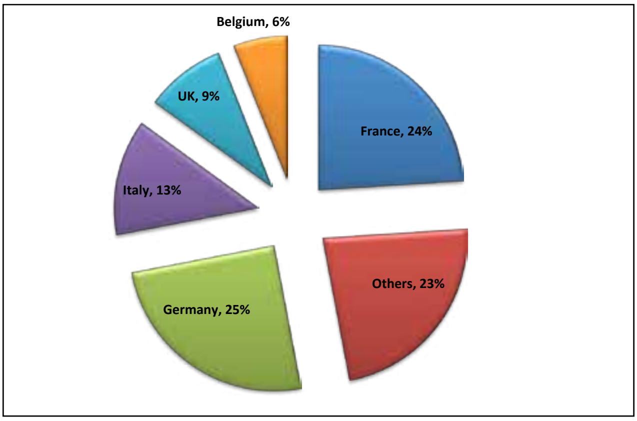
In April 2013 Russian President Vladimir Putin announced that Russia would invest 1.6-trillion rubles (around $50-billion) in its space sector by 2020.[103] The biggest project is the construction of Russia's independent launch site, known as the Vostochny Cosmodrome in the Amur Region.[104] Construction began in 2012 and was progressing on schedule.[105] The first launch of a Soyuz-2 light carrier rocket from Vostochny is planned for 2015, followed by the first manned mission in 2018.[106]

On 17 January 2013 ESA Director-General Dordain announced a budget of 4.1-billion Euros for FY 2014, a 4% drop from the previous year.[107] ESA program sectors receiving the most funding in 2014 include Earth Observation (22.3%, 915.9-million Euros), Navigation (15.4%, 630.2-million Euros), Launchers (15.1%, 617.4-million Euros), and the ESA Scientific Program (12.3%, 506.5-million Euros).[108] Programs within the first three sectors are 'optional', which means that ESA Member States are free to determine how much they want to contribute.[109] Participation in activities of the Science Program is mandatory, with costs shared among Member States based on their Gross Domestic Product.[110]

The Japanese Office of National Space Policy introduced a new Basic Plan that envisages a significant shift in Japanese space policy. Over the next five years, JAXA will reduce the number of research and development programs and focus primarily on projects that promise the best return on investment.[112] ONSP director Hirotoshi Kunitomo observed that "for 20 years, so much money has been spent by JAXA [and its predecessor, Nasda] on R&D, but there has been very little commercial return."[113]

The Basic Plan on Space Policy identifies three priorities: national security and disaster management, development of industries, and space science.[114] These priorities will guide current and future JAXA programs, which include the development of a new launcher, the H-3 rocket,[115] and minisatellite platform ASNARO (Advanced Satellite with New system ARchitecture for Observation),[116] as well as the launch of the Hayabusa-2 mission to collect samples from an asteroid.[117]

Figure 2.4: Top contributors to ESA's 2013 General Budget*[111]



* This chart includes ESA member states that contribute 5% or more.

The unofficial JAXA budget for FY2014 was set at 181.5-billion yen ($1.75-billion),[118] 3.9-billion yen ($37.5-million) lower than the previous year, and includes 27.1-billion yen ($260-million) of predicted supplementary budget appropriations.[119] JAXA allocated 7-billion yen ($67-million) from the main budget to develop its 2014 flagship program, the Hayabusa-2 launch vehicle.[120]

Russia, Ukraine announce plans to accelerate growth in space industry

Russia

In a January 2013 space industry publication Russia announced plans to increase its share of the global space market from the current 10% to 15% by 2020. The plans were reiterated by Prime Minister Dimitry Medvedev in February on a visit to Cuba. Russia hopes to achieve its goal by bringing more satellites into orbit and participating in international launches. Russia's space industry is being restructured to unite dozens of enterprises into between five and seven major state-controlled holdings. The government has earmarked $69-billion to the space program through 2020, with a portion expected from private investment.[121]

In April Russian President Vladimir Putin reportedly said that Russia would spend 1.6-trillion rubles ($50-billion) in space-related activities by 2020.[122] He inspected Vostochny Cosmodrome construction in the Amur Region, designed to reduce Russia's dependency on the Baikonur Cosmodrome in Kazakhstan. The first launch from Vostochny is expected in 2015 and the first manned flight in 2018.[123]

In October the Russian government announced its plan to consolidate the space industry to combat inefficiencies and the misuse of funds. Deputy Prime Minister Rogozin unveiled plans that call for the creation of a new state entity, United Rocket and Space Corporation, to take over manufacturing facilities from the Federal Space Agency, which had overseen a number of failed rocket launches.[124]

Roscosmos will continue to serve as the federal executive body and contracting authority for programs to be implemented by the industry.[125] In October Roscosmos chief Vladimir Popovkin was replaced by Oleg Ostapenko.[126]

Ukraine

In April President Viktor Yanukovych highlighted Ukraine's progress in the aerospace industry and claimed that his country would continue to develop space projects. Ukraine was implementing a number of space projects with Russia and Kazakhstan and collaborating with Brazil in a joint launch of Cyclone-4 rockets from the Alcântara Launch Center in Brazil.

Since 2011 Ukraine has been one of the top five space rocket-launching entities in the world, along with China, the EU, Russia, and the United States. Since 1991 it has launched 128 rockets and delivered into orbit 250 satellites for 19 countries.

Ukraine allocated about $322-million to promote its aerospace industry over the next five years.[127] In October Prime Minister Mykola Azarov announced plans to increase local space industry output by 50% by 2017 through closer cooperation with investors.[128]

China launches second manned mission to Tiangong-1 space station

On 11 June 2013, just a year after its first manned mission to the Tiangong-1 space station, China launched another mission atop the Long March-2F carrier rocket from the Jiuquan Satellite Launch Center.[129] The Shenzhou-10 spacecraft with three Chinese astronauts onboard reached the Tiangong-1 space laboratory two days later and successfully completed an automated docking.[130] During a 15-day mission in orbit, the crew performed a manual re-docking operation and a two-hour fly-around test,[131] and conducted medical and technology experiments.[132] Wang Yaping, China's second female astronaut, delivered a live video lecture for school children.[133]

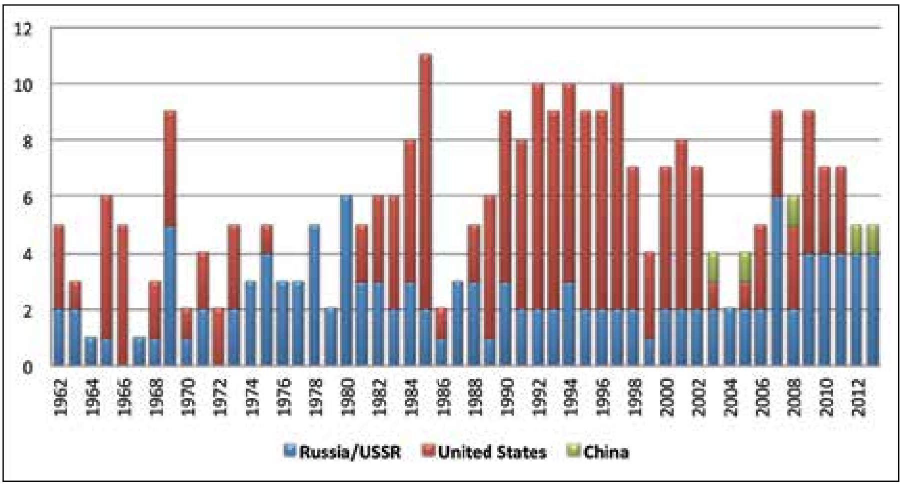
The mission safely returned to Earth on 26 June 2013, landing at the main landing area in north China's Inner Mongolia Autonomous Region.[134] Director General of the China Manned Space Agency Wang Zhaoyao stated that "with a complete success of this spaceflight mission as a milestone, China's manned space program will enter into a new phase of manned space station construction."[135] According to Wang, the total cost of the Chinese human spaceflight program since its beginning in 1992 is $6.35-billion.[136]

India launches Mars mission

On 5 November 2013 the Indian Space Research Organisation (ISRO) launched India's first interplanetary mission to Mars.[137] The Mars Orbiter Mission Spacecraft, informally called Mangalyaan (Hindi for "Mars Craft") is scheduled to reach Mars orbit in September 2014 after a 300-day journey.[138] The spacecraft was launched aboard ISRO Polar Satellite Launch Vehicle PSLV-C25 from the Satish Dhawan Space Centre in Sriharikota.[139]

According to ISRO, the primary aim of the mission is "to develop the technologies required for design, planning, management and operations of an interplanetary mission."[140] The instruments onboard the spacecraft, which include a camera, two spectrometers, a radiometer, and a photometer,[141] will analyze the planet's exosphere, atmosphere, and surface features, in particular, its morphology and mineralogy.[142] The Mars Orbiter Mission is estimated to cost between $72-million[143] and $75-million,[144] and has already been dubbed "the world's least-expensive Mars endeavor."[145]

Figure 2.5: Human spaceflight missions by country, 1961–2013



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, with scientific satellites a key driver for cooperation.[146] One of the first scientific satellites, Ariel-1, launched in 1962, was the world's first international satellite, built by NASA to carry UK experiments. 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 countries including the United States, Afghanistan, Austria, Bulgaria, Canada, France, Germany, Japan, Slovenia, Syria, and the United Kingdom to enable astronauts to conduct experiments onboard the Mir space station.[147] Many barriers to global partnership have been overcome since the end of the Cold War. Examples include the EU-Russia collaboration on launcher development and utilization, and EU-China cooperation on the Galileo navigation system. From 1995-1998 there were nine dockings of the U.S. Space Shuttle to the Mir space station, with various crew exchanges.[148] The ESA and NASA have collaborated on many scientific missions, including the Hubble Space Telescope, the Galileo Jupiter probe, and the Cassini-Huygens Saturn probe.

The most prominent example of international civil space cooperation is the ISS, the largest, most expensive international engineering project ever undertaken. The project partners are NASA, Roscosmos, ESA, JAXA, and the CSA. Brazil participates through a separate agreement with NASA. The first module was launched in 1998. The ISS is projected to cost approximately $129-billion over 30 years of operation.[149]

There has also been increased recognition in recent years that SSA effectiveness is enhanced by sharing data among diverse governmental and nongovernmental space actors. This view was underscored by the 2009 collision between the Iridium and Cosmos satellites—the first such event—which prompted numerous calls for improved conjunction prediction and data sharing among satellite owners and operators. Recent collaboration efforts related to SSA data sharing are covered in Theme 1, Indicator 1.4.

2013 Developments

NASA and ESA agree to cooperate on a lunar flyby and the 'Dark Universe' mission

In January 2013 ESA and NASA announced plans to partner on two deep space missions. The first venture, NASA's Exploration Space Mission-1, is an unmanned lunar flyby scheduled for 2017.[150] Under an agreement between the two space agencies reached on 16 January 2013, the Orion Multi-Purpose Crew Vehicle will consist of an ATV-derived service module supplied by ESA and the Orion crew capsule provided by NASA.[151] The Exploration Space Mission-1 will be launched aboard the Space Launch System, a heavy-lift rocket under development by NASA.[152]

As announced on 24 January 2013, NASA will collaborate with ESA on the Euclid or 'Dark Universe' mission, scheduled to launch in 2020.[153] Its primary objective is "to map the geometry of the dark Universe"[154] and "provide insight into the nature of dark energy and dark matter by accurate measurement of the accelerated expansion of the Universe."[155] The total cost of the Euclid mission is approximately $1-billion, with $50-million from NASA.[156] NASA is currently developing the Wide-Field Infrared Survey Telescope to study dark energy.[157]

ESA and Roscosmos partner on two missions to Mars

On 14 March 2013 ESA and Roscosmos signed a partnership agreement for the ExoMars (Exobiology on Mars) program,[158] which aims to send a mission to Mars in 2016 and another in 2018 to search for signs of life.[159] The first mission will consist of the Trace Gas Orbiter and the Entry, Descent and Landing Demonstrator Module provided by ESA.[160] ESA will provide a rover and carrier for the second mission. Roscosmos will supply the descent module and surface platform for the 2018 mission.[161] Both missions will be launched with Russian Proton-M rockets.[162]

The ExoMars program was initially intended as a joint project of ESA and NASA, but budget constraints resulted in NASA's withdrawal in 2012.[163] Nevertheless, NASA will provide ExoMars with a telecommunications package and engineering support for the 2016 mission.[164]

Vladimir Popovkin, the head of Roscosmos, noted that "the ExoMars programme is to become the second large project after Soyuz in Kourou."[165] He pointed out that "it confirms again that projects of such tremendous scale have to be implemented through international cooperation."[166]

UK signs space cooperation agreement with Kazakhstan

On 7 March 2013 the UK Space Agency and the National Space Agency of the Republic of Kazakhstan (Kazcosmos) signed a Memorandum of Understanding on collaboration in space activities.[167] The agreement provides for the training for Kazakh satellite engineers and operators, and cooperation between Surrey Satellite Technology, an independent UK company, and state-owned Kazakhstan Gharysh Sapary in the areas of "space science, technology demonstration, communication, navigation and Earth observation."[168] According to the UK Minister for Universities and Science, "it will foster innovation and encourage greater exchange of information and technology between countries."[169]

Ecuador launches two nanosatellites

On 21 November 2013 the Ecuadorian Civilian Space Agency (EXA) launched its second satellite, NEE-02 Krysaor.[170] The cube-shaped nanosatellite, weighing 2.1 kg and made entirely in Ecuador,[171] was launched atop a Dnepr RS-20B rocket from the Dombarovsky launch site in Russia.[172] Krysaor is a technology demonstration satellite[173] with primarily educational purposes.[174] Its mission includes monitoring of near-Earth objects and space debris.[175]

The first Ecuadorian satellite, the NEE-01 Pegaso nanosatellite, was launched as a secondary payload aboard the Chinese Long March 2D rocket on 26 April 2013.[176] On 23 May Pegaso malfunctioned after passing through a debris cloud surrounding the spent upper stage of a Russian Tsyklon-3 rocket.[177] Although Pegaso was initially declared lost on 28 August 2013, EXA managed to recover the nanosatellite's signal, using Krysaor.[178]

Indicator 2.4: Growth in commercial space industry

Commercial space revenues have steadily increased since the mid-1990s, when the industry first started to grow significantly. Currently, the satellite industry comprises approximately 60% of space revenues and 4% of telecommunications revenues.[179] Of the four satellite industry segments, satellite manufacturing revenues grew the most from 2012 to 2013 (8%), followed by satellite services (5%), and ground equipment (1%). Launch industry revenues decreased by 7%.[180]

The United States accounts for nearly 70% of global satellite manufacturing revenues,[181] with 75% of that due to satellites produced for U.S. government contracts.[182] The global satellite manufacturing industry produced 107 satellites that were launched in 2013, 44% of which were communications satellites, 18% research and development (R&D) satellites, 17% remote sensing satellites, 10% scientific satellites, 6% military surveillance satellites, 5% navigation satellites, and 1% meteorology satellites.[183]

Although the United States accounts for 45% of global launch industry revenues, more than 70% of these revenues are from launching U.S. government satellites on commercial launch vehicles.[184] Globally, government customers accounted for 70% of commercially procured satellite revenues.[185]

The telecommunications industry has long been a driver of commercial uses of space. The first commercial satellite was the Telstar-1, launched by NASA in July 1962 for telecommunications giant AT&T.[186] Satellite industry revenues were first reported in 1978, when Communication Satellite Corporation claimed operating revenues of almost $154-million for 1976.[187] By 1980 it is estimated that the worldwide commercial space sector already accounted for revenues of $2.1-billion.[188] Individual consumers are becoming important stakeholders in space with their demand for telecommunications services, particularly Direct Broadcasting Services, but also global satellite positioning and commercial remote sensing images.

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.[189] PanAmSat, New Skies, GE Americom, Loral Skynet, Eutelsat, Iridium, EchoStar, and Globalstar were some of the prominent companies to emerge during this time. Major companies today include SES Global, Intelsat, Eutelsat, Telesat, and Inmarsat.

Although satellite manufacturers continue to experience pressure to lower prices, strong demand for broadcasting, broadband, and mobile satellite services and a strong replacement market drive an increase in orders that is projected to continue.[190]

The shape of the commercial space industry has been shifting as it becomes more global. Although it is still dominated by Europe, Russia, and the United States, countries such as India and China have become increasingly involved, with developing countries the prime focus of these efforts.[191] India has been positioning itself to compete for a portion of the commercial launch service market by offering lower cost launches.[192] For the first time in 2007 China both manufactured and launched a satellite for another country, Nigeria's Nigcomsat-1.[193]

2013 Developments

Growth in satellite market

Satellite market continues to expand

In 2013 there were 81 orbital launches (23 commercial), up from 78 launches (20 commercial) in 2012.[194] Russia had the highest number of launches at 32, with 12 commercial; in 2012 Russia had 24 launches, with seven commercial.

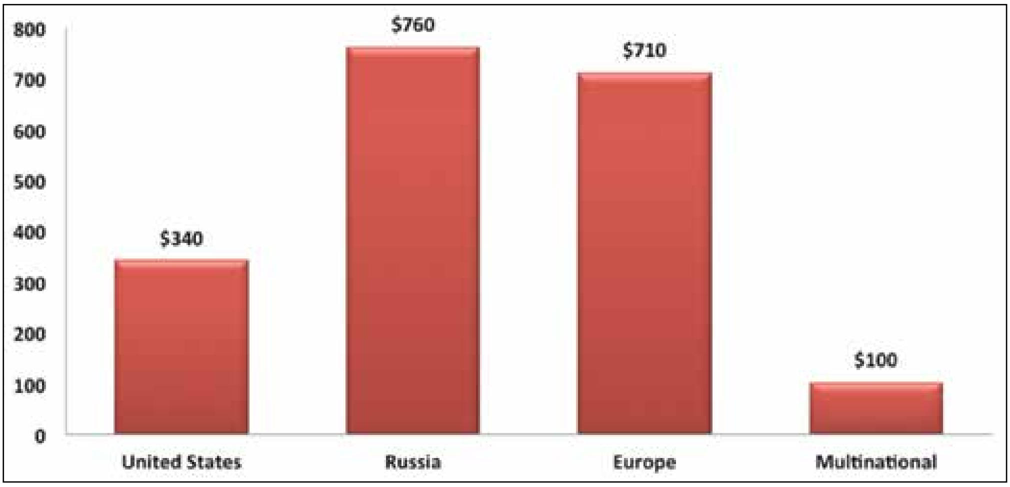
The number of commercial geosynchronous launches decreased from 15 in 2012 to 11 in 2013—the lowest number since 2007.[195] The only providers of commercial launches are Russia, the United States, Europe, and the multinational Sea Launch.[196] Revenue from 2013 commercial launches was approximately $1.9-billion, nearly half-a-billion dollars less than in 2012.[197]

According to Euroconsult,

> 115 satellites will be launched on average each year worldwide over the next 10 years (2013-2022). As several commercial and government constellations will be launched into low earth orbit (LEO) in the coming years, up to 140 satellites per year are expected between 2015 and 2017, decelerating to 100 units afterwards. Revenues from the manufacture and launch of these 1,150 satellites over the decade will be worth $236 billion, up 26 percent from those generated by the 810 satellites launched in the past ten years (2003-2012). Revenue growth between the two decades is lower than the growth in number of satellites since many small satellites are being developed, requiring shorter development time and lower launch costs…. In the commercial space sector, three-quarters of recent satellite orders will be launched to replace aged satellites in geostationary orbit (GEO).[198]

Intelsat, now a privately held satellite services company, planned an IPO in New York to pay down debt. Renamed Intelsat SA, it aspired to sell 21.7-million common shares at $21-25 a share, raising as much as $710-million.[199] The April 2013 IPO sold only 19.3-million shares at $18 per share.[200]

Figure 2.6: Approximate commercial launch revenue by country in 2013 (in US$millions)[201]



Commercial launch market

ISS Cargo Missions (Orbital Sciences and SpaceX Developments)

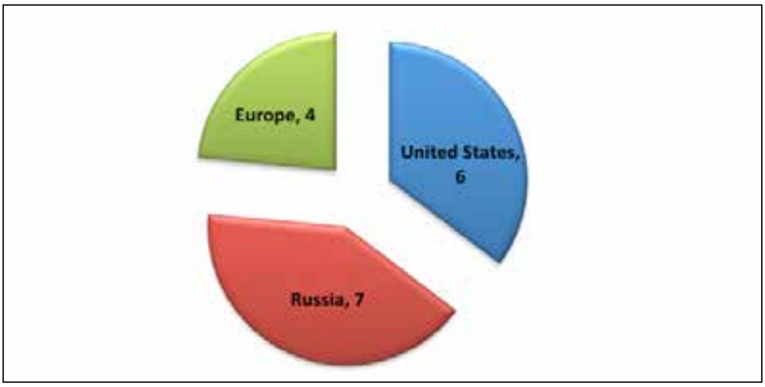
In April 2013 Virginia-based Orbital Sciences successfully launched their first Antares rocket.[202] In September Antares was launched with the unmanned Cygnus cargo ship to the ISS. Orbital Sciences joined SpaceX as the second private company delivering payloads to the ISS on behalf of the United States.[203] The Cygnus cargo ship remained at the ISS for 23 days before successfully concluding its mission. Orbital Sciences is contracted for eight operational resupply missions by the Antares/Cygnus system.[204]

SpaceX continued its cargo missions to the ISS under contract with NASA[205] and in October 2013 reached its eighth milestone under the Commercial Crew Integrated Capability (CCiCap) initiative. It was set to achieve all 15 milestones by summer 2014.[206] SpaceX tested a reusable rocket nicknamed “Grasshopper” in August; such a reusable system would significantly decrease launch costs.[207] After two delays, SpaceX successfully launched its first commercial satellite to a geostationary transfer orbit for Swiss company SES.[208]

Astrium successfully launches Ariane 5

Astrium, a division of Airbus, is the sole prime contractor and lead manufacturer for the Ariane 5 rocket, which includes a heavy-lift version, tested and successfully launched in 2013.[209] This launch vehicle, which Astrium describes as “a major element in Europe’s unrestricted, independent access to space,” has an increased geostationary transfer orbit capacity.[210] Astrium acts as the sole prime contractor to deliver “a complete, fully-tested, cost effective launcher, in line with demanding market conditions” to Arianespace. It is also the lead manufacturer, responsible for production of all stages of Ariane 5 and the single point of ESA contact for Ariane 5.[211]

Figure 2.7: Worldwide commercial launch activity in 2013[212]



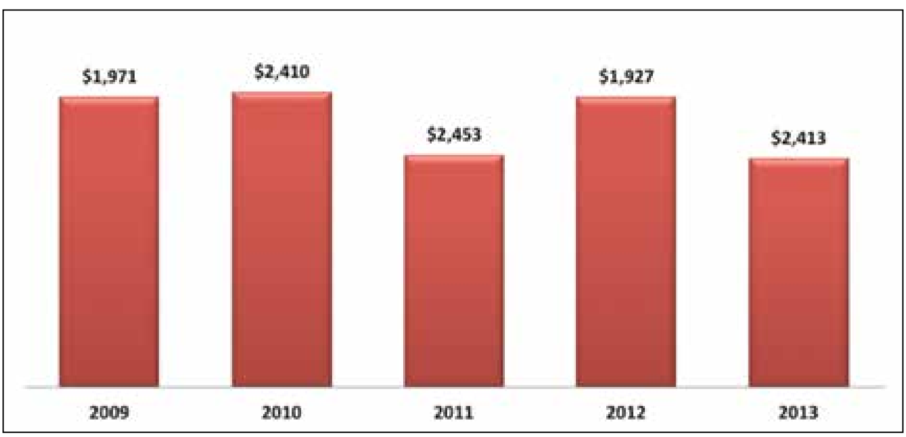
Swiss Space Systems develops suborbital small satellite deployment system

Switzerland-based company Swiss Space Systems (S3) officially launched on 13 March 2013[213] to develop small satellite launch capabilities[214] and conduct microgravity research operations. It has arranged to use Spaceport Colorado[215] and Spaceport Malaysia for launches.[216] S3 has partnered with companies such as Thales Alenia Space and Dassault Aviation to develop low-cost launch capabilities for small satellites and high-speed passenger transportation.[217]

Sierra Nevada Corporation makes progress with Dream Chaser Shuttle

Sierra Nevada Corporation successfully performed a free-flight approach-and-landing test of their Dream Chaser spacecraft.[218] By the end of 2013 Sierra Nevada had completed all milestones under NASA's Commercial Crew Development 2 phase.[219] It recently announced that the first orbital flight of the Dream Chaser will take place on 1 November 2016. Corporate vice-president Mark Sirangelo stated that "SNC is thrilled to be the first company to confirm a launch date for our country's return to orbital human spaceflight and the restart of human spaceflight operations from Florida's Space Coast."[220]

Figure 2.8: Worldwide commercial launch revenue by year. 2009-2013 (in US$millions)[221]



Space tourism

Virgin Galactic continues testing of SpaceShipTwo

Virgin Galactic continued testing of their suborbital tourist spaceship. During an April 2013 test, SpaceShipTwo was launched by WhiteKnightTwo, and achieved a speed 1.2 times the speed of sound.[222] A second supersonic test from Mojave Air and Space Port "demonstrated the vehicle's full technical mission profile in a single flight for the first time, including a high altitude deployment of the unique wing 'feathering' re-entry mechanism."[223] A third supersonic flight took place in January of 2014.[224]

Blue Origin tests oxygen and hydrogen engine

Blue Origin, based in Washington State, tested a new hydrogen- and oxygen-fueled engine capable of carrying manned spacecraft to LEO. The BE-3 engine was fired in a pattern simulating a suborbital mission, demonstrating a full-mission duty cycle. The BE-3 is part of the Reusable Booster System that is soft-landed on Earth and can be reused for subsequent missions.[225] The BE-3 has been designed for use with the New Shepard suborbital system.[226] Blue Origin has also committed to extending a Commercial Crew Development Round 2 partnership with NASA.[227]

XCOR continues development and testing of engines for Lynx vehicle

In early 2013 XCOR, which is selling suborbital flights to individuals for $95,000-100,000,[228] performed the first firing of a piston pump-powered rocket engine with a flight-weight Lynx fuselage. Pumps delivering kerosene and liquid oxygen to the engines make possible multiple daily flights and eliminate heavy high-pressure tanks.[229] Later in the year, the first successful hot fire of the XR-5H25 engine was performed. An integrated test of the engine and piston pumps was scheduled for 2014.[230] As part of its AXEApollo campaign, Unilever purchased 22 flights on the Lynx suborbital vehicle for winners of an extensive promotional campaign.[231]

Golden Spike continues planning for lunar missions

Golden Spike Company, which is planning revenue-generating expeditions to the Moon, received data from Zero Point Frontiers on feasible vehicles to support Golden Spike's mission.[232] Previously, Northrup Grumman had completed a feasibility study for a GSC lunar lander craft—a minimalist ascent pod nicknamed "Pumpkin."[233]

WVE & high-altitude balloons

World View Enterprises began planning tourism trips in a high-altitude balloon that will carry passengers 30 km above Earth, where they can see the void of space and the curvature of Earth before returning by parachute in a capsule.[234] The FAA has classified the capsule as a spacecraft for regulatory purposes[235] to accommodate WVE, as these missions fall outside the usual scope of space activities.

Spanish company zero2infinity was also marketing suborbital high-altitude balloon rides to potential space tourists.[236]

Commercial space stations

NASA has agreed to purchase an inflatable space station module from Bigelow Aerospace to attach to the ISS in mid-2015.[237] The Bigelow Expandable Activity Module (BEAM), which, when inflated, is a 13x10 foot cylinder, will be launched on a SpaceX Dragon rocket. The BEAM will be attached to the ISS for a two-year test cycle, after which it will be detached and will disintegrate on Earth reentry.[238] The BEAM precedes the Bigelow BA 330, which can serve as an independent space station or can be linked to other modules to create a larger station.[239] The planned Bigelow Alpha Station will consist of two BA 330 modules.[240]

Commercial spaceports

Sea Launch failures

Sea Launch, originally a consortium of companies from four countries, was established as a direct equatorial launch platform for geostationary satellites. After Sea Launch emerged from Chapter 11 bankruptcy in 2010, the Russian corporation Energia Overseas Limited became majority owner. Sea Launch has had three launch failures; the latest was the Intelsat 27 in early 2013--its first failure since emerging from bankruptcy.[241] The spacecraft was a total loss.[242] The 15 April 2014 launch of Eutelsat 3B was postponed due to a mechanical problem[243] and was successfully launched on 26 May 2014.[244]

Planned spaceports: A sample

Russia has planned a new space complex at the Vostochny Cosmodrome, to be used for both manned and unmanned missions, including commercial programs. The facility should be ready to launch unmanned missions in 2015 and manned missions in 2018.[245]

HDR, Inc. has been conducting feasibility studies for the new Spaceport Colorado project since 25 February 2013. These studies should pave the way for FAA licensing of the commercial spaceport.[246] Additional spaceports have been proposed for Texas (Houston,[247] Midland,[248] and Brownsville[249]), southern Georgia,[250] northern Florida,[251] and Alaska.[252]

Spaceport Sweden continues to be at the forefront of European manned commercial spaceflight, having hosted parabolic weightless flights as part of an astronaut-training program.[253] Lossiemouth airbase in Scotland has been proposed as a polar launch and space tourism launch facility.[254]

Spaceport America update

Spaceport America in New Mexico completed its twentieth vertical launch with the SL-8 suborbital sounding rocket, designed for private sector, educational, and government launches.[255] On 9 December 2013 the FAA renewed Spaceport America's Launch Site Operator license,[256] which is valid until 14 December 2018.[257]

Mid-Atlantic Regional Spaceport (MARS)

MARS, on Wallops Island, Virginia, wants to become a hub for launching activities, beginning with cargo missions to the ISS. The possibility of conducting human spaceflight operations from the Wallops Island facility is under discussion.[258]

Indicator 2.5: Public-private collaboration on space activities

Governments have played a critical role in the development of the commercial space sector. Many spacefaring states consider their space systems to be an extension of critical national infrastructure, and a growing number view their space systems as inextricably linked to national security. 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. Certain sectors, such as remote sensing or commercial launch industries, rely more heavily on government clients, while the satellite communications industry is commercially sustainable without government contracts. Due to the security concerns associated with commercial space technologies, governments still play an active role in the sector through regulation, including export controls and controls on certain applications, such as Earth imaging.

The U.S. Space Launch Cost Reduction Act of 1998 established a low-interest loan program to support the development of reusable vehicles.[259] In 2002 the USAF requested $1-billion in subsidies for development of Lockheed Martin's Atlas-5 and Boeing's Delta-4 vehicles, under the Evolved Expendable Launch Vehicle (EELV) program.[260] The 2005 Space Transportation Policy required the DoD to pay the fixed costs to support both companies (since merged into the United Launch Alliance) until the end of the decade, rather than force price-driven competition.[261] A 2006 report commissioned by the FAA indicated that a successful U.S. commercial launch industry is viewed as "beneficial to national interests."[262] Also in 2006 NASA announced the COTS program, designed to coordinate the transportation of crews and cargo to the ISS by private companies.[263] In January 2011 it was announced that NASA would increase its investment in COTS, assigning cash payouts for the achievement of specific milestones related to logistical services for the ISS.[264]

The European Guaranteed Access to Space Program adopted in 2003 requires that ESA underwrite the development costs of the Ariane-5, ensuring its competitiveness in the international launch market.[265] The program explicitly recognizes a competitive European launch industry as a strategic asset and is intended to ensure sustained government funding for launcher design and development, infrastructure maintenance, and upkeep.[266] The 2007 European Space Policy "emphasizes the vital importance for Europe to maintain an independent, reliable and cost-effective access to space at affordable conditions…bearing in mind that a critical mass of launcher activities is a precondition for the viability of this sector."[267]

In many instances governments have partnered with the private sector to subsidize the commercial development of systems also intended to meet national needs. However, partnering with the commercial sector often involves mixing national security considerations with private commercial interests. For instance, in 2008 the Canadian government intervened to block the sale of MacDonald, Dettwiler and Associates, maker of the Radarsat-2 satellite, to a U.S. firm, citing national interests.[268]

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. However, achieving that 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. Dual-use concerns have led states to develop national and international export control regimes aimed at preventing proliferation.

Exports of USML items are licensed under the International Traffic in Arms Regulations (ITAR) regime, which adds several additional reporting and licensing requirements for U.S. satellite manufacturers. One way to get around ITAR restrictions has been by purchasing ITAR-free satellites and launch services. For instance, in 2007 China was able to launch the Chinasat 6B telecommunications satellite, built by Thales Alenia Space, because the satellite was deliberately built without U.S. components.[269]

2013 Developments

United States

Space Technology Mission Directorate established

In February 2013 NASA administrator Charles Bolden announced the creation of a Space Technology Mission Directorate. Its purpose is to "develop the cross-cutting, advanced and pioneering new technologies needed for NASA's current and future missions, many of which also benefit America's aerospace industries, other government agencies, and address national needs."[270] Collaboration, with both private industry and academia, is core to the directorate's mission.[271] NASA recently selected research proposals from U.S. small businesses for space technology under the Small Business Innovation Research Program, which is managed by the new Space Technology Mission Directorate.[272]

TeleCommunication Systems' VSAT equipment

TeleCommunication Systems, Inc. was granted $3.4-million in incremental funding "for equipment, field services support and maintenance of Secure Internet Protocol Router and Non-Secure Internet Protocol Router Access Point (SNAP) Very Small Aperture Terminal (VSAT) satellite systems equipment."[273] These modular, plug-and-play SNAP solutions are to be easily transportable, rugged, and easily set up and used. They are meant to provide encrypted multimedia communication capability.[274]

The Australian Defence Science and Technology Organisation has also ordered a VSAT system from TeleCommunication Systems.[275]

NASA awards IDIQ contracts

The U.S. government can contract with private entities for space services using indefinite-delivery, indefinite-quantity (IDIQ) contracts. A contract, modified in 2013, was awarded to Jacobs Technology of New Orleans to support U.S. human spaceflight efforts, including "work on the Orion spacecraft and modifications to manufacture the core stage of NASA's Space Launch System Rocket."[276] A subsequent contract was awarded to Jacobs Technology of Tullahoma, Tennessee to support institutional and research operations, along with maintenance and engineering, at Langley Research Center.[277]

Science Applications International also received an IDIQ contract for biomedical, medical, and health services for programs at Johnson Space Center involving human spaceflight. They are slated to perform research and develop biotechnology and operational space medicine. This contract extends to the Commercial Crew and Cargo program and thus will cover interaction with private companies providing launch services for that program.[278]

In early 2013 Astrotech Corporation was awarded an IDIQ contract for commercial payload processing services. Astrotech will process data from the Soil Moisture Active Passive satellite to measure soil moisture and freeze/thaw state from space.[279]

NASA and Planetary Resources agree to crowdsource asteroid detection

A crowdsourced software solution is being developed to create an enhanced system to detect NEOs. NASA is funding the project, which will utilize public interest in space activities and more specifically, asteroid detection.[280] A contest will offer prize money to individuals who develop algorithms that more effectively identify asteroids.[281] This project will help Planetary Resources to identify prospective asteroids with high concentrations of water and precious minerals that could be mined in future.[282] Space resource extraction and development is a potential key growth area.

Orbital Sciences projects

In addition to newly developed launch capabilities, Orbital Sciences has been commissioned by NASA to design, manufacture, and integrate a new astrophysics satellite as part of the TESS (Transiting Exoplanet Survey Satellite) program,[283] as well as an Icon Space Weather Satellite.[284] Orbital Sciences launched the Landsat Data Continuity Satellite for NASA in February 2013[285] and has partnered with the Department of Defense in the design and production of the Minotaur I rocket, which will provide "responsive, reliable and low-cost launch systems for U.S. Government-sponsored spacecraft."[286] The 19 November 2013 launch was the twenty-fifth Minotaur launch since 2000.[287]

Russia

Russia increases efforts to increase share of space market

Russia is striving to increase its share of the global space market from 10% to 15%.[288] In October 2013 the Russian government "announced plans to consolidate Russia's space industry under a single state-controlled corporation that would eventually undergo an initial public offering."[289] The retirement of the U.S. shuttle fleet led to a January 2013 bill permitting the United States to pay Russia for transportation of American astronauts to and from the ISS through 2020.[290]

Russia, currently the only viable provider of human spaceflight, continues to promote space tourism aboard the ISS, selling a seat to British singer Sarah Brightman for October 2015.[291] Additionally, Swiss Space Systems is attempting to partner with Roscosmos for the cost-efficient launch of mini-satellites.[292]

Europe

European Space Agency engages in various partnership agreements

The ESA and 28 partners from the European science and technology industry are involved in a 20-million-euro 3D printing project intended to be capable of printing a satellite in a single piece, thus reducing costs by 50%.[293] The project, known as AMAZE (Additive Manufacturing Aiming towards Zero Waste and Efficient Production of High-Tech Metal Products), could also be used in other industries, including aviation.[294] ESA has also partnered with architects Foster and Partners to test the feasibility of 3D printing using lunar soil to build a lunar habitat; the basic concept has been confirmed.[295]

A long-term agreement has been signed to develop a European space-based Automatic Dependent Surveillance Broadcast (ADS-B) satellite constellation, which would monitor global air traffic control. The contracting partners, including the German Aerospace Center, Thales Alenia Space Germany, and SES TechCom S.A., will jointly develop the system, which will keep aircraft continuously visible during their global journeys. One ADS-B payload is already operational aboard the Proba-V satellite,[296] which is the first satellite to receive aircraft tracking signals to allow flight tracking from space.[297]

Germany contracted with OHB-System AG to develop and integrate SARah, a satellite-based radar reconnaissance system. SARah is the follow-up system to SAR-Lupe, also developed and built by OHB, which will operate until 2017.[298]

Astrium launched the Gaia satellite for the ESA in December 2013. Designed to operate at the L2 Lagrangian point, this space telescope will map the Milky Way galaxy in 3D.[299]

China

Beidou system opened for civilian use

In 2013 China opened its GNSS system, Beidou, for civilian use. When the system is fully deployed, Beidou access will be available from the entire planet and competitive with GPS, Galileo, and GLONASS.[300] "Beidou is the only satellite navigation system that offers telecommunication services. That means that, apart from giving users location and time information, Beidou can also send users' information to other people and communicate with users via text messages."[301] Like the United States, China is offering free civilian service to encourage users to adopt the system.[302]

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. This includes early warning; communications; intelligence, surveillance, and reconnaissance; meteorology; as well as navigation and weapons guidance applications. Although the United States accounts for the vast majority of global spending on space-based military applications, expenditures on military space programs are gradually increasing around the world.

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 the Earth to provide 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 means for arms control verification. The space age broke new ground in the development of reconnaissance, surveillance, and intelligence collection capabilities through the use of satellite imagery and space-based electronic intelligence collection. In addition, satellite communications provided extraordinary new capabilities for real-time command and control of military forces deployed throughout 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. The development of radar satellites offered the potential to detect opposition forces on the ground in all weather conditions at all times.

The United States currently leads in deployment of dedicated space systems to support military operations, accounting for roughly half of all dedicated military satellites.[303] Russia maintains the second largest number, with roughly a quarter of the total. Together, these two nations dominate all other military space actors, although several countries are pursuing space-based military capabilities. The United States and USSR/Russia have launched more than 3,000 military satellites, while all other states combined have launched fewer than 100.

In 1964 the first navigation system was deployed for military applications by the U.S. Navy. Its position resolution was accurate to 100 m. This system and others that followed were ultimately replaced by GPS, which was declared operational in 1993 and uses a minimum constellation of 24 satellites orbiting at an altitude of approximately 20,000 km. On the battlefield GPS is used for a variety of functions, from navigation of terrestrial equipment and individual soldiers to target identification and precision weapons guidance. GPS also has important civil and commercial uses. Although commercially available, the GPS system provides its military users with a higher degree of accuracy.

Russia maintains the second largest fleet of dedicated military satellites.[304] Its early warning, imaging intelligence, communications, and navigation systems were developed during the Cold War and by 2003 from 70-80% of these spacecraft had exceeded their designed lifespan.[305] Forced to prioritize upgrades, Russia focused first on its early warning systems and continues to move to complete the GLONASS navigation system, which was declared fully operational in 2011.[306] Since 2004 Russia has focused on "maintaining and protecting" its fleet of satellites and developing satellites with post-Soviet technology.[307] In 2006, the first year of a 10-year federal space program, Russia increased its military space budget by as much as one-third, following a decade of severe budget cutbacks.[308]

China operates the Beidou regional navigation system, four satellites in GEO designed to augment the data received from the U.S. GPS system and enable China to maintain navigational capability if the United States were to deny GPS services in times of conflict.[309] Beidou may also improve the accuracy of China's intercontinental ballistic missiles (ICBMs) and cruise missiles.[310] China launched the first Compass-M1 test satellite into MEO in 2007.[311] The country has been working to upgrade Beidou to a global satellite navigation system. The Beidou-2 or Compass system, expanding on the initial system to include five satellites in GEO and 30 in MEO, is expected to provide global coverage by 2020.[312]

India has one of the oldest and largest space programs in the world, with a range of indigenous dual-use capabilities. Space launch has been the driving force behind ISRO. It successfully launched its Satellite Launch Vehicle to LEO in 1980, followed by the Augmented Satellite Launch Vehicle in 1994, the Polar Satellite Launch Vehicle in 1994, and the Geostationary Satellite Launch Vehicle in 2004. The Cartosat-series remote sensing satellites are generally considered to be dual-use in nature, although organizations such as the Union of Concerned Scientists have classified the primary users of Cartosat-2A as military.[313]

States such as Australia, Canada, France, Germany, Japan, Israel, Italy, and Spain have also been developing multiuse satellites with a wider range of functions applicable to the military. 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.

The military space sector is an important driver behind the advancement of capabilities to access and use space. It has played a key role in bringing down the cost of space access; many of today's common space applications, such as satellite-based navigation, were first developed for military use. The increased use of space has also led to greater competition for scarce space resources such as orbital slots and, in particular, radio frequency spectrum allocations. While disputes over scarce resources also affect the civil and commercial space sectors, they become more acute in the military sector, as they are associated with national security.

Space assets play an important strategic role in the terrestrial military operations of certain states. Space systems have augmented the military capabilities of several states by enhancing battlefield awareness, including precise navigation and targeting support, early warning of missile launch, and real-time communications. Remote sensing satellites have served as a national technical means 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.

Space capabilities and space-derived information are integrated into the day-to-day military planning of major spacefaring states. This can have a positive effect on space security by increasing the collective vested interest in space security, as a result of heightened mutual vulnerabilities. Conversely, the use of space to support terrestrial military operations can be detrimental to space security if adversaries, viewing space as a new source of military threat or as critical military infrastructure, develop space system negation capabilities to neutralize the advantages of those systems, potentially triggering an arms race in outer space.

Because the space systems that support military operations are seen as vulnerable, actors have a greater incentive to protect them by developing space system protection and negation capabilities, which could potentially lead to an escalation of arms. Moreover, many of the space systems used for military purposes today are integrated with civilian and commercial uses, thus raising the potential of extensive collateral damage if they are targeted during warfare.

Concern has been expressed that extensive use of space in support of terrestrial military operations blurs the notion of "peaceful purposes" as 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.

2013 Developments

Major spacefaring nations

The United States updates existing systems and pushes new technologies

The United States completed 17 successful launches in 2013 with no failures.[314] The record-breaking Minotaur 1 launch on 19 November carried 29 satellites.[315] During the year 25 military space systems were deployed: five communications satellites, two surveillance satellites, one remote sensing satellite, one navigation satellite (the only non-dedicated military system this year), one early warning satellite, and 15 technology demonstration satellites.[316]

Intelligence, surveillance, and reconnaissance

The United States launched two surveillance satellites, one remote sensing satellite, and one early warning satellite in 2013. On 19 March the USAF launched SBIRS GEO 2, an early warning satellite, on an Atlas V rocket from Cape Canaveral, Florida.[317] NROL 65, a surveillance satellite, was launched by the National Reconnaissance Office (NRO) on 28 August atop Delta IV Heavy from Vandenberg Air Force Base; STARE-B, a remote sensing satellite, was launched on an Atlas V rocket on 19 November; NROL 39, another surveillance satellite and part of the Future Imagery Architecture, was launched on an Atlas V on 5 December.[318]

On 11 December 2012 the first USAF unmanned X-37B spaceplane launched for a second time on a classified mission, OTV-3, achieving its reusability milestone.[319] This flight broke the previous record of 470 days; it was still in orbit on 1 April 2014.[320]

In April the United States signed its first advanced SSA sharing memorandum with another nation, Australia.[321]

Figure 2.9: U.S. dedicated military satellites launched in 2013

Satellite	Operator	Function	Orbit	Launch Date
SNaP-3-1	US Southern Command	Communications	LEO	12/6/2013
SMDC-ONE 2.4	US Army Space and Missile Defense Command	Technology Development	LEO	12/6/2013
SMDC-ONE 2.3	US Army Space and Missile Defense Command	Technology Development	LEO	12/6/2013
ALICE	US Air Force Institute of Technology	Technology Development	LEO	12/6/2013
NROL 39	NRO	Reconnaissance	LEO	12/5/2013
Prometheus 4B	Los Alamos National Laboratory	Technology Development	LEO	11/19/2013
Prometheus 4A	Los Alamos National Laboratory	Technology Development	LEO	11/19/2013
Prometheus 3B	Los Alamos National Laboratory	Technology Development	LEO	11/19/2013
Prometheus 3A	Los Alamos National Laboratory	Technology Development	LEO	11/19/2013
Prometheus 2B	Los Alamos National Laboratory	Technology Development	LEO	11/19/2013
Prometheus 2A	Los Alamos National Laboratory	Technology Development	LEO	11/19/2013
Prometheus 1B	Los Alamos National Laboratory	Technology Development	LEO	11/19/2013
Prometheus 1A	Los Alamos National Laboratory	Technology Development	LEO	11/19/2013
STARE-B	NRO	Remote Sensing	LEO	11/19/2013
STPSat-3	US Air Force	Technology Development	LEO	11/19/2013
ORSES	US Army	Technology Development	LEO	11/19/2013
ORS - Tech 2	US Army	Technology Development	LEO	11/19/2013
ORS - Tech 1	US Army	Technology Development	LEO	11/19/2013
AEHF-3	US Air Force	Communications	GEO	9/18/2013
NROL 65	NRO	Reconnaissance	LEO	8/28/2013
WGS-6	US Air Force	Communications	GEO	8/8/2013
MUOS-2	DoD/US Navy	Communications	GEO	7/19/2013
WGS-5	US Air Force	Communications	GEO	5/25/2013
SBIRS GEO 2	US Air Force	Early Warning	GEO	3/19/2013

Weather

The USAF continues to tackle the looming 2015 satellite weather gap. In March it signed a 12-month contract with Millennium Space Systems as part of the Weather Satellite Follow-On Activities project to identify short-term solutions.[322] The expected gap in satellite coverage will affect polar orbits and the United States government continues to push programs despite budgetary constraints.[323]

Satellite communications

The United States launched five communications satellites in 2013. On 25 May the USAF WGS-5—the fifth satellite of the Wideband Global Satellite Communications (WGS) system—was launched aboard a United Launch Alliance Delta IV rocket from Cape Canaveral.[324] According to Luke Schaub, chief of the Wideband SATCOM division of the MILSATCOM Systems directorate at the Space and Missile Systems Center in Los Angeles, "WGS 5 will provide three new capabilities that expand the constellation—increase in capacity to the U.S. and six international partners, expanded coverage leading us to near-worldwide coverage at this point and, with operational acceptance of WGS 5, we will be able to achieve full operational capability of the system."[325]

On 7 August WGS-6 was launched, also aboard a United Launch Alliance Delta IV rocket.[326] WGS-6 was the final element of Block II of the WGS system, which includes WGS-4 and WGS-5.[327] Block II satellites are fitted with RF Bypass equipment, allowing higher bandwidth signals to support Unmanned Aerial Vehicle operations.[328] They are otherwise identical to Block I satellites. Funding for the WGS-6 satellite and infrastructure expansion was provided by the Government of Australia in exchange for access to the system;[329] other countries, including Canada, Denmark, Luxembourg, the Netherlands, and New Zealand have jointly provided funding for the WGS-9 satellite, which has yet to be launched.[330]

On 19 July the joint DoD/U.S. Navy Mobile User Objective System MUOS-2 satellite was launched on an Atlas V rocket from Cape Canaveral.[331] The MUOS system—which is to be made up of five satellites, at an estimated cost of $6-billion—is expected to provide global satellite communications narrowband connectivity for communications use by the United States. On 18 September the USAF AEHF-3 was launched from Cape Canaveral on an Atlas V rocket.[332] The satellite is the third in a series of six highly secure communications satellites being built by Lockheed Martin Space Systems.[333] When fully deployed, the AEHF constellation will consist of four satellites in geostationary orbit and secure communications payloads hosted aboard classified satellites in polar orbit.[334] SNaP-3-1, operated by U.S. Southern Command, was launched on 6 December atop an Atlas V from Vandenberg Air Force Base.[335]

Navigation/GPS

On 5 May 2013 an Atlas V deployed the fourth USAF Block 2F interim navigation satellite for GPS.[336] The $121.3-million spacecraft, operational 21 June, replaced the GPS 2A-25 satellite in Plane C, Slot 2.[337] The current GPS constellation comprises nine Block 2A spacecraft built by Boeing, 12 Block 2R satellites built by Lockheed Martin, seven modernized 2R spacecraft built by Lockheed Martin, and four Block 2F satellites built by Boeing.[338] A total of 12 interim satellites are planned to replace aging elements of the system, some of which will remain in their respective planes as backups.[339] The oldest operational satellite is 23 years old.[340]

Launch

The USAF is encouraging diversification in its launch vehicles. A December 2013 modification of a contract with United Launch Alliance (ULA), the sole USAF launch provider from 2006-2013, committed the USAF to the purchase of 35 rocket cores from ULA and allowed as many as 14 to be awarded competitively. The contract also applies to all activities previously funded. In addition, DoD continues to develop criteria for contract awards.[341] The most recent cost estimate projects the EELV (Evolved Expendable Launch Vehicle) program will cost $70-billion through 2030.[342]

The largest benefactor of the change is likely to be relatively new Space Exploration Technologies (SpaceX), which spearheaded efforts to reform the contract process. The aforementioned reform and agreements with the USAF indicate that these efforts met with considerable success.[343] The need to diversify has heightened with the 2014 crisis in Ukraine, which has put ULA's RD-180 engine production line at risk; this risk was identified in 2013.[344]

Russia

Russia completed 31 successful launches in 2013 with one failure.[345] Ten military space systems were deployed in 2013: seven communications satellites, two surveillance satellites, and one navigation satellite (the only non-dedicated military system this year).[346]

Navigation/GLONASS

Russia successfully launched its GLONASS-M satellite (GLONASS 747) on 26 May aboard a Soyuz 2. On 2 July a Proton-M rocket carrying three GLONASS satellites swerved and crashed to the ground. The rocket carried the first DM-03 booster used since a similar incident in 2010. No casualties were reported.[347]

In 2013 concern was expressed over the placement of GLONASS monitoring stations on U.S. territory.[348] Many in defense circles considered it a possible breach of U.S. sovereignty, which gave Russia too much access to the continental United States. Others noted that there are many GPS monitoring stations in Russia, which would be difficult to relocate. Ultimately the United States barred placement of the stations within its territory and Russia was forced to look elsewhere at the last minute. Countries, including Cuba and Brazil (where the first station outside Russia opened in February 2013), were eager to offer assistance.[349]

Figure 2.10: Russian dedicated military satellites launched in 2013

Satellite	Operator	Function	Orbit	Launch Date
Rodnik (Cosmos 2490)	Russian Ministry of Defense	Communications	LEO	12/25/2013
Rodnik (Cosmos 2489)	Russian Ministry of Defense	Communications	LEO	12/25/2013
Rodnik (Cosmos 2488)	Russian Ministry of Defense	Communications	LEO	12/25/2013
Raduga-1-M3	Russian Ministry of Defense	Communications	GEO	11/11/2013
Kondor	Russian Ministry of Defense	Reconnaissance	LEO	6/27/2013
Persona-2	Russian Ministry of Defense	Reconnaissance	LEO	6/7/2013
Rodnik (Cosmos 2484)	Russian Ministry of Defense	Communications	LEO	1/15/2013
Rodnik (Cosmos 2483)	Russian Ministry of Defense	Communications	LEO	1/15/2013
Rodnik (Cosmos 2482)	Russian Ministry of Defense	Communications	LEO	1/15/2013

Communications

Russia launched two Rokot vehicles in 2013, each carrying three satellites to form part of the Rodnik constellation: Cosmos 2482, 2483, 2484 on 15 January and Cosmos 2488, 2489, 2450 on 25 December.[350] These satellites provide communications to armed forces in remote areas.[351]

On 11 November Russia launched the Raduga-1-M3 communications satellite atop a Proton M. This is the third satellite in the updated Raduga-1-M constellation, which features multi-transponder transmission across multiple bands, ensuring communications with mobile and remote receivers.[352] The system is largely classified.

Intelligence, surveillance, and reconnaissance

On 7 June Russia launched the Persona-2 optical reconnaissance satellite with a Soyuz 2.1b. The first Persona reportedly failed after launch in July 2008.[353]

On 27 June Russia launched the Kondor reconnaissance satellite, its first radar imaging satellite, with a Strela. It marks the attempt to cut costs through large reductions in mass. Originally proposed before the collapse of the Soviet Union, funding only became available recently.[354]

Launch

Following the failure of the Proton rocket in July, Russia began a massive reorganization of its space program. Its space sector will be consolidated into an open stock company, United Rocket and Space Corporation, similar to the system used in airline, rail, and energy sectors. The Russian government says that the move will preserve and enhance Roscosmos, which will submit a proposal to the government on how to accomplish the change.[355]

China

China completed 14 successful launches in 2013 with one failure.[356] Eight dedicated military space systems were deployed in 2013: five remote sensing satellites and three technology development satellite.[357]

Figure 2.11: Chinese dedicated military satellites launched in 2013

Satellite	Operator	Function	Orbit	Launch Date
Yaogan 19	People's Liberation Army	Remote Sensing	LEO	11/20/2013
Yaogan 18	People's Liberation Army	Remote Sensing	LEO	10/29/2013
Yaogan 17C	People's Liberation Army	Remote Sensing	LEO	9/1/2013
Yaogan 17B	People's Liberation Army	Remote Sensing	LEO	9/1/2013
Yaogan 17A	People's Liberation Army	Remote Sensing	LEO	9/1/2013
Shiyan 7	Chinese Academy of Space Technology	Technology Development	LEO	7/19/2013
Chuangxin 3	Chinese Academy of Space Technology	Technology Development	LEO	7/19/2013
Shijian 15	Chinese Academy of Space Technology	Technology Development	LEO	7/19/2013

Intelligence, surveillance, and reconnaissance

China's Yaogan constellation fulfills multiple remote sensing missions. On 1 September Yaogan 17A, 17B, and 17C were launched atop a single Long March 4C. Yaogan 17, with Yaogan 9 and 16, provide broad ocean surveillance. Yaogan 18 was launched aboard a Long March 2C on October 29. Yaogan 18 and Yaogan 10, 13, and 14 carry small aperture radar for weather and imaging data collection. Yaogan 19 was launched on a Long March 4C on 20 November. Yaogan 19 and Yaogan 15 are optical imaging satellites.[358]

China bolsters ASAT capabilities

On 19 July 2013 China launched three experimental spacecraft atop a Long March 4C. The tracking of these spacecraft indicates that the launch was likely a demonstration of more advanced anti-satellite capabilities that would be guided on-orbit, rather than a test of kinetic kill vehicles (common in the past).[359] The maturity of China's ASAT program was shown in the March launch of its first test above 10,000 km, although nothing was placed in orbit.[360]

A 13 May launch is unofficially considered a test of a new direct ascent ASAT system evolved from terrestrially mobile launch systems.[361] The last launch publically acknowledged to have military dimensions was in January 2013;[362] it was described as a mid-course ballistic missile defense test.

Other spacefaring nations

India

On 29 August India launched its GSAT-7 communications satellite from Guiana Space Center on an Ariane 5 ECA rocket. The satellite is operated in GEO by the Indian National Satellite System. Designed for exclusive use by the Indian Navy, it is the first satellite custom-built by India for military communications.[363]

Israel

On 31 August Israel launched its Amos 4 dual commercial and military communications satellite into GEO from the Baikonour Cosmodrome atop a Zenit 2SB. Amos 4 provides broadband Internet, direct-to-home television, and other services in Asia, as well as military communications to Israel.[364]

Canada

On 25 February Canada's Sapphire space observation satellite was launched into LEO by an Indian Polar Satellite Launch Vehicle from Satish Dhawan Space Centre.[365] The Sapphire satellite, which began operations in January 2014, will serve as a contributing element of the U.S. Space Surveillance Network. It uses an electro-optical sensor to track space objects in high Earth orbits and is operated by the Canadian Department of National Defence.[366] See Indicator 1.3.

Security of space systems

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

Satellite ground stations and communications links are 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. Still, satellite communications can usually be restored and ground stations rebuilt for a fraction of what it costs to replace a satellite.

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. General Accounting Office recommended that "commercial satellites be identified as critical infrastructure."[1] In the event of an attack the use of standardized protocols and communications equipment could allow alternative commercial ground stations to be brought online. To be sure, most if not all space actors are capable of providing effective physical protection for their satellite ground stations within the general boundaries of their relative military capabilities.

Satellite communication links require specific electronic measures to safeguard their utility. 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, are also able to 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] Sophisticated electronic protection measures were traditionally unique to the military communications systems of technologically advanced states, but they are slowly being expanded to commercial satellites.

The United States and other countries, including Germany and France, have reportedly been developing laser-based communications systems, which could provide a degree of immunity from conventional jamming techniques in addition to more rapid communications; however, these developments involve significant technological challenges.[3] The United States has also established a Cyber Command (USCYBERCOM) to be responsible for the military's Internet and other computer networks, which reached Full Operational Capability in 2010.[4]

2013 Developments

DoD continues developing the AEHF satellite system while the Netherlands and Canada become the first international partners for testing it

In July 2013 the Netherlands and Canada, international partners of the U.S. military in the Advanced Extremely High Frequency (AEHF) program, participated in the first international testing of the AEHF system, which is to replace the existing Milstar satellite system. The AEHF, which is to expand protected MILSATCOM capabilities, is expected to "increase user data rates five-fold, permitting transmission of tactical military communications, such as real-time video, battlefield maps and targeting data."[5]

During the July tests the three nations used the system simultaneously for the first time, as the Netherlands connected to U.S., Canadian, and domestic terminals. This was the second international test; a test call using the AEHF-1 satellite and SMART-T terminal took place in June.

Raytheon continues to develop fielded AEHF satellite terminals to the U.S. Air Force, Navy, and Army. In December 2013 Raytheon was selected to construct a terminal for the USAF that "transmits emergency messages to aircrews during nuclear and non-nuclear missions.… The terminals will be installed at fixed sites, including wing command posts, nuclear task forces and munitions support squadrons, and forward deployed mobile support teams."[6]

Fielding is scheduled for FY 2017. The terminals have already demonstrated interoperable communications with the newest AEHF satellite's Extended Data Rate (XDR) waveform that moves data five times faster than the existing satellite systems. "Raytheon terminals currently support military operations on older Milstar satellites, and are deployed and ready to operate with the newest AEHF satellites as soon as they are declared operational."[7]

Lockheed Martin completes on-orbit check of MUOS-2, improving secure communications for U.S. Navy

On 2 December 2013 the second MUOS satellite and three MUOS ground stations were handed over to the U.S. Navy after Lockheed Martin completed on-orbit testing. The ground stations will relay voice and high-speed data signals for mobile users worldwide.[8] "We completed our baseline on-orbit testing in half the time compared to MUOS-1," noted Iris Bombelyn, vice president of Narrowband Communications at Lockheed Martin.[9] The formal government commissioning was scheduled for 2014. Before that, the Naval Satellite Operations Center will test and evaluate the equipment.

The MUOS constellation is to achieve full operational capability in 2015, extending narrowband availability past 2025.

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 capabilities to refit space systems by launching new satellites into orbit in a timely manner to replace satellites damaged or destroyed by a potential attack are critical resilience measures.

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.[10] A significant number of Russia's current launches, however, are of other nations' satellites and Russia has struggled to maintain existing military systems in operational condition.

The United States has undertaken significant efforts to develop responsive space capabilities. 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.[11] ORS has three main objectives:

1) Rapid Design, Build, Test with a launch-ready spacecraft within 15 months from authority to proceed;
2) Responsive Launch, Checkout, Operations to include launch within one week of a call-up from a stored state; and
3) Militarily Significant Capability to include obtaining images with tactically significant resolution provided directly to the theater.

New launch capabilities form the cornerstone of this program. Initial steps included a Small Launch Vehicle (SLV) subprogram for a rocket capable of placing 100 to 1,000 kg into LEO on 24-hours notice.[12] Under this program AirLaunch LLC was asked to develop the QuickReach air-launch rocket and SpaceX to develop the Falcon-1 reusable launch vehicle to fulfill the SLV requirements.[13] In September 2008 Falcon-1 reached orbit on its fourth attempt.[14]

The USAF TacSat microsatellite series was also intended for ORS demonstration, combining existing military and commercial technologies such as imaging and communications with new commercial launch systems to provide "more rapid and less expensive access to space."[15] A full ORS capability could allow the United States to replace satellites on short notice, enabling rapid recovery from space negation attacks and reducing general space systems vulnerabilities.

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.[16] The first technology demonstrators built were the X-40 (USAF) and the X-37A (NASA/DARPA).[17] A successor to the X-37A, the X-37B unmanned, reusable spacecraft was launched for the first time in April 2010 under significant secrecy. India is reportedly working on a Reusable Launch Vehicle, which is not anticipated before 2015.[18] The commercial space industry is contributing to responsive launch technology development through advancements with small launch vehicles, such as the Falcon-1 by SpaceX and its successors.

2013 Developments

Satellite servicing

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

The NASA Robotic Refueling Mission (RRM) and the Canadian Space Agency continued working 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.[19] The U.S. RRM mission was launched to the ISS in July 2011.

Since the 2011 launch, the CSA's Special Purpose Dexterous Manipulator (SPDM or Dextre) and the RRM have conducted a number of tests and experiments: Launch Rock Removal and Vision Task in September 2011 and Gas Fittings Removal Task in March and June 2012. On 26 January 2013 Dextre and the RRM successfully terminated the six-day actual demonstration of refueling in a space environment aboard the ISS.

With the August 2013 launch of new hardware to the ISS aboard the Japanese H-II Transfer Vehicle 4, the RRM entered Phase 2, which goes beyond satellite refueling. Phase 2 is 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."[20] Additional hardware for Phase 2 was scheduled to be launched in early 2014, with RRM Phase 2 operations scheduled to begin that year. The work with Dextre continues in 2014.

Distributed architectures

NovaWurks awarded contract for DARPA Phoenix project

Phoenix is "an ambitious effort to recycle parts from dead satellites now in orbit." According to DARPA, other goals of the Phoenix project are to "demonstrate a new concept in satellite design and manufacturing where the concepts of 'cellularization' and 'morphological reconstruction' are applied to a new satellite construct named a 'Satlet;'" and to "demonstrate the ability to launch and dispense on-orbit small mass systems at a high tempo via commercial satellite hosted ride-alongs using a new construct named a payload orbital delivery system or PODs."[21]

NovaWurks of Los Alamitos, California was awarded a contract worth up to $ 42.6-million for work on Phoenix Phase 2, after contributing to the first phase. Phase 2 is expected to take 26 months; it is intended that by that point "all hardware components achieve at a minimum critical design level maturity and all flight hardware assembled, qualified and integrated into the Servicer/Tender prior to environmental test and ready for launch."[22] In the last phase (6-12 months), the system will be tested in orbit.

Development of small satellites and microsatellite systems contributes to redundancy and resiliency of space systems

On 19 November 2013 the Minotaur I rocket, sponsored by the NASA Educational Launch of Nanosatellites program, lifted 28 cube satellites from Wallops Flight Facility in Virginia. This payload included the first satellite designed by high school students, a PhoneSat 2.4, a second-generation smartphone mission,[23] as well as two experimental cube satellites designed by Johns Hopkins University Applied Physics laboratory. These satellites "represent a new capability for the military and intelligence and science community—a small satellite that can get to space inexpensively and be tough enough for long-term use."[24]

According to Seth Bowden and David Williamson from the National Reconnaissance Office, "The NRO, Air Force, and NASA have made significant investments into CubeSat activities" since 2007, when it was determined that "CubeSats were mature enough to provide utility for government applications." A newly established CubeSat Program Office "actively engaged government partners, universities, service academies, laboratories, and industry, to advance the state of practice."[25]

On 8 December 2013 an Atlas V rocket lifted the U.S. Southern Command-sponsored nanosatellite developed by NASA Jet Propulsion Lab. Juan Hurtado, the U.S. Southern Command science and technology advisor, said that this new equipment is "about ready to offer a transformational capability to support troops in the field, not just within Southern Command, but throughout the Department of Defense."[26] If the initial demonstration phase is successful, the two additional nanosatellites will be launched in December 2014.

A new family of small satellites within Boeing's Phantom Phoenix program is "designed to conduct intelligence surveillance and reconnaissance operations as well as science and weather missions."[27] "The Phantom Phoenix satellite prototypes are available in three configurations including a 500 to 1,000 kg Phantom Phoenix satellite, a 180 kg ESPA-class, and a 4 to 10 kg nanosatellite. Up to six small satellites could be deployed during a single mission, reducing launch costs."[28] The satellites are designed for all major launch vehicles.

In May 2013 specialists from the company SPUTNIX assembled and tested the onboard control system equipment based on Space Plug-and-Play Architecture specifications. Within the onboard control system SPUTNIX developed their own set of architecture specifications (SxPA); main objectives: "to quickly aggregate and configure microsatellite subsystems with the use of Plug-and-Play principle" and "to plug the device in the system without its preliminary preparation and without preparing the onboard control system."[29]

Disaggregation is becoming more common as a viable way to improve resiliency. In the White Paper by the Air Force Space Command disaggregated space architectures are described as a "strategy to improve resiliency, offering a means to trade cost, schedule, performance, and risk to increase flexibility and capability survivability." "Carefully pursued, disaggregation can lead to less costly and more resilient space architectures in the face of a rapidly evolving security environment."[30]

DARPA cancels formation-flying satellite demo

DARPA terminated the Future, Fast, Flexible, Fractionated Free-flying Spacecraft United (F6) by Information Exchange. The notional launch date for the system had been 2015.

The program was intended to "demonstrate and explore the benefits of dispersing the functions of a single satellite across smaller platforms"[31] when satellites exchange data in space. Development of the program was spread among a number of universities and companies. According to Brad Tousley, the director of DARPA's Tactical Technology Office, software development delays and contractor performance issues were among the program's problems.[32] DARPA invested approximately $200-million in this mission.

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 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).[33] Kinetic hit-to-kill technology 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.[34]

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 was later granted funding by Congress from FY1996 through FY2005.[35] For FY2005 Congress appropriated $14-million for the KE-ASAT program through the MDA Ballistic Missile Defense Products budget.[36] The KE-ASAT program was part of the Army Counterspace Technology testbed at Redstone Arsenal.[37]

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.[38] EKVs use infrared sensors to detect ballistic missiles in midcourse and maneuver into the trajectory of the missile to ensure a hit to kill.[39] With limited modification, the EKV may be used against satellites in LEO.[40] 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.[41]

Notably, 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 be used against a satellite, the United States has stressed that it was a "one-time event,"[42] not part of an ASAT development and testing program.

Russia developed an anti-satellite system called the Co-Orbital ASAT system, designed to launch conventional explosives into orbit near a target satellite via a missile, which maneuvers toward the satellite, then dives at it and explodes.[43] Russia has continued to observe a voluntary moratorium on anti-satellite tests since its last test in 1982. Russia also developed a long-range (350-km) exoatmospheric missile, the Gorgon, for its A-135 anti-ballistic missile system.[44]

China has developed an advanced kinetic anti-satellite 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-fuelled ballistic missile, possibly the DF-21.[45] However, China called the event an experiment, not an anti-satellite test.[46] The UK, Israel, and India have also explored techniques for exoatmospheric interceptors.[47]

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.[48] Given the current global dependence on satellites, such an attack could have a devastating and wide-ranging impact on society. 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.[49]

Low-powered lasers have been used to "dazzle" or degrade unhardened sensors on satellites in LEO.[50] In 1997 a 30-watt laser used for alignment and tracking of a target satellite for the megawatt U.S. Mid-Infrared Advanced Chemical Laser (MIRACL) was directed at a satellite in a 420-km orbit, damaging the satellite's sensors.[51] This suggests that even a commercially available low-watt laser functioning from the ground could be used to "dazzle" or temporarily disrupt a satellite.[52] In addition, ground-based lasers, adaptive optics, and tracking systems 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 enables 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 countries such as Canada, China, Japan, the United States, Russia, and India.[53]

The Boeing YAL-1 Airborne Laser Test Bed (ALTB) system—formerly known as Airborne Laser—of the USAF is central to plans for Boost Phase Ballistic Missile Defense.[54] This technology is believed by some experts to have potential ASAT capabilities, despite the significant technical and cost challenges it has faced.[55] The program was initiated in 1996 and took 12 years to reach first light, at a cost of $5-billion.[56] The first ballistic missile interception was planned for late 2009[57] and finally occurred in February 2010 when the ALTB system successfully shot down a test ballistic missile.[58]

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

2013 Developments

Missile development continues in some nations

On 13 May China conducted a test of its Dong Ning-2 (DN-2) missile. The Chinese government claims that it was a space exploration experiment. The state-run Xinhua news service reported that "the experiment was designed to investigate energetic particles and magnetic fields in the ionized stratum and near-Earth space." Some observers, however, saw it as potential ASAT testing. According to Brian Weeden, technical adviser at Secure World Foundation, "while there is no conclusive proof, the available evidence strongly suggests that China's May 2013 launch was the test of the rocket component of a new direct ascent ASAT weapons system derived from a road-mobile ballistic missile."[59]

The test displayed a capability by the Chinese military to perform specific maneuvers that could be employed against satellites. Potentially a high Earth-orbit attack missile, the DN-2 is reportedly able to hit targets between 12,000 and 22,236 miles above Earth, where many valuable satellites orbit.[60]

In January 2013 Boeing's Ground-based Midcourse Defense program performed a successful non-intercept flight test that used an upgraded version of Raytheon's Exoatmospheric Kill Vehicle (EKV). The EKV maneuvered the interceptor to the required altitude and velocity.[61]

At the 5 July trial of the Ground-based Midcourse Defense system, the Ground-based Interceptor failed to intercept its target, apparently due to an unsuccessful separation.[62]

Raytheon's SM-3 Block IB passed successful intercept tests in May, September, and October, while the SM-3 Block IA passed tests in February and September. Block IIA completed a critical design review in October; the program then moved into the build phase. Block IB is on track to be delivered in 2015 and Block IIA is scheduled to begin flight testing in 2015.[63]

India is planning to extend the range of its ballistic missile defense system. The first test of the system's Prithvi Defence Vehicle (PDV) interceptor was successfully conducted on 27 April 2014.[64] The interceptor can engage targets in the exo-atmosphere region at more than 120 km altitude within a range of 2,500 km. "In an automated operation, radar based detection and tracking system detected and tracked the enemy's ballistic missile," said a statement by India's Defence Research and Development Organisation (DRDO). The test fire has been hailed as a "significant milestone" achieved in the direction of developing a two-layered Ballistic Missile Defence (BMD) system.[65]

Russia considers potential space-based countermeasures to U.S. missile defense shield

In May Russian Deputy Defense Minister Anatoly Antonov said that, if NATO and the United States proceeded with the European anti-ballistic missile (ABM) shield without Russia as an equal partner, Russia would ready "military-technical measures" to hamper the shield's ability to function. Russia has been adamantly opposed to the unilateral shield, claiming that it threatens Russian security and is an obstacle to bilateral relations.[66]

In August Moscow claimed that talks with the United States showed no sign of progress and that they remained far apart on ABM and other means of nuclear arms control. He acknowledged guarantees offered by the United States at an August 5 meeting with U.S. officials, but indicated that they were insufficient.[67]

In November President Putin announced the cancellation of a 2011 presidential order by which an interdepartmental working group was convened to develop ways to establish cooperation with NATO on missile defense.[68] In December Russia announced that it had moved its nuclear-capable Iskander missiles closer to borders with Europe in response to the proposed missile defense shield.[69] This action was met with alarm by the United States, Poland, and the Baltic states.[70]

Jamming incidents continue

Thaicom, Thailand's satellite television provider, experienced jamming on several satellites by anti-government protestors. Pro-government Bluesky TV was severely affected. Thaicom claimed that the interference, intermittent in November and December, was created by a mobile upload unit.[71]

Al Jazeera, a Qatar-based network, claimed that its satellites were being jammed by Egyptian authorities following the military takeover on 3 July. Independent experts identified several locations around Cairo, each within 1.6 km of a military installation, as the most likely sources of the jamming.[72]

Boeing claims to have applied anti-jamming technology to existing satellites, demonstrating the ability to send protected data through satellites that do not already have anti-jamming technology. In December Boeing transmitted a government-developed, protected signal through a Wideband Global SATCOM satellite. This will provide a cheaper option for protecting communications on existing satellites.[73]

The Arab States Broadcasting Union (ASBU), in collaboration with Arabsat, held an international symposium on satellite interference and jamming on 6-7 October. The director of ASBU claimed that satellite interference and jamming had "worsened recently on a global scale, particularly in the Arab region."[74] Satellite jamming can be either deliberate or unintentional, but it has reportedly led to the loss of millions of dollars, primarily impacting television exchanges among Arab countries.[75] In response the World Broadcasting Unions (WBU) launched a joint action plan to address satellite jamming. Recommended actions include educational campaigns, improvement of uplink engineer training, and new regulations to punish intentional jamming.[76]

Indicator 3.4: Space-based negation-enabling capabilities

Deploying space-based ASATs—using kinetic-kill, directed energy, or conventional explosive techniques—would require enabling technologies somewhat more advanced than the fundamental requirements for orbital launch. While microsatellites, maneuverability, and other 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.

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, due to its small size, a space-mine microsatellite can be hard to detect.

Microsatellite technology has become widespread, involving an array of civil, military, commercial, and academic actors. In 2000 the partnership between China and Surrey Satellite Technology Ltd. of the UK saw the launch of the Tsinghua-1 microsatellite and companion Surrey Nanosatellite Application Platform to test on-orbit rendezvous capabilities.[77]

A variety of U.S. programs have developed advanced technologies that would be foundational for a space-based conventional anti-satellite program, including maneuverability, docking, and onboard optics. 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.

The MDA Near-Field Infrared Experiment (NFIRE), a satellite designed to provide support to ballistic missile defense, at one point was expected to employ a kill vehicle to encounter a ballistic missile at close range, with a sensor to record the findings. In 2005 MDA cancelled the kill vehicle experiment after Congress expressed concerns about its applicability to ASAT development;[78] the kill vehicle was replaced with a laser communications payload. In 2006 the United States launched a pair of Micro-satellite Technology Experiment (MiTEx) satellites into an unknown geostationary transfer orbit. These satellites are technology demonstrators for the Microsatellite Demonstration Science and Technology Experiment Program (MiDSTEP) sponsored by DARPA, the USAF, and the U.S. Navy. A major goal of the MiTEx demonstrations is to assess the potential of small satellites in GEO for defense applications.[79] In January 2009 the Pentagon confirmed that the two MiTEx microsatellites had maneuvered in close proximity to a failing satellite in GEO.[80] This incident raised concerns that the ability to get in such close proximity to another satellite could potentially be used for hostile actions.[81]

On-orbit servicing is also a key research priority for several civil space programs and supporting commercial companies. Germany is developing the Deutsche Orbitale Servicing Mission, which "will focus on Guidance and Navigation, capturing of non-cooperative as well as cooperative client satellites, performing orbital maneuvers with the coupled system and the controlled de-orbiting of the two coupled satellites."[82] Sweden has developed the automated rendezvous and proximity operation PRISMA satellites, which were successfully launched in June 2010 from Yasni, Russia.[83] The PRISMA satellite project demonstrates technologies for autonomous formation flying, approach, rendezvous, and proximity operations.[84] While there is no evidence to suggest that these programs are intended to support space systems negation and Sweden has been quite transparent about the nature of this project, this type of technology could conceivably be modified for such an application.

2013 Developments

On-orbit capabilities and space debris removal

Debris removal and satellite servicing

DARPA's Phoenix program awarded Phase 2 prime contracts to develop technologies in three primary areas: advanced GEO space robotics, satlets, and a Payload Orbital Delivery (POD) system. DARPA is looking for 10 retired satellites to participate in an experiment on satellite servicing and salvaging. The agency hopes to choose the finalists by the end of 2014 and conduct a test in 2016.[85]

Switzerland's Ecole Polytechnique Fédérale de Lausanne (EPFL) is developing a debris removal satellite named CleanSpace One. Capable of rendezvous and docking, the microsatellite is intended to remove debris from orbit. EPFL has partnered with Swiss Space Systems and plans to launch the satellite by 2018.[86]

Japan is developing the Space Tethered Autonomous Robotic Satellite-2 (Stars-2), which will test tether technologies that aid in space debris cleanup. Electricity generated by the tether will slow the orbits of other objects in space so that they eventually burn up in the atmosphere. Full deployment is expected to take place in 2019.[87]

China's unusual satellite maneuvering raises international concern

In late September 2013 China conducted a satellite capture test in space. The maneuver involved a satellite fitted with a mechanical arm. Three satellites—Chuangxin-3, Shiyan-7, and Shijian-15, which had been launched on 20 July and included the spacecraft involved in the capture—were reported to be conducting experiments in space maintenance techniques, such as space arm operations.[88]

These maneuvers raised concerns that "the tests go beyond the stated objectives and are actually cover for testing on-orbit ASAT technology."[89] Technologies with on-orbit servicing, space debris removal applications could potentially also be used for offensive purposes.

Jonathan McDowell, with the Harvard-Smithsonian Center for Astrophysics, said, "What we're seeing is a heightened sense in the United States that China is a potential threat and that it has the technology to be a threat if it wishes to. As China becomes a space superpower, and given that it does have a significant military component to its space program, it is inevitable that the U.S. will be concerned about threats to its most valued satellite systems, whether or not China actually intends to deploy such aggressive systems."[90]

THEME FOUR

Outer space governance

Indicator 4.1: National space policies

Most spacefaring states explicitly support the principles of peaceful and equitable use of space in their space policies and emphasize the goals of using space to promote national socioeconomic, scientific, and technological progress. Virtually all space actors underscore the importance of international cooperation in their space policies; because of this cooperation several developing nations have been able to secure access to space.

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] Similar to those of the United States, 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]

The 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. The ESA has established strong links of cooperation with larger space powers, such as the United States and Russia.

Fueled in part by military technological advances, the national policies and military doctrines of a number of states also reflect a growing reliance on space-based applications to support military functions. Consequently, major space powers and several emerging spacefaring nations increasingly view their space assets as an integral element of their national security infrastructure. In addition, countries' policies increasingly highlight the need to develop and revitalize the industrial sector as a key partner in achieving national objectives in the space sector.

2013 Developments

Australia releases its new Satellite Utilisation Policy

On 9 April 2013 the Australian government released its new Satellite Utilisation Policy, which articulates Australia's space interests and objectives and identifies existing and emerging opportunities.

Australia again committed to seven guiding principles: (1) focusing on space applications of national significance; (2) assuring access to space capability; (3) strengthening and increasing international cooperation; (4) contributing to a stable space environment; (5) improving domestic coordination, (6) supporting innovation, science, and skills development; and (7) enhancing and protecting national security and economic wellbeing.[10]

Australia's goal is to achieve (1) improved productivity, (2) better environmental management, (3) a safe and secure Australia, (4) a smarter workforce, and (5) equal access to information and services.[11]

Japan adopts Basic Plan on Space Policy

On 25 January 2013 the Japanese government formally adopted the Basic Plan on Space Policy established by the Strategic Headquarters for Space Policy. It reflects Japan's desire to move from "measures that focus on technological development to those that emphasize space utilization."[12] Recognizing that promoting space utilization requires funding and time in a period of financial stringency, the plan calls for the prioritization of space development programs, space science, and large-scale space exploration that will yield the best results.[13]

These priorities are to reflect the six basic pillars for Japan's development and utilization of space: (1) peaceful use of space, (2) improvement of people's lives, (3) development of industry, (4) prosperity of human society, (5) promotion and international cooperation, and (6) consideration for the environment.[14]

United States may transfer space technology to South Korea, laws restrict transfers to China

South Korea

The U.S. Congress approved the sale of four Block 30 Global Hawk high-altitude unmanned aerial vehicles, as well as associated equipment, parts, training, and logistical support to South Korea. The deal is estimated to be worth $1.2-billion and will be authorized under the Foreign Military Sales program. It is in line with the 2015 transition of intelligence-gathering from the U.S.-led Combined Forces Command to the South Korean military.[15] Seoul's Defense Acquisition Program Administration (DAPA) picked the Global Hawk as the only candidate after a review of other options fell short.[16]

China

The National Defense Authorization Act for Fiscal Year 2013, which came into effect 2 January 2013, relaxed some export restrictions but continued to ban the export, re-export, or transfer of satellites to China and the launching of U.S. satellites in Chinese territory.[17] The U.S. International Traffic in Arms Regulations were expanded in 1999 to include satellites.[18]

China complained that it is placed under the same satellite export ban as countries that the United States deems to be supporting terrorism—the Democratic People's Republic of Korea, Iran, Cuba, Syria, and Sudan.[19]

United States eases export rules on less sensitive items from U.S. Munitions List

The U.S. State Department has eased rules on the export of select items in the aerospace industry to reduce disadvantages to U.S. firms. A series of "less sensitive items" were removed from the U.S. Munitions List, which regulates exports, and placed on a separate list maintained by the Commerce Department and seen by industry as less stringent. The items include parts and components related to aircraft and gas turbine engines, which account for more than $20-billion in annual exports.[20]

Sequester affects U.S. space program

In March 2013 a deadlock in the U.S. Congress triggered the sequester—automatic budget cuts. While NASA began the fiscal year under a six-month continuing resolution that funded the Agency at the previous year's level, the budget for the second half of the fiscal year provided NASA with $16.865-billion or $935-million less than the previous year.[21] In April NASA Administrator Charles Bolden warned that if sequestration continued through 2014, it would affect long-term and top-priority projects such as the Space Launch System heavy-lift rocket, the Orion Multi-Purpose Crew Vehicle, and the James Webb Space Telescope. Bolden noted that he would likely have to furlough civil servants, which would affect the institutional knowledge and expertise.[22]

Various countries announce goals for next stages of space exploration

United States

The House of Representatives unanimously approved a Senate amendment to bipartisan bill H.R. 6586, extending a risk-sharing and liability regime to support U.S. commercial space transportation operators against catastrophic losses by the uninvolved public.

The amended bill extended a waiver until 2020 to allow U.S. astronauts to continue to fly aboard Russian spacecraft to access the International Space Station. The bill also conveyed a Sense of Congress on future U.S. human spaceflight capabilities, "stressing the need to ensure continued development of NASA's Space Launch System and Orion Multi-Purpose Crew Vehicle." as well as congressional approval of commercial crew services to the ISS.[23]

Russia

In April Deputy Prime Minister Dmitry Rogozin said that new technologies will lay the groundwork for manned flights by Russia to Mars. Speaking at a meeting on the space industry, Rogozin pointed to a new-generation spacecraft and robot system as examples of technology that would help Russia achieve its goal.[24]

South Korea

In November the South Korean government announced plans to launch its own space launch vehicles that would put a satellite in orbit by 2020.[25]

Chinese Vice-President calls for peaceful exploration and use of space; the United States clarifies NASA ban on Chinese scientists

At the opening of the 64th International Astronautical Congress (IAC) in September Vice-President Li Yuanchao called for the peaceful exploration and use of space to serve the interests of people and countries across the world. He noted that all countries enjoy equal rights to space resources.[26]

A decision by NASA in October to bar Chinese scientists from the Kepler Science Conference on exoplanets was due to an "inaccurate" reading of a 2011 law, according to the law's drafter, Congressman Frank Wolf. The law prevents NASA funds from being used to collaborate with China or to host Chinese visitors at U.S. space agency facilities. Wolf specified that these restrictions did not limit the activities of Chinese nationals "unless those nationals are acting as official representatives of the Chinese government." Prominent U.S. scientists threatened to boycott the event.[27] NASA then reconsidered the applications of Chinese scientists[28] and eventually overturned its initial decision.[29]

Indicator 4.2: Multilateral forums for space governance

Multilateral institutions like the CD and COPUOS play an essential role in space security by providing a venue to address common challenges related to space activities. For instance, member states can discuss solutions to potential disagreements over the allocation of scarce space resources and develop new international law. In addition, multilateral institutions also help to provide the technical support that is needed to ensure access to and use of space by all nations.

Issues of space security are often debated at the First Committee (Disarmament and International Security) of the UN General Assembly, the main deliberative organ. While UNGA's decisions are not legally binding, they carry the weight of world opinion. The UNGA has long held that preventing an arms race in outer space is a significant contribution to international peace and security.

In 1958 the General Assembly created COPUOS to review the scope of international cooperation in the peaceful uses of outer space, develop relevant UN programs, encourage research and information exchanges on outer space matters, and study legal problems arising from the exploration of outer space. COPUOS and its two standing committees—the Scientific and Technical Subcommittee and the Legal Subcommittee—develop recommendations based on questions and issues put before them by UNGA and Member States. By the end of 2013 there were 74 Member States of COPUOS, which works by consensus. A few 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.

In 2010 the Scientific and Technical Subcommittee established the Working Group on the Long-Term Sustainability of Outer Space Activities. In 2011 a working paper containing the proposal of the Chair for the terms of reference, method of work, and work plan for the Working Group was presented to the Subcommittee. The mandate of the Working Group, which held its first formal meetings in 2012, is to examine and propose measures to ensure the safe and sustainable use of outer space for peaceful purposes, for the benefit of all countries. It is expected to prepare a report on the long-term sustainability of outer space activities that includes a consolidated set of current practices and operating procedures, technical standards, and policies associated with the safe conduct of space activities.

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, 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.[30] 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.[31] While space actors have stopped short of actually deploying weapons in space or attacking the space assets of another nation from Earth, ASATs have been tested by some states against their own satellites—for example by China in 2007[32] and the United States in 2008.[33]

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."[34] 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":[35]

- 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.

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.[36] However, the Moon Agreement has not been widely ratified because of contentions related to lunar exploration.[37] 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 4.1: 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 analysed 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.
UN 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.

The Conference on Disarmament is the primary multilateral disarmament negotiating forum. First established in 1962 as the Eighteen Nation Disarmament Committee, it went through several name changes as its membership grew, receiving its present name in 1979. The CD, with 65 current Member States, 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 1982 the Mongolian People's Republic put forward a proposal to create a committee to negotiate a treaty to address these shortcomings.[38] After three years of deliberation, the CD Committee on PAROS was created and given a mandate "to examine, as a first step…the prevention of an arms race in outer space."[39] 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.[40]

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 2000 then CD President Ambassador Amorim of Brazil unsuccessfully attempted to break the deadlock by proposing the creation of four subcommittees, two of which would deal with, respectively, PAROS and an FMCT. In 2004 several states called for the establishment of a CD expert group to discuss the broader technical questions surrounding space weapons. While in 2009 the CD adopted its first program of work in over a decade, this advance was short-lived as the CD reverted to a deadlock following objections from Pakistan over FMCT discussions. By the end of 2013 the CD had not been able to gain agreement on a Program of Work.

The UN Charter establishes the fundamental objective of peaceful relations among states. Article 2(4) of the Charter 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.[41] In 2011 the UN Secretary-General established, on the basis of equitable geographical distribution, a Group of Governmental Experts on Transparency and Confidence-building Measures in Outer Space Activities to conduct a study, which took place during 2012 and was reported to UNGA in 2013.

In addition to treaties, six UN resolutions known as principles have been adopted by the General Assembly 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.

2013 Developments

UN General Assembly receives expert report on transparency and confidence-building measures

On 29 July 2013 the UN Group of Governmental Experts on Transparency and Confidence-Building Measures in Outer Space Activities submitted their report to the General Assembly. It concluded that the world's growing reliance on space-based technologies meant that collaborative efforts in the form of transparency and confidence-building measures were needed to enhance the sustainability and security of outer space activities. Member States and international organizations were encouraged to adopt non-legally binding measures such as the exchange of information relating to national space policy, notifications on outer space activities, visits to space launch sites and facilities, and coordination and consultative mechanisms between spacefaring nations to complement legally binding treaties on outer space.[42]

UN General Assembly adopts resolutions proposed by First and Fourth Committees to enhance the peaceful use of outer space

On 5 December 2013 the UN General Assembly adopted Resolutions 68/29 and 68/50 following reports of the First Committee on Disarmament and International Security. Resolution 68/29 called upon all states, particularly major spacefarers, "to contribute actively to the objective of the peaceful use of outer space and of the prevention of an arms race in outer space and to refrain from actions contrary to that objective."[43] Resolution 68/50 welcomed a report made by the Group of Governmental Experts on outer space transparency and confidence-building measures and encouraged Member States to review and implement the proposed transparency and confidence-building measures through relevant national mechanisms. The Resolution recommended the circulation of the recommendations from the expert report to COPUOS, the Disarmament Commission, and the Conference on Disarmament, as well as other relevant UN entities.[44]

On 11 December 2013 the UN General Assembly adopted Resolutions 68/74 and 68/75 on the recommendations of the Fourth Committee (Special Political and Decolonization Committee). Resolution 68/74 recommended that when Member States were enacting regulatory frameworks for national space activities that they consider their various space governance obligations including, inter alia, authorizing, registering, and monitoring launches and return of objects to and from outer space.[45] Resolution 68/75 endorsed the COPUOS report at the 56th session and called upon major spacefaring states to contribute actively to the peaceful use of outer space and the prevention of an outer space arms race and to refrain from actions harmful to this objective.[46]

UN COPUOS, Member States increase cooperation on NEOs

The 56th session of COPUOS took place from 12-21 June in Vienna. The Committee endorsed the agreement for enhanced international coordination to deal with potential threats posed by asteroids. The new COPUOS Action Team on Near-Earth Objects will assist in the establishment of an international asteroid warning network and a space mission planning advisory group, in partial fulfilment of the recommendations for an international response to an asteroid threat.[47]

On 19 June 2013 the UN Office of Outer Space Affairs signed a cooperation agreement with the Ministry of the Russian Federation for Civil Defense, Emergencies and Elimination of Consequences of Natural Disasters (EMERCOM) to establish the 16th Regional Support Office of the UN Platform for Space-based Information for Disaster Management and Emergency Response. NASA Administrator Charles Bolden informed COPUOS about actions NASA was taking with international partners to redirect an asteroid for further study and to improve detection, characterization, and mitigation planning for potentially hazardous asteroids.[48]

Figure 4.2: Status of major UN space treaties as of April 2014[49]

Treaty	Date	Total P*	Total S*
Outer Space Treaty	1967	101	26
Rescue Agreement	1968	92	24
Liability Convention	1972	90	23
Registration Convention	1975	57	4
Moon Agreement	1979	13	4

P*: Party
S*: Signatory

UN Security Council sanctions North Korean Space Agency

Prompted by North Korea's ballistic missile launch on 12 December 2012, in January 2013 the UN Security Council unanimously adopted Resolution 2087, condemning the launch and expanding existing UN sanctions. Six entities, including North Korea's space agency, and four individuals had their assets frozen and were prohibited from engaging in financial transactions. A travel ban was imposed on the individuals, including space agency officials, limiting their ability to procure technology and expertise and to strike commercial deals abroad.[50] North Korea threatened to retaliate with "high-profile measures"[51] and conducted additional tests in 2013.[52]

Russia and the United States agree to protect satellite navigation at UN ICG

The two countries, concerned about competing navigation systems from the EU and China, agreed to secure frequency spectrum and other positions for their GLONASS and GPS satellite navigation systems at the UN's International Committee on GNSS. Observers note that EU and Chinese products were expected to be superior to the U.S. and Russian systems.[53]

In November Russia announced that a GPS-only phone would become illegal in Russia starting in 2014, thereby favoring its own GLONASS.[54] In December Russian media reported that provisions securing GPS security in the U.S. congressional 2014 defense bill effectively banned GLONASS stations in the United States.[55]

Figure 4.3: UN-related institutions relevant to international space security

Indicator 4.3: Other initiatives

Historically, the key governance challenges facing outer space activities have been discussed at multilateral bodies related to, or under the auspices of, the United Nations, such as COPUOS, the General Assembly First Committee, or the CD. However, diplomatic efforts outside these forums have been undertaken.

A notable example is the process to develop an International Code of Conduct for Outer Space Activities. The European Union, which has led the process, made an early decision to carry out deliberations and consultations in an ad hoc manner, not bound by the decision-making rules of procedure of traditional UN bodies. Adoption of the Code would take place at an ad hoc diplomatic conference.

A growing number of diplomatic initiatives relate to bilateral or regional collaborations in space activities. Examples 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).[56]

The UN Institute for Disarmament Research—an autonomous institute within the UN system—has also played a key role to facilitate 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.

2013 Developments

EU continues multilateral consultation process on proposed International Code of Conduct for Outer Space Activities

On 16 September 2013 the European Union released the latest draft of the International Code of Conduct for Outer Space Activities.[57] During 2013 the EU held two open-ended consultations, with representatives from more than 60 countries at each event —the first in Kiev (May) and the second in Bangkok (November)—to address calls for more inclusive and transparent consultations on Code content.[58] UNIDIR participated "to facilitate information dissemination and exchange of views."[59]

The Code of Conduct was first introduced in 2008 "as a means to achieve enhanced safety and security in outer space through the development and implementation of transparency and confidence-building measures."[60] The September draft is based on the following principles:

- 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;
- 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;
- the responsibility of States to take all appropriate measures and cooperate in good faith to avoid armful interference with outer space activities; and
- 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.[61]

EU-led efforts to develop a code of conduct for space activities received a diplomatic boost in 2012, when U.S. Secretary of State Hillary Clinton announced that "the United States has decided to join with the European Union and other nations to develop an International Code of Conduct for Outer Space Activities."[62] Also in 2012 Australian Foreign Minister Kevin Rudd stated that "the Australian government believes a code of conduct is the best approach to tackle this complex issue, and so has given the proposal in-principle support and will actively engage in negotiations to finalise a deal."[63] In January 2013 Japanese Ambassador to the CD Hiroyuki Yamamoto stated that "Japan is actively contributing to the development of an International Code of Conduct for Outer Space Activities…. We consider it a suitable gateway for further development of international rules."[64]

UNIDIR conference addresses new geopolitical context of space activity

UNIDIR held its 12th annual Space Security Conference, "Enhancing confidence, ensuring space stability," on 2-3 April 2013 in Geneva. A common refrain was that the geopolitical climate for space activity had undergone massive change in recent years, due to (1) the increased number of state and private actors engaging in outer space activity, each with its own interests and needs; (2) a technological evolution that gave actors access to a broader range of affordable civil and military space capabilities; and (3) the widespread use of space-based services, making outer space a crucial element of modern economic and social infrastructures.[65]

Panelists referred to several multilateral initiatives that addressed space security threats by encouraging cooperative measures rather than competitive conduct. The consensus was that a competitive space environment would destabilize space as a domain and reduce the socioeconomic value of space activities. It was hoped that responsible cooperative behavior would ensure a safe and sustainable space environment for all.[66]

Participants stressed the role of non-traditional actors in developing tools to enhance security in space. This role will be enhanced as the number of actors in space grows and motivations for space activities become increasingly complex.[67]

Russia and Kazakhstan compromise on legal framework for Baikonur

In December 2012 Russia sent a note to the Kazak government expressing concern over comments reportedly made by Kazcosmos head Talgat Musabayev advocating plans to deny Russia's rights to the Baikonur Cosmodrome.[68] The Kazakh Foreign Ministry claimed that implementation of Musabayev's plans would be "naïve and unreasonable" and that his words had been distorted by journalists. Still, Russia sought additional assurances that their rights in Baikonur remained secure and pushed for greater involvement in the administration of the spaceport. Russia's Director of the Council for National Strategy Valery Khomyakov argued that Kazakhstan lacked specialists to adequately run the facility.[69] Exacerbating tensions was Kazakhstan's refusal to accept Russia's proposed number of Proton launches.[70]

In February 2013 Russia and Kazakhstan reached a compromise on Kazakh-Russian space launch facility Baiterek, to be built at Baikonur. This facility will be modified for the launch of Russia's Zenit carrier rockets. Eventually Russia intends to leave Baikonur for its own space center at Vostochny.[71]

In December presidents of both countries announced a three-year agreement on the joint use of Baikonur.[72]

UK and Kazakhstan agree to collaborate in space

The UK Space Agency and the National Space Agency of the Republic of Kazakhstan (Kazcosmos) signed an agreement outlining cooperation in the area of space activities. Proposed collaborative projects include:

- Training Kazakhstan personnel in the field of satellite engineering and operations;
- Facilitating collaboration between UK space company SSTL and organizations within the joint stock company Kazakhstan Gharysh Sapary (KGS) on space projects for space science, technology demonstration, communication, navigation, and Earth observation;
- Facilitating discussions between KGS and SSTL on ongoing space projects in each organization.[73]

Russia and the United States extend space cooperation

In March Prime Minister Dmitry Medvedev signed a decree extending the United States-Russia agreement on cooperation in the use and exploration of outer space to 2020. The agreement is designed to promote national and joint U.S.-Russian space projects, including exploration of the Moon and Mars. Initially signed on 17 June 1992, the agreement between NASA and the Russian Space Agency was previously extended in 1997, 2002, and 2007. Russia remains the only source for transportation of U.S. space crews to the ISS.[74]

Space Security and the Challenge of Collective Action

James Clay Moltz[1]

The international agreements that govern space activities today evolved largely under the influence of the Cold War and the actions of the two superpowers. Fortunately, the cumulative effects of the harmful actions that took place during this period—debris releases from normal operations, intentional destruction of satellites, and emissions of electromagnetic pulse radiation—were relatively limited, given the small number of actors and space's sheer size. Some critical bilateral diplomacy halted certain extremely dangerous activities (such as nuclear explosions), allowing for continued safe access. Overall, policies of military restraint by the two superpowers in space facilitated successful technological development of an increasingly sophisticated array for civil, commercial, and military support purposes.

But the factors influencing space security began to change in the 1990s, as the number of influential players expanded to include several dozen countries as well as many private companies, international organizations, and even individual actors. The number of spacecraft increased accordingly: from a few hundred active satellites to now over 1,100, with a foreseeable further jump in the near future to several thousand, as cubesats and other inexpensive spacecraft proliferate. The space community has also witnessed a corresponding surge in the fields of trackable (>10 cm) and non-trackable (<10 cm) orbital debris. Where near-Earth space once seemed almost infinite, it now has become increasingly crowded.

Under these circumstances, near-Earth space "resources"—locations in the geostationary belt, usable radio frequencies, and debris-free orbital space—have become increasingly stressed. These same features are common to many natural environments on Earth, such as the world's oceans and its dwindling forests. As in some of these cases, the Cold War treaties, conventions, and organizations intended to allocate resources, prevent conflicts, and help ensure safe access seem inadequate to the tasks facing us in the twenty-first century.

The problems we must address today have long been predicted. In the 1960s biologist Garrett Hardin discussed a number of threatened "global commons"—such as the Earth's seas and airspace—and predicted that eventual overuse would create increasing conflict among actors and the ruination of these common spaces.[2] In the 1980s Swedish economist Per Magnus Wijkman predicted increasing pressure on cooperative space regimes in the face of the coming expansion of space actors and activities. These pressures, he observed, would create conditions ripe for "enclosing" space's common resources through privatization or hostile seizure.[3]

Evidence for many of these predictions can be seen in the contemporary space context, which the U.S. government now describes as "congested, contested, and competitive."[4] These three "Cs" have been mentioned repeatedly by U.S. officials in attempting to explain today's space threats, which traditionally constituted the main focus of the Department of Defense. But a fourth, more hopeful "C" needs to be added to round out the actual picture in space: cooperation. Indeed, even DoD is now engaged in significant international outreach. Thus, despite the growth of competitive pressures, international cooperation is flourishing in space, creating an important counterweight and raising the prospects for the successful avoidance of some of Hardin's apocalyptic predictions.

At this juncture in space history, it is worthwhile for participants, analysts, and government officials to take stock of the challenges we face and to consider possible means for dealing with them collaboratively—before the threats to space security become unmanageable. Unfortunately, this situation and the challenges of building or maintaining the necessary consensus for international cooperation are complex and involve a variety of actors across different fields of activity.

A good way to characterize the challenges the international space community faces in 2014 is with three related, but distinct "collective action" problems:

1. How do we prevent military conflict in space and enhance (and monitor) new space security arrangements?
2. How do we build confidence among civil space actors through cooperation in human spaceflight and robotic exploration?
3. How do we facilitate favorable conditions for sustainable commercial space development, which eventually will benefit all humanity?

I will consider the nature of emerging problems in each of these areas, discuss key developments over the course of 2013, and then propose some practical (although not easy) mechanisms for collective action to overcome the serious challenges countries, companies, and individuals face in "getting along" in space under emerging conditions.

Military space

The framework for existing military space security rests upon a series of Cold War agreements, which have received little reinforcement since the 1970s. Still, the reinforcing nature of such efforts as the 1963 Partial Test Ban Treaty, the 1967 Outer Space Treaty, the 1968 Rescue and Return Agreement, the 1972 Anti-Ballistic Missile Treaty (no longer in force), and the 1975 Registration Convention provided a floor for space stability, restraint, and limited cooperation during the Cold War. But periodic efforts over the past three decades to move beyond this basic set of agreements to more inclusive space security cooperation, weapons limits, and effective international monitoring have failed due to distrust, lack of interest, and political distraction. The sole exception was the creation of the Inter-Agency Debris Coordination Committee in the early 1990s, whose efforts through the UN Committee on the Peaceful Uses of Outer Space gained international approval for a set of voluntary debris mitigation guidelines by the UN General Assembly in December 2007.

More formal efforts, such as the 2008 Russo-Chinese treaty proposal on the Prevention of the Placement of Weapons in Outer Space (PPWT), have thus far not gained widespread support. The PPWT's inattention to critical threats such as debris-producing weapons and the testing of ground-, sea-, and air-based systems against space objects has limited its appeal and utility. The 2008 European Code of Conduct and 2013 draft of the International Code of Conduct (ICoC) for space have gained considerably more traction. These codes are an important effort in norm-building in space, based on the assumption that conditions in the first decade of the twenty-first century were not ripe for a treaty. But the initiative is moving slowly and national pledges will be voluntary, raising questions about whether the rapid pace of military developments and weapons testing will outstrip the ICoC's ability to institute meaningful and quick collaboration, consultation, and restraint.

The main UN-affiliated body responsible for arms control—the Conference on Disarmament in Geneva—has remained largely moribund since the late 1990s, due to national disputes over agenda priorities and an antiquated unanimity rule. This situation is unlikely to generate a new space treaty soon.

Unfortunately, the problems in military space are becoming more and more complex as actors and potentially harmful technologies continue to proliferate. States seem to be asking themselves: "Why cooperate when other actors can't be trusted, existing verification mechanisms are so limited, and enforcement is so weak?"

A number of events in 2013 raised further concerns. In May China's launch of what it called a high-orbit "science experiment" raised international alarms about what might lead to a dangerous weaponization of space's previously peaceful high altitudes.[5] China failed to silence critics when it did not offer any meaningful scientific findings. Some experts also commented on China's launch of three satellites in close proximity in July 2013 and its experiment in September with a manipulator arm, which could have counterspace uses.[6] Meanwhile, the United States conducted a long-duration flight of its experimental X-37B spacecraft, whose purposes remain unclear, despite U.S. claims of commitment to military space "transparency."

On the other hand, the successful conclusion of the meetings of the UN Group of Governmental Experts in July 2013 and the release of a consensus report marked the first evidence of U.S.-Chinese-Russian cooperation on space security in many years. The report called for more transparency regarding national space plans, enhanced information exchanges about national space assets, prior consultations before potentially hazardous activities, the opening of space-launch facilities to invitational visitors, and greater outreach to developing countries and the general public. These recommendations will feed into other efforts, such as the work of the UN Committee on the Peaceful Uses of Outer Space on the long-term sustainability of space activities.

Another promising sign of greater international cooperation in space security has been the expansion of data-sharing on space situational awareness. While some data remains sensitive, the series of partnerships that the U.S. military has formed with Australia, Canada, France, Italy, and Japan suggests a steadily increasing level of transparency as well as greater effectiveness in preventing collisions in space and in verifying harmful actions. DoD also recently reached a first-of-its-kind agreement with the commercially led Space Data Association to cooperate on identifying sources of radio frequency and electromagnetic interference.

Less heartening was the slowdown in funding for the new space fence that the United States is building to gather higher-resolution data on space objects.

In examining these developments we might have an answer for cynics who ask "why bother cooperating?" In the face of today's threats, at least two reasons should be mentioned: 1) international cooperation is needed to put pressure on states that might be tempted to violate norms of restraint in space; and 2) international data collection is needed to provide proof of harmful activities and to serve as a future deterrent.

These motivations seem to have come into play in the recent U.S. decision to declassify its Geosynchronous Space Situational Awareness Program (GSAP). According to Gen. William Shelton of Air Force Space Command, GSAP satellites will allow the U.S. military to observe satellites in geostationary orbit, suggesting that any possible weapons tests or threats to U.S. assets in this area of space will be observable.[7] One official stated that the announcement was intended to deter possible ASAT activity in this sensitive orbital region.

A better approach for long-term SSA, however, would be truly international, with international assets and data that could be easily shared, as well as analytical processes that could be independently and openly corroborated. Such a system could draw on both public and private support, given the interest of all entities in safe access to space. It might include a database operated by a small international organization staffed by scientists with data provided by military assets, ideally supplemented by a network of civil and scientific radars and telescopes. An alternative model might be an expanded Space Data Association, financed by user fees and aimed at the implementation of market-based best practices.

Civil space

Trends in civil space run in two directions as well: competitive and cooperative. We are seeing an increase in competitive exploration activities—many of them scientifically redundant (such as lunar mapping)—driven by the rise of nationalism in various regions of the world. This development is hardly unique to the current period, but the virulence of action-reaction in civil space programs—especially in Asia—raises concerns that space will be viewed by leaders and their publics in an increasingly competitive light. There is virtually no space cooperation between China and main Asian rivals Japan and India. Moreover, military space expenditures are rising in tandem with civil competition.

In this context, the 2013 release of the movie *Gravity* reminded audiences that space threats recognize no borders and that all spacefarers share similar risks. The film's message (a bit sensationalized) brought about a new public awareness of the problems posed by orbital debris and the need for international cooperation. Such efforts are moving forward in collaborative space missions, data exchanges on space weather and disaster warnings, and various programs involved in cooperative Earth-remote sensing.

In February 2013 the shocking explosion of a small meteor above Chelyabinsk, Russia, reminded everyone of our shared vulnerability, as well as the risks of possible climate change or even planetary-scale damage from large meteors. Fortunately, the event stimulated talks in international organizations—such as the UN COPUOS—to begin to study the problem, develop a database of near-Earth objects, and consider possible means of Earth defense.

Another important example of ongoing international cooperation is the conduct of activities on the ISS, which continue to expand with new technologies, research, and services. The ISS remains the world's largest collaborative science project and presents a possible model for future efforts in space. Work in this direction is under way within the framework of the International Space Exploration Coordination Group (ISECG), which includes non-ISS members India and China. Beyond politics, practical factors related to cost, technological specialization, and risk reduction continue to push countries into at least considering cooperation when planning major civil space missions. But the ISECG is not a formal organization and does not involve operational cooperation.

Despite NASA's current plan to explore an asteroid, a more inclusive international project would be a lunar return, base establishment, and eventual mission to Mars. The question remains: can the countries of the world cooperate in the next big push in human spaceflight, given recent tensions among the major spacefaring nations and examples of unfulfilled collaboration?

NASA's decision, in the face of budgetary pressure, to withdraw from the ExoMars project with the European Space Agency marked a low point for U.S. space cooperation. Coming on the heels of the 2009 cancellation of the Constellation program, the failure of Congress to provide NASA with the necessary finances led to further damage to the U.S. reputation as a reliable space partner.

The souring of U.S.-Russian relations over Ukrainian events in 2014 has damaged existing space cooperation. While the ISS has been exempted, long-term space relations now seem very much in doubt. Meanwhile, U.S.-Chinese space relations remained largely moribund, due to ongoing Congressional restrictions on funding and concerns about China's military space intentions.

In January 2014 the U.S. State Department's decision to host the International Space Exploration Forum for space agency representatives from 30 countries marked a useful effort to renew the U.S. commitment to international space cooperation and the ISECG process. Getting from this kind of discussion forum to an actual operational plan and burden-sharing framework should be the next step, but it is not yet being considered.

Commercial space

Since 1957 governance of commercial space activities has been driven by functional needs related to the allocation of finite space resources and the need to limit interference with the peaceful activities of other space actors. Many efforts in commercial space during the Cold War were tinged with nationalist competition, such as the U.S. sponsorship of the Comsat corporation to act as the sole service provider within the Intelsat organization. But, like Intelsat itself, commercial space has now become internationalized and is moving increasingly into private hands. The recent innovation of cubesats; the spread of various technologies for communications, observation, and navigation; and the prospect of greatly expanded commercial human spaceflight have raised hopes of a bold new era for space services. At the same time, there are questions about the adequacy of the existing regulatory framework to handle potentially disruptive developments, due to current gaps in the capabilities of international organizations to allocate resources, monitor fair use, and prevent conflict.

Many of the key principles of commerce hark back to the UN resolution passed in 1963 that extended international law to space. These concepts were later codified in general terms in the Outer Space Treaty and made more operational through the 1972 Liability Convention and the 1975 Registration Convention. In broadcasting, the International Telecommunication Union took on the necessary task of registering and allocating claims to the radio frequency spectrum and of distributing slots above the equator in geostationary orbit. While compliance within this framework has not been perfect, these agreements have served a valuable purpose in creating additional norms for space security. The 1979 Moon Treaty, by contrast, has not contributed significantly to space cooperation, given its implicit efforts to use lunar commerce as a means to address global economic inequities. This limited commercial space regime will be sorely tested in the coming few decades. It is likely to come up lacking.

In the area of human spaceflight, there is the real prospect that thousands of private citizens will visit the lower reaches of space by 2020, thanks to the coming startup of suborbital and, later, orbital flights aboard a range of planned commercial services (from Virgin Galactic to XCOR Aerospace to Blue Origin to Bigelow Industries). Tracking debris and ensuring the safety of passengers will be a new challenge.

Increasing crowding of the radio frequency spectrum, combined with growing evidence of the jamming of commercial signals by certain governments, may also put at risk norms of noninterference that have prevailed in space so far. Late-entry space actors complain about problems of inequity in access to the spectrum as well as available slots in geostationary orbit. New technologies, such as laser or microwave communications, may alleviate some of these pressures, but not in the near term. The seeming inability of existing international organizations to impose effective sanctions on countries (such as Iran) that violate satellite agreements by jamming signals raises the specter of failed governance.

With a growing population of satellites, registration becomes another challenge. The current policy of some governments (such as the Netherlands) not to require the registration of non-maneuvering cubesats poses a serious traffic hazard and eventual debris control problem. All of these problems suggest that more effective international regulatory bodies are likely to be needed to facilitate successful space commerce in the future.

Finally, the planned initiation of mining operations on the Moon and asteroids by several companies raises risks of conflict among enterprises and nations if mechanisms for allocating claims, encouraging best practices, and providing reasonable oversight are not developed. While no company wants onerous restrictions, the risks associated with a free-for-all include environmental damage, violation of the Outer Space Treaty's ban on seizing territory, and possible attacks on facilities by rivals. An international effort to develop reasonable guidelines and perhaps a replacement to the Moon Treaty is needed to prevent these negative outcomes. A first step might be an international study by UN COPUOS on parameters for lunar and asteroid development as a follow-on to its work on long-term sustainability.

Considerations for policymaking

A number of new initiatives are needed to address the challenges humanity faces in overcoming emerging obstacles to space cooperation. If humankind is to avoid the "closure" of space and the breakdown of the space security framework that has served the world well for the past five decades, strong political leadership and new international partnerships are required.

Near-term military priorities could include implementation of the norm of noninterference, prevention of further debris-producing weapons tests, and initiation of a practical process for enhanced trust and transparency via the step-by-step creation of an international space situational awareness system.

The noninterference concept played a valuable confidence-building role during the Cold War, in large part due to the explicit legal requirement in a series of U.S.-Soviet arms control treaties beginning in 1972 "not to interfere with the national technical means of verification of the other Party." While contained more generally in Article IX of the Outer Space Treaty, it has remained vague in global practice. The adoption of specific military noninterference pledges in various critical dyads (such as United States-China, China-India, and Israel-Iran) and as part of a broader UN or ICoC process could provide an important step toward risk reduction and improved communications among military space programs.

Adoption of a global prohibition on debris-producing ASAT tests could remove a major concern for many space actors. This effort could begin with unilateral statements by the leading military powers and then become established more formally through an international treaty. The most workable formula seems to be a ban above 150 miles (approximately 241 km), which would prevent long-lasting debris while avoiding discrimination charges by less developed countries.[8] To keep this latter loophole as small as possible, additional requirements include explicit recognition of international liability for any damages caused, the conduct of prior consultations, and implementation of a debris mitigation plan.

The formation of an international verification mechanism will provide easily sharable data to organizations and the public. We can begin by creating a shared database that combines publicly available information with selective military contributions from various countries.

This network could be maintained by a new international SSA organization (a possible outgrowth of the ICoC, if implemented) or by expanding an existing private entity such as the Space Data Association. Crowd-sourced data and analysis from scientists and amateur astronomers could supplement such an open system and provide a further deterrent against attempts to cheat, which would bring international notoriety and the greater possibility of legal action via a newly verifiable Liability Convention.

The greatest shared priorities for civil space seem to be ensuring continued safe access to space, facilitating cooperation among major spacefaring nations, and preventing conflicts. Efforts such as the long-term sustainability studies at UN COPUOS help to identify topics and possible mechanisms in space applications, debris mitigation, natural disaster warning, and space weather forecasting. Further work is needed to move from study to implementation.

Although the current U.S. administration cancelled the Constellation effort, prospects of using lunar exploration and settlement to foster cooperation in human spaceflight remain. Start by operationalizing the ISECG process to plan joint robotic missions that would establish a permanent scientific research base on the Moon (using equipment and other contributions from a variety of international partners). This base might be populated by astronauts from multiple countries by the early 2020s. Creating this framework and a meaningful cost-sharing mechanism will be difficult and require compromises—especially if all ISECG members, including China, were involved—but it would provide numerous benefits in building trust, planning cooperative missions, and engaging the international community.

The biggest threats to successful commercial development are, arguably, orbital debris, lack of adequate SSA to enforce future liability claims, and potential resource conflict on celestial bodies. These threats could be addressed by:

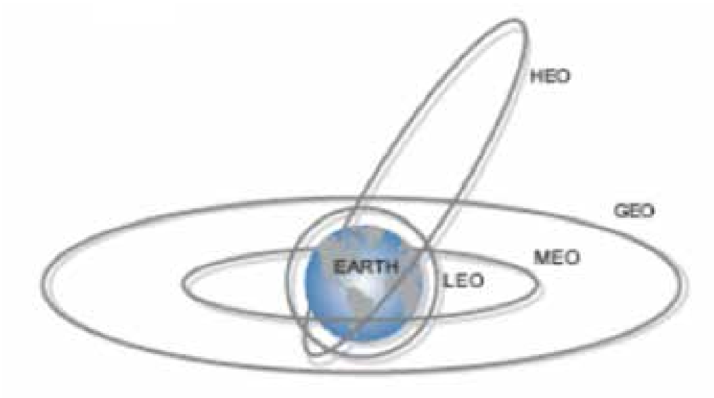
- ensuring more rapid de-orbiting of spacecraft after their service lives (especially in LEO) by requiring end-of-life deployment of magnetic tethers or drag sails for a national license to launch;
- enhancing data on satellite orbits and orbital changes with an expanded Registration Convention to allow better tracking of spacecraft to prevent collisions (and assign blame for willfully caused problems); and
- creating an industry-led commission to help COPUOS craft guidelines for future lunar and asteroid development, possibly leading to a new treaty for managing space resources.

Industry can play a positive role in space security, as long as the incentive system helps facilitate successful operations, allows for profits, and assures more reliable delivery of services.

Hardin's prediction of the "tragedy of the commons" can be avoided in space. But it will not be through inaction or heightened nationalism. Space activity necessarily involves a significant level of interdependence, given the ability of any actor to interfere or harm the activities of others in this fragile environment.

We must change our way of thinking about space. We need to accept the fact that our shared vulnerabilities in orbit are far greater than the threats we face from one another. Overcoming mistrust will take time and require more transparency, which makes many organizations, especially national militaries, uncomfortable. But the costs of failing to cooperate are higher than the risks of building new bridges.

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.

Polar Orbit refers to spacecraft at near-polar inclination and an altitude of between 700 and 800 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.

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.

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.

European Union – 31 March 2014

DRAFT International Code of Conduct for Outer Space Activities*

Preamble

The Subscribing States

- 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;
- 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;
- 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;
- Noting that all States, both spacefaring and non-spacefaring, should actively contribute to the promotion and strengthening of international cooperation relating to these activities;
- Recognising the need for the widest possible adherence to relevant existing international instruments that promote the peaceful exploration and use of outer space;
- Noting the importance of preventing an arms race in outer space;
- 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;
- 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;
- Recognizing it is in the shared interest of all States to reinforce international norms for responsible behaviour in outer space;
- 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 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;
- 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;
- Reaffirming existing commitments to resolve any dispute concerning activities in outer space by peaceful means;
- Recognising the necessity of a comprehensive approach to safety, security, and sustainability in outer space;
- Reaffirming their commitment to the Charter of the United Nations;

- 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;
- Subscribe to the following International Code of Conduct for Outer Space Activities (hereinafter referred to as the "Code"):

I. Purpose, Scope and General Principles

1. Purpose and Scope

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.

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.

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.

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.

2. General Principles

The Subscribing States decide to abide by the following principles:

- 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;
- 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;
- the responsibility of States to take all appropriate measures and cooperate in good faith to avoid harmful interference with outer space activities; and
- 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.

3. Compliance with and Promotion of Treaties, Conventions and Other Commitments Relating to Outer Space Activities

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:

- Existing international legal instruments relevant to outer space activities, including:
  – 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);
  – the Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space (1968);
  – the Convention on International Liability for Damage Caused by Space Objects (1972);
  – the Convention on Registration of Objects Launched into Outer Space (1975);
  – the Constitution and Convention of the International Telecommunication Union and its Radio Regulations, as amended;
  – the Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and under Water (1963) and the Comprehensive Nuclear Test Ban Treaty (1996).
- Declarations, principles, recommendations and guidelines, including:
  – International Co-operation in the Peaceful Uses of Outer Space as adopted by the United Nations General Assembly's (UNGA) Resolution 1721 (December 1961);
  – 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);
  – 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);
  – 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);
  – 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);
  – the Recommendations on Enhancing the Practice of States and International Intergovernmental Organisations in Registering Space Objects as endorsed by UNGA Resolution 62/101 (2007);
  – 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).

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.

II. Safety, Security and Sustainability of Outer Space Activities

4. Measures on Outer Space Operations and Space Debris Mitigation

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.

4.2. The Subscribing States resolve, in conducting outer space activities, to:

- 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;

- take appropriate measures to minimize the risk of collision; and
- 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.

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.

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).

III. Cooperation Mechanisms

5. Notification of Outer Space Activities

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:

- scheduled manoeuvres that could pose a risk to the safety of flight of the space objects of other States;
- predicted conjunctions posing an apparent on-orbit collision risk, due to natural orbital motion, between space objects or between space objects and space debris;
- pre-notification of launch of space objects;
- collisions, break-ups in orbit, and any other destruction of a space object(s) which have taken place generating measurable orbital debris;
- 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;
- 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.

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:

- through the Central Point of Contact to be established under section 9; or
- through diplomatic channels; or
- by any other method as may be mutually determined by the Subscribing States.

In notifying the Central Point of Contact, the Subscribing States should identify, if applicable, the potentially affected States.

The Central Point of Contact should ensure the timely distribution of the notifications received.

6. Information on Outer Space Activities

6.1. The Subscribing States resolve to share, on an annual basis, where available and appropriate, information with the other Subscribing States on:

- 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;
- their major outer space research and space applications programmes;
- 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
- efforts taken in order to promote universal adoption and adherence to legal and political regulatory instruments concerning outer space activities.

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.

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.

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.

7. Consultation Mechanism

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:

- 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.
- The Subscribing States involved in a consultation process resolve to:
  - consult through diplomatic channels or by other methods as may be mutually determined; and
  - work jointly and cooperatively in a timeframe sufficiently urgent to mitigate or eliminate the identified risk initially triggering the consultations.
- 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.
- The Subscribing States participating in the consultations resolve to seek mutually acceptable solutions in accordance with international law.

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.

IV. Organisational Aspects

8. Meeting of Subscribing States

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.

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.

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.

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.

9. Central Point of Contact

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:

- receiving and communicating notifications that a State subscribes to the Code;
- serving as a mechanism to facilitate communication of information exchanged under the Code to all Subscribing States;
- serving as secretariat at the Meetings of Subscribing States;
- maintaining an electronic database and communications system;
- 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
- carrying out other tasks as decided by the Meeting of the Subscribing States.

9.2. The Subscribing States resolve to create an electronic database and communications system, which would be used to:

- collect and disseminate notifications and information submitted in accordance with this Code; and
- serve as a mechanism to channel requests for consultations.

9.3. The electronic database is to be used exclusively in the interests of the Subscribing States.

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.

10. Participation by Regional Integration Organisations and International Intergovernmental Organisations

In this Code, references to Subscribing States are intended to apply, upon their subscription to the Code:

- To any regional integration organisation which has competences over matters covered by this Code, without prejudice to the competences of its member States.
- 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.

* Source: European Union, *Revised Code of Conduct for Outer Space Activities*, 31 March 2014, online: www.eeas.europa.eu/non-proliferation-and-disarmament/pdf/space_code_conduct_draft_vers_31-march-2014_en.pdf.

Conference on Disarmament – 10 June 2014
Draft

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

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.

Spacecraft Launched in 2013*

Satellite name	Owner	Actor type	Primary function	Orbit	Launch vehicle	Launch date
AIST-1	Russia	Civil	Technology Development	LEO	Soyuz 2,1v	28/12/2013
Express-AM5	Russia	Commercial	Communications	GEO	Proton M	26/12/2013
Rodnik (Cosmos 2488)	Russia	Military	Communications	LEO	Rokot	25/12/2013
Rodnik (Cosmos 2489)	Russia	Military	Communications	LEO	Rokot	25/12/2013
Rodnik (Cosmos 2490)	Russia	Military	Communications	LEO	Rokot	25/12/2013
TKSat-1	Bolivia	Government	Communications	GEO	Long March 3B	20/12/2013
INMARSAT 5 F1	United Kingdom	Commercial	Communications	GEO	Proton M	08/12/2013
Aerocube 5A	USA	Commercial	Technology Development	LEO	Atlas 5	06/12/2013
Aerocube 5B	USA	Commercial	Technology Development	LEO	Atlas 5	06/12/2013
ALiCE	USA	Military	Technology Development	LEO	Atlas 5	06/12/2013
CUNYSat-1	USA	Civil	Technology Development	LEO	Atlas 5	06/12/2013
FIA Radar 3, NROL-39 , USA 247, Topaz)	USA	Military	Reconnaissance	LEO	Atlas 5	06/12/2013
Firebird-A	USA	Civil/ Government	Space Science	LEO	Atlas 5	06/12/2013
Firebird-B	USA	Civil/ Government	Space Science	LEO	Atlas 5	06/12/2013
IPEX	USA	Government	Technology Development	LEO	Atlas 5	06/12/2013
MCubed-2	USA	Civil	Technology Development	LEO	Atlas 5	06/12/2013
SMDC-ONE 2.3	USA	Military	Technology Development	LEO	Atlas 5	06/12/2013
SMDC-ONE 2.4	USA	Military	Technology Development	LEO	Atlas 5	06/12/2013
SNaP-3-1	USA	Military	Communications	LEO	Atlas 5	06/12/2013
SES-8	USA	Commercial	Communications	GEO	Falcon 9	03/12/2013
Shiyan 5	China (PR)	Government	Remote Sensing/ Research	LEO	Long March 2D	25/11/2013
SWARM-A	ESA	Government	Earth Science	LEO	Rokot	22/11/2013
SWARM-B	ESA	Government	Earth Science	LEO	Rokot	22/11/2013
SWARM-C	ESA	Government	Earth Science	LEO	Rokot	22/11/2013
AprizeSat 7	USA/ Argentina	Commercial	Communications/Maritime Tracking	LEO	Dnepr	21/11/2013
AprizeSat 8	USA/ Argentina	Commercial	Communications/Maritime Tracking	LEO	Dnepr	21/11/2013
BRITE-PL-1	Multinational	Government	Space Science	LEO	Dnepr	21/11/2013
CINEMA-2	USA	Civil	Space Science	LEO	Dnepr	21/11/2013
CINEMA-3	USA	Civil	Space Science	LEO	Dnepr	21/11/2013
Cubebug 2 (Manolito, LO-74)	Argentina	Civil	Technology Development	LEO	Dnepr	21/11/2013
Delfi-n3Xt	Netherlands	Civil	Technology Development	LEO	Dnepr	21/11/2013

Satellite name	Owner	Actor type	Primary function	Orbit	Launch vehicle	Launch date
Dove-3	USA	Commercial	Technology Development	LEO	Dnepr	21/11/2013
Dove-4	USA	Commercial	Technology Development	LEO	Dnepr	21/11/2013
DubaiSat-2	UAE	Government	Earth Observation	LEO	Dnepr	21/11/2013
Eagle 2	USA	Civil	Technology Development	LEO	Dnepr	21/11/2013
FUNCube-1 (AO-73)	Netherlands	Civil	Communications	LEO	Dnepr	21/11/2013
GATOSS	Denmark	Commercial	Technology Development	LEO	Dnepr	21/11/2013
HumSat-D	Spain	Civil	Technology Development	LEO	Dnepr	21/11/2013
ICube	Pakistan	Government	Technology Development	LEO	Dnepr	21/11/2013
OPTOS	Spain	Government	Technology Development	LEO	Dnepr	21/11/2013
PUCPSat-1	Peru	Civil	Technology Development	LEO	Dnepr	21/11/2013
SkySat-1	USA	Commercial	Remote Sensing	LEO	Dnepr	21/11/2013
STSat-3	South Korea	Government	Technology Development	LEO	Dnepr	21/11/2013
Triton-1	Netherlands	Commercial	Technology Development	LEO	Dnepr	21/11/2013
Unisat-5	Italy	Civil	Scientific Research	LEO	Dnepr	21/11/2013
UWE-3	Germany	Civil	Communications	LEO	Dnepr	21/11/2013
Velox P2	Singapore	Civil	Technology Development	LEO	Dnepr	21/11/2013
WNISat-1	Japan	Commercial	Earth Observation	LEO	Dnepr	21/11/2013
Wren	Germany	Commercial	Technology Development	LEO	Dnepr	21/11/2013
ZACube-1	South Africa	Civil	Technology Development	LEO	Dnepr	21/11/2013
Yaogan 19	China (PR)	Military	Remote Sensing	LEO	Long March 4C	20/11/2013
Ardusat-1	USA	Commercial	Technology Development	LEO	JSSOD	19/11/2013
CAPE-2	USA	Civil	Technology Development	LEO	Minotaur	19/11/2013
Firefly	USA	Government/ Civil	Earth Science	LEO	Minotaur 1	19/11/2013
Ho'oponopono-2 (H2)	USA	Civil	Radar Calibration	LEO	Minotaur 1	19/11/2013
KySat-2	USA	Civil	Technology Development	LEO	Minotaur 1	19/11/2013
NPS-SCAT	USA	Government	Technology Development	LEO	Minotaur	19/11/2013
ORS - Tech 1	USA	Military	Technology Development	LEO	Minotaur	19/11/2013
ORS - Tech 2	USA	Military	Technology Development	LEO	Minotaur	19/11/2013
ORSES (ORS Enabler Satellite)	USA	Military	Technology Development	LEO	Minotaur	19/11/2013
Phonesat 2.4	USA	Government	Technology Development	LEO	Minotaur	19/11/2013
PicoDragon	Vietnam	Government	Technology Development	LEO	JSSOD	19/11/2013
Prometheus 1A	USA	Military	Technology Development	LEO	Minotaur 1	19/11/2013
Prometheus 1B	USA	Military	Technology Development	LEO	Minotaur 1	19/11/2013
Prometheus 2A	USA	Military	Technology Development	LEO	Minotaur 1	19/11/2013
Prometheus 2B	USA	Military	Technology Development	LEO	Minotaur 1	19/11/2013
Prometheus 3A	USA	Military	Technology Development	LEO	Minotaur 1	19/11/2013
Prometheus 3B	USA	Military	Technology Development	LEO	Minotaur 1	19/11/2013
Prometheus 4A	USA	Military	Technology Development	LEO	Minotaur 1	19/11/2013

Satellite name	Owner	Actor type	Primary function	Orbit	Launch vehicle	Launch date
Prometheus 4B	USA	Military	Technology Development	LEO	Minotaur 1	19/11/2013
STARE-B	USA	Military	Remote Sensing	LEO	Minotaur 1	19/11/2013
STPSat-3	USA	Military	Technology Development	LEO	Minotaur 1	19/11/2013
Vermont Lunar Cubesat	USA	Civil	Technology Development	LEO	Minotaur	19/11/2013
Raduga 1-M3	Russia	Military	Communications	GEO	Proton M	11/11/2013
Yaogan 18	China (PR)	Military	Remote Sensing	LEO	Long March 2C	29/10/2013
Shijian 16 (SJ-16)	China (PR)	Government	Technology Development	LEO	Long March 4B	25/10/2013
Sirius FM-6	USA	Commercial	Communications	GEO	Proton M	25/10/2013
Astra 2E	Luxembourg	Commercial	Communications	GEO	Proton M	29/09/2013
Cassiope	Canada	Government	Earth Science	Elliptical	Falcon 9	29/09/2013
CUSat-1	USA	Civil	Technology Development	LEO	Falcon 9	29/09/2013
DANDE	USA	Civil/ Government	Technology Development	LEO	Falcon 9	29/09/2013
Kuaizhou-1	China (PR)	Government	Remote Sensing	LEO	Kuaizhou	25/09/2013
Fengyun 3C	China (PR)	Government	Earth Science	LEO	Long March 4C	23/09/2013
AEHF-3	USA	Military	Communications	GEO	Atlas 5	18/09/2013
Hisaki	Japan	Government	Space Science	Elliptical	Epsilon	14/09/2013
Gonets M-14	Russia	Commercial/ Government	Communications	LEO	Rokot	11/09/2013
Gonets M-16	Russia	Commercial/ Government	Communications	LEO	Rokot	11/09/2013
Gonets M-17	Russia	Commercial/ Government	Communications	LEO	Rokot	11/09/2013
Yaogan 17A	China (PR)	Military	Remote Sensing	LEO	Long March 4C	01/09/2013
Yaogan 17B	China (PR)	Military	Remote Sensing	LEO	Long March 4C	01/09/2013
Yaogan 17C	China (PR)	Military	Remote Sensing	LEO	Long March 4C	01/09/2013
Amos 4	Israel	Military/ Commercial	Communications	GEO	Zenit 2SB	31/08/2013
Eutelsat 25B (Es'hail 1)	Multinational	Commercial	Communications	GEO	Ariane 5 ECA	29/08/2013
GSAT-7	India	Military	Communications	GEO	Ariane 5 ECA	29/08/2013
Keyhole 7	USA	Military	Reconnaissance	LEO	Delta 4 Heavy	28/08/2013
Kompsat-5	South Korea	Government/ Commercial	Earth Observation	LEO	Dnepr	22/08/2013
Wideband Global Satcom 6	USA	Military	Communications	GEO	Delta 4	08/08/2013
Alphasat I-XL	UK/ESA	Commercial/ Government	Communications/ Technology Development	GEO	Ariane 5 ECA	25/07/2013
INSAT 3D	India	Government	Meteorology	GEO	Ariane 5 ECA	25/07/2013
Chuangxin-3	China (PR)	Government	Technology Development	LEO	Long March 2C	19/07/2013
MUOS-2	USA	Military	Communications	GEO	Atlas 5	19/07/2013
Shijian 15	China (PR)	Government	Technology Development	LEO	Long March 3C	19/07/2013
Shiyan 7	China (PR)	Military	Technology Development	LEO	Long March 4C	19/07/2013

Satellite name	Owner	Actor type	Primary function	Orbit	Launch vehicle	Launch date
Shijian 11-05	China (PR)	Government	Technology Development	LEO	Long March 2C	15/07/2013
IRNSS-1A	India	Government	Navigation	GEO	PSLV	01/07/2013
IRIS	USA	Government	Space Science	LEO	L1011	28/06/2013
Kondor	Russia	Military	Reconnaissance	LEO	Strela	27/06/2013
O3b FM02	UK	Commercial	Communications	MEO	Soyuz-ST	25/06/2013
O3b FM04	UK	Commercial	Communications	MEO	Soyuz-ST	25/06/2013
O3b FM05	UK	Commercial	Communications	MEO	Soyuz-ST	25/06/2013
O3b PFM	UK	Commercial	Communications	MEO	Soyuz-ST	25/06/2013
Resurs-P1	Russia	Government/ Commercial	Earth Observation	LEO	Soyuz-2.1b	25/06/2013
Persona-2 (Cosmos 2486)	Russia	Military	Reconnaissance	LEO	Soyuz 2.1b	07/06/2013
SES-6	USA	Commercial	Communications	GEO	Proton M	03/06/2013
Wideband Global Satcom 5	USA	Military	Communications	GEO	Delta 4	25/05/2013
Navstar GPS IIF-4	USA	Military/ Commercial	Navigation/Global Positioning	MEO	Atlas 5	15/05/2013
Eutelsat 3D	Multinational	Commercial	Communications	GEO	Proton M	14/05/2013
EstCube-1	Estonia	Civil	Technology Development	LEO	Vega	07/05/2013
Proba V	ESA	Government	Earth Observation	LEO	Vega	07/05/2013
VNREDSat 1A	Vietnam	Government	Earth Observation	LEO	Vega	07/05/2013
Zhongxing 11	China (PR)	Government	Communications	GEO	Long March 3B	01/05/2013
Cubebug 1	Argentina	Civil	Technology Development	LEO	CZ-2D	26/04/2013
Gaofen 1	China (PR)	Government	Remote Sensing	LEO	CZ-2D	26/04/2013
Glonass 747 (Cosmos 2485)	Russia	Military/ Commercial	Navigation/Global Positioning	MEO	Soyuz 2	26/04/2013
AIST-2	Russia	Civil	Technology Development	LEO	Soyuz 2.1a	19/04/2013
BeeSat-2	Germany	Civil	Technology Development	LEO	Soyuz 2.1a	19/04/2013
BeeSat-3	Germany	Civil	Technology Development	LEO	Soyuz 2.1a	19/04/2013
Dove-2	USA	Commercial	Technology Development	LEO	Soyuz 2-1A	19/04/2013
Anik G1	Canada	Commercial	Communications	GEO	Proton M	15/04/2013
Satmex 8	Mexico	Commercial	Communications	GEO	Proton M	26/03/2013
SBIRS GEO 2	USA	Military	Early Warning	GEO	Atlas 5	19/03/2013
AAUSat-3	Denmark	Civil	Technology Development	LEO	PSLV	25/02/2013
Can-X3a	Canada	Civil	Space Science	LEO	PSLV	25/02/2013
NEOSSat	Canada	Government	Space Observation	LEO	PSLV	25/02/2013
Sapphire	Canada	Military	Space Observation	LEO	PSLV	25/02/2013
SARAL	India/France	Government	Earth Science	LEO	PSLV	25/02/2013
STRaND-1	UK	Commercial	Technology Development	LEO	PSLV	25/02/2013
TUGSat-1	Austria	Civil	Technology Development	LEO	PSLV	25/02/2013
Landsat 8	USA	Government	Earth Science	LEO	Atlas 5	11/02/2013
Amazonas-3	Spain	Commercial	Communications	GEO	Ariane 5 ECA	07/02/2013

Satellite name	Owner	Actor type	Primary function	Orbit	Launch vehicle	Launch date
Azersat-1	Azerbaijan	Government	Communications	GEO	Ariane 5 ECA	07/02/2013
Globalstar M078	USA	Commercial	Communications	LEO	Soyuz.2.1a/ Fregat	06/02/2013
Globalstar M093	USA	Commercial	Communications	LEO	Soyuz.2.1a/ Fregat	06/02/2013
Globalstar M094	USA	Commercial	Communications	LEO	Soyuz.2.1a/ Fregat	06/02/2013
Globalstar M095	USA	Commercial	Communications	LEO	Soyuz.2.1a/ Fregat	06/02/2013
Globalstar M096	USA	Commercial	Communications	LEO	Soyuz.2.1a/ Fregat	06/02/2013
Globalstar M097	USA	Commercial	Communications	LEO	Soyuz.2.1a/ Fregat	06/02/2013
TDRS-11	USA	Government	Communications	GEO	Atlas 5	31/01/2013
STSat-2C	South Korea	Government	Technology Development	LEO	Naro-1	30/01/2013
IGS-8A	Japan	Government	Reconnaissance	LEO	H2A	27/01/2013
IGS-8B	Japan	Government	Reconnaissance	LEO	H2A	27/01/2013
Rodnik (Cosmos 2482, Strela 3M)	Russia	Military	Communications	LEO	Rokot	15/01/2013
Rodnik (Cosmos 2483, Strela 3M)	Russia	Military	Communications	LEO	Rokot	15/01/2013
Rodnik (Cosmos 2484, Strela 3M)	Russia	Military	Communications	LEO	Rokot	15/01/2013

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