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Cover image: Soyuz TMA-07M Spacecraft ISS034-E-010181 (21 Dec. 2012)
As the International Space Station and Soyuz TMA-07M spacecraft were making their relative approaches on Dec. 21, one of the Expedition 34 crew members on the orbital outpost captured this photo of the Soyuz. Credit: NASA.

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ACRONYMS AND ABBREVIATIONS

ADR	Active Debris Removal
AEHF	Advanced Extremely High Frequency system (U.S.)
AEOS	Advanced Electro-Optical System
ALASA	Airborne Launch Assist Space Access (U.S.)
ALTB	Airborne Laser Test Bed
ASAT	Anti-Satellite Weapon
ASEAN	Association of Southeast Asian Nations
ASI	Agenzia Spaziale Italiana
ATV	Automated Transfer Vehicle
CALT	China Academy of Launch Vehicle Technology
CAST	China Academy of Space Technology
CCL	Commerce Control List (U.S.)
CCP	Commercial Crew Program
CD	Conference on Disarmament
CFE	Commercial and Foreign Entities
CNES	Centre national d’études spatiales (France)
CNSA	China National Space Administration
COMSAT	Communications Satellite Corporation
COPUOS	Committee on the Peaceful Uses of Outer Space (UN)
COTS	Commercial Orbital Transportation Services (U.S.)
CRS	Commercial Resupply Service
CSA	Canadian Space Agency
CSpO	Combined Space Operations
DARPA	Defense Advanced Research Projects Agency (U.S.)
DLR	German Aerospace Center
DoD	Department of Defense (U.S.)
EDDE	ElectroDynamic Debris Eliminator
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
ESOC	European Space Operations Centre
ESTEC	European Space Research and Technology Centre
EU	European Union
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FAA	Federal Aviation Administration (U.S.)
FCC	Federal Communications Commission (U.S.)
FMCT	Fissile Material Cut-off Treaty
FSS	Fixed Service Satellite
GEO	Geostationary Earth Orbit
GEOSS	Global Earth Observation System of Systems
GGE	Group of Governmental Experts (UN)

GLONASS	Global Navigation Satellite System (Russia)
GMES	Global Monitoring for Environment and Security (Europe)
GPS	Global Positioning System (U.S.)
GRAIL	Gravity Recovery and Interior Laboratory
GTO	Geosynchronous Transfer Orbit
HAND	High Altitude Nuclear Detonation
HELLADS	High Energy Liquid Laser Area Defense System
HEO	Highly Elliptical Orbit
HF	High frequency
HIGPS	High-integrity GPS
HTV	Hypersonic Test Vehicle
IADC	Inter-Agency Space Debris Coordination Committee
ICBM	Intercontinental Ballistic Missile
Inmarsat	International Maritime Satellite Organisation
Intelsat	International Telecommunications Satellite Organization
IRNSS	Indian Regional Navigation Satellite System
ISON	International Scientific Optical Network
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
JEM	Japanese Experimental Module
JHPSSL	Joint High-Power Solid-State Laser (U.S.)
JSpOC	Joint Space Operations Center (U.S.)
J-SSOD	JEM Small Satellite Orbital Deployer
LEO	Low Earth Orbit
LTSSA	Long-term Sustainability of Outer Space Activities
MARS	Mid-Atlantic Regional Spaceport
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.)
NASA	National Aeronautics and Space Administration (U.S.)
NDAA	National Defense Authorization Act (U.S.)
NEA	Near Earth Asteroid
NEC	Near Earth Comet
NEO	Near-Earth Object
NEOWISE	NEO Wide-field Infrared Survey Explorer
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.)
NROL	National Reconnaissance Office Launch (U.S.)
NSAU	National Space Agency of Ukraine

NTIA	National Telecommunications and Information Administration (U.S.)
ODWG	Orbital Debris Working Group (U.S.)
OECD	Organisation for Economic Co-operation and Development
OOS	On-orbit satellite servicing
ORF	Observer Research Foundation (India)
ORS	Operationally Responsive Space (U.S.)
OST	Outer Space Treaty
PAROS	Prevention of an Arms Race in Outer Space
PHA	Potentially Hazardous Asteroid
PHO	Potentially Hazardous Object
PMD	Post-mission disposal
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)
RAM	Robotic Refueling Mission
RBSP	Radiation belt storm probe
RF	Radio Frequency
RFI	Radio Frequency Interference
Roscosmos	Russian Federal Space Agency
RPO	Rendezvous and proximity
SANSA	South African National Space Agency
SDA	Space Data Association
SIA	Satellite Industry Association
SLV	Small Launch Vehicle
SSA	Space Situational Awareness
SSN	Space Surveillance Network (U.S.)
SST	Space surveillance and tracking (ESA)
SWORDS	Soldier-Warfighter Operationally Responsive Deployer for Space (U.S.)
SWPC	Space Weather Prediction Center
UARS	Upper Atmosphere Research Satellite
UNGA	United Nations General Assembly
UNIDIR	United Nations Institute for Disarmament Research
UNODA	United Nations Office of Disarmament Affairs
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
VCSFA	Virginia Commercial Space Flight Authority
WGS	Wideband Global SATCOM
WISE	Wide-field Infrared Survey Explorer
XSS	Experimental Spacecraft System (U.S.)

Space Security Index 2013 is the tenth annual report on developments related to safety, sustainability, and security in outer space, covering the period January-December 2012. 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 into the future:

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

The primary 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.

Regular readers of the report will notice a change in the way the information is structured in this report. In previous editions, key developments were organized under eight Chapters—each covering one major aspect of space activity (e.g., civil, commercial, policy, military, etc.). However, given the increasing interdependence, mutual vulnerabilities, and synergies of outer space activities, the decision was made, after consultations with several international space security experts, to reorganize information under four broad Themes, with each divided into various indicators of space security. We trust that this arrangement, as well as reducing repetition, better reflects the close relationship among developments that may have an impact on the security and sustainability of outer space. The structure of the 2013 report is as follows:

» **Theme 1: Condition of the space environment**
Indicator 1.1: *Orbital debris*
Indicator 1.2: *Radio frequency (RF) spectrum and orbital positions*
Indicator 1.3: *Near-Earth Objects*
Indicator 1.4: *Space weather*
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» **Theme 2: Access to and use of space by various actors**
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Indicator 3.4: *Earth-based capabilities to attack satellites*
Indicator 3.5: *Space-based negation enabling capabilities*

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

It was also decided by members of the SSI Governance Group to add a brief Global Assessment analysis. It will provide a broad assessment of the trends, priorities, highlights, breaking points, and dynamics that are shaping current space security discussions.

Until this present edition, each annual report included a brief "Space Security Impact" statement after each indicator of space security. The SSI Governance Group determined that such statements, in isolation, offered an inadequate assessment of outer space security, given the interdependence of space activities. A single, holistic assessment brings together the different ways in which the overall security of outer space is being affected by space activity.

The Global Assessment will be assigned to a different space security expert every year to encourage a range of perspectives. The inaugural essay is by Claire Jolly, senior policy analyst with the International Futures Programme in the Directorate for Science, Technology and Industry of the Organisation for Economic Co-operation and Development (OECD).

The Space Security Index attempts to take stock of all factors that may have an impact on the sustainability of outer space. Critical are such concerns 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 the militarization and potential weaponization of space.

From search-and-rescue operations to weather forecasting, banking to arms control treaty verification, the world has become increasingly reliant on space applications. The key challenge is to maintain a sustainable outer space domain so that the social and economic benefits derived from it can continue to be enjoyed by present and future generations.

More and more human-created space debris is orbiting the Earth. It is concentrated in the most commonly used parts of Low-Earth Orbit (LEO). In recent years awareness of the space debris problem has grown considerably, largely because various spacecraft have been hit by pieces of debris, intentional debris-generating events have occurred, and satellites have collided with one another. Thus efforts to mitigate the production of new debris through compliance with national and international guidelines are highly important. The future development and deployment of technology to remove debris promises to increase the sustainability of outer space.

If used to avoid collisions, Space Situational Awareness (SSA) capabilities that track space debris also contribute to space security. Although greater international cooperation to enhance the predictability of space operations would advance space security, the sensitive nature of some information and the small number of leading space actors with advanced tools for surveillance have kept significant data on space activities shrouded in secrecy. But recent developments covered in this report suggest that there is now greater willingness to share SSA data through international partnerships.

The distribution of scarce space resources—including orbital slots and radio frequencies—to spacefaring nations has a direct impact on the ability of actors to access and use space. An increase in the number of space actors, particularly in the communications sector, has created more competition and sometimes friction over the use of orbital slots and frequencies, which have historically been allocated on a first-come, first-served basis.

International instruments that regulate space activities have a direct effect on space security because they establish key parameters for space activities. These include the right of all countries to access space, prohibitions against the national appropriation of space and placing nuclear weapons and weapons of mass destruction in 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 can make space more secure by restricting activities that 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 painfully slow. International space actors have been unable to reach consensus on the exact nature of a space security regime, despite having specific alternatives on the table for consideration: both legally binding treaties, such as the Sino-Russian proposed ban on space weapons (known as the PPWT) and politically binding norms of behavior, such as the European Union's proposed International Code of Conduct for Outer Space Activities. The establishment of a Group of Governmental Experts on Space by the UN General Assembly (UNGA) and of the Committee on the Peaceful Uses of Outer Space (COPUOS) Working Group on the Long Term Sustainability of Space Activities, both of which held their first formal meetings in 2012, are seen as positive efforts toward the adoption of agreed transparency and confidence-building measures for space activities.

International cooperation remains central to both civil space programs and global utilities; this interaction affects space security positively by enhancing the transparency of certain civil programs. Collaborative endeavors in civil space programs can help emerging space actors access and use space. International cooperation makes possible complex and expensive projects in space, such as the International Space Station (ISS) and space exploration.

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. This can have a positive impact on space security by increasing the number of actors that have a vested interest in the maintenance of space security.

The military space sector is an important driver in 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. 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.

Space capabilities and space-derived information are integrated into the day-to-day military planning of major spacefaring states. Greater military use of space can have a positive effect on space security by raising awareness of mutual vulnerabilities and increasing the collective vested interest in space security. Conversely, the use of space systems 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 space systems of adversaries. In this sense, the security dynamics of space protection and negation are closely related and space security cannot be divorced from terrestrial security. Under some conditions protective systems can motivate adversaries to develop weapons to overcome them.

The information contained in *Space Security Index 2013* 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 to aid policy making, 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:

1) Experts on space security are asked to provide critical feedback on the draft research, which is sent to them electronically.
2) 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 about the impact of various events. This meeting also provides an important forum for related policy dialog on recent outer space developments.
3) Finally, the Governance Group for the Space Security Index reviews the penultimate draft of the text before publication.

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

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Theme 1: Condition of the space environment

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

Today the U.S. Department of Defense (DoD) is using the Space Surveillance Network to catalog more than 16,000 objects approximately 10 centimeters (cm) in diameter or larger. Roughly 23,000 pieces of debris of this size are being tracked, but not cataloged; the U.S. military only catalogs objects with known owners. Experts estimate that there are 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.

2012 Developments

Known space object population

- Cataloged debris population decreases; number of active objects on 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 continued in 2012, but was more actively managed

International awareness of debris problem increases as progress in solutions continues

- Mixed compliance with international debris mitigation guidelines
- International dialogs on debris problem, active debris removal, and other solutions continue in 2012
- Research and development on active debris removal continue in 2012

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 Geostationary Earth Orbit (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.

2012 Developments

Pressure on the radio frequency 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 2012 there were 9,448 known NEAs, 857 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.

2012 Developments

- Space agencies, amateur observers produce increasingly accurate assessment of NEO population
- International awareness of NEO threat and progress in international response continues

INDICATOR 1.4: Space weather — "Space weather" describes changing environmental conditions in near-Earth space. Explosions on the Sun create storms of radiation, fluctuating magnetic fields, and swarms of energetic particles. These phenomena travel outward through the solar system with a flow of charged particles called solar wind. When they reach Earth they interact in complex ways with Earth's magnetic field.

Some space weather storms can damage satellites and disrupt cell phone communications systems. Space is filled with magnetic fields, which control the motions of charged particles. Geomagnetic storms and more solar ultraviolet emissions heat the Earth's upper atmosphere, causing it to expand, eventually resulting in increased drag. Satellites slow down and change orbit slightly.

As technology has allowed spacecraft components to become smaller, their miniaturized systems have become increasingly vulnerable to solar energetic particles. These particles can often cause physical damage to microchips and change software commands in satellite-borne computers. Another problem for satellite operators is that when a satellite travels through this energized environment electrical discharges can harm and possibly disable spacecraft components.

2012 Developments

- Space weather events continue to affect space operations
- Progress continues on effectively forecasting space weather events

INDICATOR 1.5: 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.

2012 Developments

Capabilities

- The United States continues to invest in and develop its SSA capabilities
- Plans to improve SSA capabilities continue around the world in 2012

SSA sharing

- Efforts continue to increase SSA sharing among various space actors

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

INDICATOR 2.1: Space-based global utilities — 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 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.

2012 Developments

- Navigation systems of various nations continue to evolve
- Australia develops lightweight Earth observation satellite
- Iran launches Earth observation satellite
- South Africa to launch its first nanosatellite
- Meteosat Third Generation Agreement signed at Ministerial Meeting

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.

2012 Developments

- Changing budgetary allotments in civil space programs
- China conducts first manned mission to Tiangong-1 space station
- Canada renews commitment to International Space Station

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 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.

2012 Developments

- United States signs data-sharing agreement with Canada; eyes other countries
- China deepens cooperation on space activities with various countries
- European Commission and South Africa Space Agency enter scientific cooperation agreement
- Hungary, Poland, and Romania launch their first satellites
- Russia offers post-mission rehab to ISS astronauts

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.

2012 Developments

Growth in satellite market

- Satellite market continues to expand
- Space X delivers first commercial payload to ISS
- Commercial launch market continues growth

Space tourism

- Virgin Galactic SpaceShipTwo reaches milestone
- Golden Spike Company plans lunar commercial missions
- Actress Sarah Brightman announced as next ISS tourist

Commercial spaceports

- Various commercial spaceports under development

Commercial operators

- Satellite broadband service expands to commercial airlines

- Analysts and industry predict continued satellite industry growth
- Companies announce plans to mine asteroids
- LightSquared files for bankruptcy

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 dialog 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.

2012 Developments

- United Kingdom provides financial boost to space commercial sector
- European Defence Agency procures commercial bandwidth
- NASA awards contracts, funding to various commercial companies
- United Launch Alliance receives contracts for 11 launches from U.S. Air Force

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, Japan, Israel, Italy, 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.

2012 Developments

Military space systems in major spacefaring nations

- The United States continues to update existing space capabilities
- Russia continues to update space capabilities
- China continues deploying space-based military capabilities
- India continues improving its remote sensing satellites

Military and multiuse space capabilities in other countries

- Mexico, Brazil to enhance their telecommunications capabilities
- Iran continues to develop its space capabilities, despite launch failures
- Israel continues to build space capabilities in the past year
- North Korea launches Earth observation satellite

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.

2012 Developments

- United States begins enforcement of ban on distribution of personal GPS jamming equipment
- High Integrity Global Positioning System (HIGPS) capability prepares for full operational deployment
- Eutelsat to field test anti-jamming capability
- Chairman of the Joint Chiefs of Staff recommends establishment of United States Cyber Command (USCYBERCOM) as a unified command

INDICATOR 3.2: Protection of satellites against direct attacks — Direct interference with satellites by conventional, nuclear, or directed energy weapons is much more difficult to defend against than attacks against ground stations. The primary source of protection for satellites stems from the difficulties associated with launching an attack of conventional weapons into and through the space environment to specific locations. Passive satellite protective measures include system redundancy and interoperability, which have become characteristics of satellite navigation systems.

While no hostile anti-satellite (ASAT) attacks have been carried out, recent incidents, such as the 2007 ASAT test in which China destroyed one of its own satellites and the 2008 U.S. destruction of USA-193 using a modified SM-3 missile, testify to the availability and effectiveness of missiles to destroy an adversary's satellite. Space-based surveillance systems, such as the Space Tracking and Surveillance System (STSS) and Space Fence, enhance the ability to detect potential negation efforts.

It is almost impossible to provide a physical hardening of satellites that protects them from conventional weapons, such as kinetic hit-to-kill, explosive, or pellet clouds. Directed energy weapons can make use of a ground-based laser directed at a satellite to temporarily dazzle or disrupt sensitive optics. Optical imaging systems on a remote sensing satellite or other sensors, such as the infrared Earth sensors that are part of the attitude control system of most satellites, would be most susceptible to laser interference. Since the attacker must be in the line of sight of the target, opportunities for attack are limited to the available territory below the satellite.

Dispersing capabilities to a number of satellite operations can be used as a protective measure. Dispersion through the use of a constellation both increases the number of targets that must be negated and increases system survivability. Redundancy in satellite design and operations also offers a number of protective advantages. Since onsite repairs in space are not cost effective, some satellites employ redundant electronic systems to avoid single-point failures.

2012 Developments

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

INDICATOR 3.3: 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.

2012 Developments

- ATK awarded DARPA Phoenix contract
- NASA's Robotic Refueling Mission and CSA's Dextre perform second satellite servicing task from ISS
- Initial Operational Capability declared for Operationally Responsive Space (ORS)-1 satellite
- Deployment of smallsats on the rise

INDICATOR 3.4: 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.

2012 Developments

- Jamming incidents and capabilities proliferate
- Missile systems pursued by various countries
- Directed energy weapons continue to be developed

INDICATOR 3.5: 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.

2012 Developments

- Orbital rendezvous and docking capabilities continue to be pursued

Theme 4: Outer space policies and governance

INDICATOR 4.1: National space policies and laws — 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.

2012 Developments

- U.K. Space Agency publishes its Civil Space Strategy
- Japan eases restrictions on military space development
- States in the United States enact legislation on spaceflight liability

- U.S. DoD Space Policy Directive and Defense Strategic Guidance issued
- United States eases export controls on some satellites and related components

INDICATOR 4.2: Multilateral forums for space governance — International institutions including the First Committee of the UN General Assembly, 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. 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 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.

Also 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 2012 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 the UNGA indicates broad international consensus in support of consolidating and reinforcing the normative regime for space governance to enhance its effectiveness.

2012 Developments
- Various states deliver statements on PAROS at the CD, although the conference remains unable to agree on Program of Work
- COPUOS remains active; Working Group on Long-Term Sustainability of Space Activities holds first formal meetings
- First meeting of UN Group of Governmental Experts on TCBMs in Outer Space Activities convened
- ITU condemns satellite jamming

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 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 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 dialog 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.

2012 Developments

- EU kicks off multilateral consultation process on proposed International Code of Conduct for Outer Space Activities
- Various regional forums tackle space security, cooperation
- UNIDIR hosts 11th annual Space Security Conference

Condition of the Space Environment

Indicator 1.1: Orbital debris

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

While all space missions inevitably create some amount of space 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 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. Events of both types have created thousands of long-lasting pieces of space debris.

The U.S. Space Surveillance Network (SSN) is the system that most comprehensively tracks and catalogs space debris, although technological constraints limit it to spot checking rather than continuous surveillance and limit the size of currently cataloged objects to those greater than 10 centimeters (cm) in Low Earth Orbit (LEO), and larger in Geostationary Earth Orbit (GEO). Currently the U.S. Department of Defense (DoD) is using the SSN to catalog more than 16,000 objects.[1] It is estimated that there are over 300,000 objects with a diameter larger than 1 cm and millions smaller.[2]

Between 1961 and 1996 an average of approximately 240 new pieces of debris were cataloged each year. These pieces 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 an increase in the annual rate of debris production was observed, due to the occurrence of major debris-creating events. In January 2007 the Chinese weather satellite FY-1C was destroyed with an Anti-Satellite Weapon (ASAT) and in February 2009 two satellites—the Russian satellite Cosmos 2251 and the U.S. satellite Iridium 33—collided. There were no major debris-generating events during 2012.

Collisions between such space assets as the International Space Station (ISS) and very small pieces of untracked debris are frequent but manageable.[3] While collisions with larger objects remain rare, the ISS has had to be repositioned on various occasions to avoid a collision with a large piece of debris. The close approach of pieces of debris has also prompted the ISS crew to take precautionary measures.

Growing awareness of space debris threats has led to the development of a number of 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 COPOUS 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 2012 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.

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

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 (UARS) 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 an S14 Soviet rocket launched in 1985

2012 Developments

Known space object population[6]

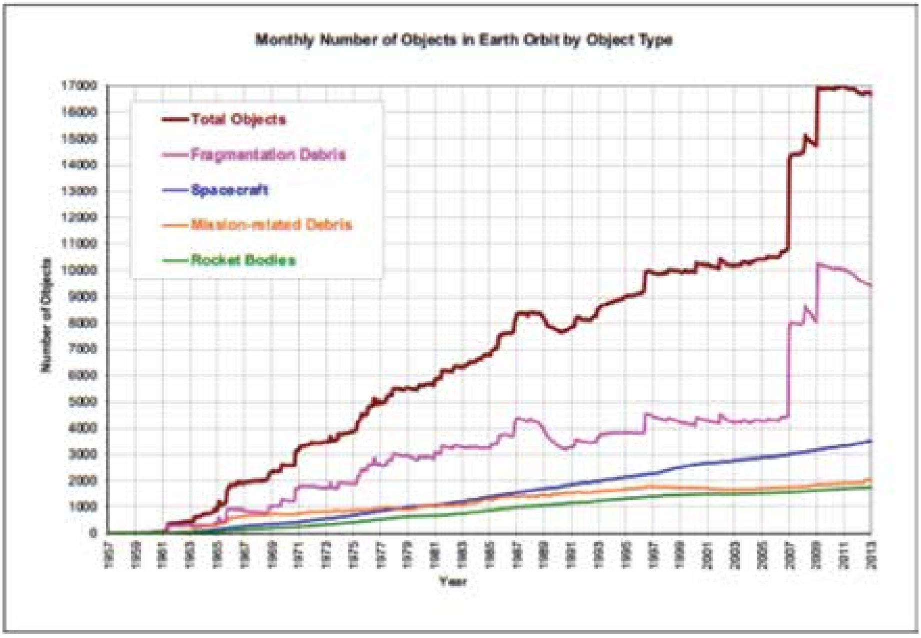
Cataloged debris population decreases; number of active objects in orbit continues to grow

The number of active satellites in orbit increased in 2012, rising to a total of 1,046.[7] This represents a 4.9% increase over the 2011 total of 994 active satellites. Notably in 2012, both North and South Korea conducted their first successful satellite launches, placing new objects in LEO.[8]

While the number of active space objects increased, the population of cataloged orbital debris decreased 7.6% during 2012.[9] This is the first time in recent years that the population has decreased; during 2011 the population increased 7.8% and during 2010 5.1%. The 2012 decrease is due to the solar cycle reaching its maximum in 2013,[10] speeding up orbital decay for many objects. The number of cataloged debris items may have fallen under 16,000, but roughly 23,000 pieces of debris 10 cm or larger are being tracked, though not cataloged.[11]

It is believed that the number of objects of that size is closer to 29,000, but some objects cannot be tracked with current SSA capabilities.[12]

Figure 1.2: Growth in on-orbit population by category[13]



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

While the overall number of cataloged items may have decreased, the U.S. Space Surveillance Network (SSN) continues to log debris from the 2007 Chinese anti-satellite weapons (ASAT) test and the 2009 accidental Iridium-Cosmos satellite collision.[14] A total of 5,500 pieces of debris from these two events have been cataloged by the SSN, accounting for 36% of all LEO debris.[15]

In 2012 two major rocket body explosions contributed to orbital congestion, each creating significant debris clouds. On 26 February 2012 the third stage of a Chinese Long March 3 launch vehicle exploded in a geosynchronous transfer orbit (GTO) shortly after releasing its payload, the Beidou G5 navigation satellite.[16] The SSN has only cataloged two of the dozens of pieces of debris associated with this explosion.[17] On 16 October 2012 the upper stage of a failed Russian launch vehicle exploded in LEO, creating thousands of pieces of debris.[18] The Briz-M booster debris is expected to decay relatively quickly, but will threaten spacecraft and the ISS until then.[19]

Figure 1.3: Top 10 breakups of on-orbit objects[20]

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 year 2012 also saw a few sizeable additions to the debris population, including the now inactive Envisat and two new satellites stranded by the failure of a Russian Briz-M booster during launch.[21] On 8 October 2012 the European Space Agency (ESA) lost contact with its 10-year-old Earth observation satellite, Envisat.[22] After a month of attempts to reestablish contact, ESA was forced to declare the end of the satellite's mission.[23] The large mass of the bus-sized Envisat and its position in a crowded orbit make it a particularly threatening piece of debris.[24] In early August 2012 a failed Russian Proton-M rocket launch stranded two telecommunications satellites – Indonesia's Telkom-3 and Russia's Express-MD2 – rendering them unusable and adding to the debris population.[25]

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 those aboard the International Space Station, despite the year's decrease in cataloged objects. U.S. Strategic Command (USSTRATCOM) issued approximately 20-30 emergency notifications per day in 2012 for possible conjunctions.[26] This rate is similar to that of previous years.[27] The ISS was maneuvered three times in 2012 to avoid debris.[28] In March ISS crew members had to take cover when a piece of debris approached the station with insufficient notice to conduct an avoidance maneuver.[29]

Figure 1.4: ISS collision avoidance maneuvers and precautionary measures during 2012

Date	Debris	Action taken
13 January 2012	Fragmentation debris from 2009 Iridium-Cosmos collision	ISS maneuvered
28 January 2012	Fragmentation debris from 2007 Chinese ASAT test	ISS maneuvered
24 March 2012	Fragmentation debris from 2009 Iridium-Cosmos collision	Insufficient notification for maneuver; crew takes cover in life craft
31 October 2012	Fragmentation debris from 2009 Iridium-Cosmos collision	ISS maneuvered

In 2012 ESA did not conduct any collision avoidance maneuvers, but had several close calls.[30] France conducted 13 collision avoidance maneuvers, and identified well over a hundred possible conjunctions.[31] NASA conducted eight collision avoidance maneuvers for U.S. robotic satellites;[32] three were prompted by a close approach with debris generated by the 2009 Iridium-Cosmos collision and one by debris from the 2007 Chinese ASAT test.[33]

Figure 1.5: NASA collision avoidance maneuvers for U.S. robotic satellites during 2012[34]

Mean altitude	Spacecraft	Object avoided	Maneuver date
550 km	GLAST (2008-029A)	Cosmos 1805	3 April 2012
700 km	AURA (2004-026A)	Cosmos 2251 debris	17 May 2012
700 km	CALIPSO (2006-016B)	Cosmos 2251 debris	2 October 2012
700 km	CLOUDSAT (2006-016A)	Sinah 1	8 September 2012
700 km	LANDSAT 5 (1984-021A)	Agena D stage debris	1 July 2012
700 km	LANDSAT 7 (1999-020A)	Fengyun-1c debris Meteor 1-10 debris	9 March 2012 17 April 2012
825 km	NPP (2011-061A)	Agena D stage debris	1 February 2012

The risk posed by debris and satellite reentries continued in 2012, but was more actively managed

Not all debris-related risks occur in outer space. The risks associated with debris reentering Earth's atmosphere are also noteworthy and more emphasis is being placed on predicting and controlling reentries.[35] Controlled reentries of 14 spacecraft and 11 launch vehicles were executed in 2012 by space actors that included China, France, Japan, Russia, and the United States.[36] This total can be compared with three controlled entries in 2010 and eight in 2011.[37] However, most reentries in 2012 were uncontrolled.[38] More than 400[39] controlled and uncontrolled reentries of space objects were monitored by the SSN in 2012.

After months of international coordination aimed at both recovering the spacecraft and predicting its reentry, the failed Phobos-Grunt spacecraft landed in the Pacific Ocean on 15 January 2012.[40] On 22 February[41] debris from a French Ariane IV launch vehicle fell in a small Brazilian village, but did not injure anyone.[42] It fell within an hour of the predicted time issued by U.S. Strategic Command.[43] On 25 March 2012 the Express-AM4, a stranded Russian communications satellite, experienced a controlled reentry over the Pacific Ocean.[44]

International awareness of debris problem increases as progress toward solutions continues

Mixed compliance with international debris mitigation guidelines

As in previous years, compliance with international debris mitigation guidelines was mixed in 2012. Nine GEO spacecraft were reorbited 250 km above GEO to comply with the 2007 IADC debris mitigation guidelines. Four were reorbited, but not high enough to comply with the guidelines. One spacecraft was abandoned in GEO.[45] In LEO, Helios 1-A underwent a post-mission disposal (PMD) that shortened its orbital lifetime to roughly 18 years.[46]

Figure 1.6: Compliance with debris mitigation guidelines in 2012

Spacecraft	Owner	Reorbited above GEO	IADC Guideline compliance*
Apstar 2R	China	257 x 345 km	YES
Beidou 3	China	135 x 145 km	NO
Zhongxing-22	China	835 x 860 km	YES
Eutelsat W1	EUTELSAT	564 x 631 km	YES
Telecom 2D	France	449 x 591 km	YES
AsiaSat 2	Hong Kong/China	247 x 299 km	YES
Insat 2E	India	149 x 198 km	NO
Cakrawatra 1	Indonesia	N/A, remains in GEO	NO
Palapa C1	Indonesia	156 x 227 km	NO
Inmarsat 2-F4	INMARSAT	635 x 697 km	YES
Intelsat VI F-2	INTELSAT	336 x 382 km	YES
AMOS 1/Intelsat 24	Israel/INTELSAT	867 x 950 km	YES
GOES 7	United States	121 x 89 km	NO
USA 111	United States	422 x 443 km	YES

*Note: Not all of these 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.

On 17 December 2012 NASA sent its two Gravity Recovery and Interior Laboratory (GRAIL) lunar orbiters on controlled impacts into the moon in compliance with internal debris mitigation requirements.[47] NASA's Radiation Belt Storm Probes (RBSPs, renamed Van Allen Probes in November 2012) were launched on 30 August; they were designed to comply with debris mitigation guidelines in two particular ways. First, the RBSPs will be deorbited at end of life to an altitude where they will decay naturally within one year, more than satisfying IADC guidelines, which call for a decay rate of 25 years or less.[48] Second, because the Centaur upper stage used to launch the RBSPs posed a particular threat to Earth, NASA decided to execute a controlled reentry of the upper stage.[49] Several other controlled reentries of launch vehicles took place in 2012.[50] On 8 December 2012 another Russian Proton-M rocket failed due to a malfunction of its Briz-M upper stage.[51] The Russians passivated the remaining two Briz-M boosters completely to eliminate the risk of explosion and mitigate debris.[52]

Figure 1.7: UN COPUOS Space Debris Mitigation Guidelines[53]

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.

Not all developments in 2012 reflect progress on debris mitigation. While the Long March 2 and 4 vehicles have been safely passivated, China has not been able to design passivation procedures for its Long March 3.[54] The third stage on this launch vehicle has exploded four times in the last five years, creating clouds of debris that have been largely untracked, partially due to "SSN limitations in observing small debris in low inclination, highly elliptical orbits."[55]

International dialogs on debris problem, active debris removal, and other solutions continue in 2012

Global awareness of the issues surrounding orbital debris continued to grow in 2012. A number of discussions and meetings to address the debris problem and possible solutions took place. NASA and the U.S. Department of Defense (DoD) held their 15th annual Orbital Debris Working Group (ODWG) meeting on 17-18 April 2012;[56] the ODWG gives NASA and the DoD the opportunity to discuss and collaborate on debris concerns and, especially in recent years, active debris removal (ADR) concepts.[57] The 2012 IADC meeting was held 22-25 May, hosted by the Canadian Space Agency in Montreal.[58] The ESA announced its CleanSpace initiative, which seeks to minimize ESA's environmental impact in space and on Earth and includes debris mitigation elements.[59] As part of this initiative, two workshops were held in 2012, one hosted by the European Space Research and Technology Centre (ESTEC) in June and the other by the European Space Operations Centre (ESOC) in September.[60] In addition, the sharing of SSA data continued to be emphasized as a solution to the debris challenge. See Indicator 1.5.

The Expert Groups of UN COPUOS Long-Term Sustainability of Space Activities Working Group held their first formal meetings in 2012.[61] The four groups are outlined below:

A – Sustainable space utilization supporting sustainable development on Earth; co-chaired by Portugal and Mexico

B – Space debris, space operations, and tools to support space situational awareness sharing; co-chaired by Italy and the United States

C – Space weather, co-chaired by Japan and Canada

D – Regulatory regimes and guidance for new actors in the space arena; co-chaired by Australia and Italy.[62]

Discussions on the orbital debris situation and solutions took place primarily in Expert Group B.

Talk also continued on servicing satellites in orbit. Refueling and repairing satellites could extend their orbital lives and reduce contributions to the debris population. Projects such as the Defense Advanced Research Projects Agency's (DARPA) Phoenix and ViviSat's Mission Extension Vehicle are relevant examples of ongoing projects. Two major conferences on rendezvous and proximity operations (RPO), which include ADR and on-orbit satellite servicing (OOS), occurred in 2012. The first was held by DARPA near Washington, DC; the second was hosted by Secure World Foundation in Brussels. These conferences addressed the non-technical elements of RPO, such as pertinent legal, political, and commercial concerns.[63] See Theme 3 for potential ASAT applications of RPO.

Research and development in active debris removal continue in 2012

Many projects and programs in recent years have tackled the growing orbital debris problem not only with mitigation measures, but active remediation. Recent studies indicate that even with post-mission disposal compliance of approximately 90%, the population of trackable debris in LEO will continue to grow.[64] Projects such as ATK's Multi-layered Shield[65] and the NASA-supported ElectroDynamic Delivery Experiment (EDDE) being designed by Star Technology and Research[66] progressed this year, as did work on the Swiss Space Center's CleanSpaceOne.[67]

Also in 2012 DLR awarded Astrium a one-year contract valued at 15 million euros for the preparatory mission and product design stages of its ADR and satellite servicing project, called DEOS.[68] Hardware construction stages will follow.[69] New concepts to emerge in 2012 include the Rensselaer Polytechnic Institute's design for a propellant-free spacecraft that would exploit atmospheric drag to maneuver and could serve as an ADR concept.[70]

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.[71]

Originally adopted in 1994, the International Telecommunication Union (ITU) Constitution[72] 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."[73] Military communications are exempt from the ITU Constitution, though they must observe measures to prevent harmful interference. It is observed that "interference from the military communication and tracking systems into satellite communications is on the rise,"[74] as military demand for bandwidth grows.

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.

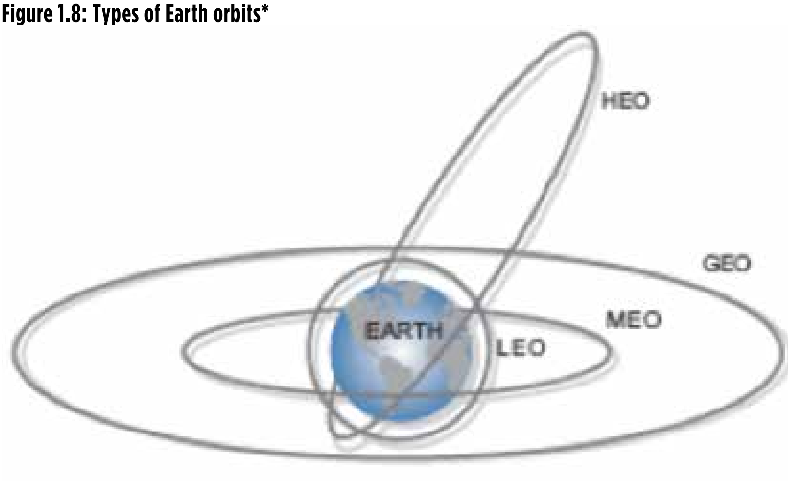
Issues of interference arise primarily when two spacecraft require the same frequencies at the same time and their fields of view overlap or when they are transmitting in close proximity to each other. While interference is not epidemic, it is a growing concern for satellite operators, particularly in 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 approximately 1,071 operating satellites, of which 523 were in LEO, 75 in MEO, 435 in GEO, and 38 in Highly Elliptical Orbit (HEO).[75] HEO is increasingly used for specific applications, such as early warning satellites and polar communications coverage. LEO is often used for remote sensing and Earth observation, and MEO is home to space-based navigation systems such as the U.S. Global Positioning System (GPS). Most communications and some weather satellites are in GEO; because orbital movement at this altitude is synchronized with 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;[76] these slots are also optimal for the rest of the Americas. Similarly desirable spots exist over Africa for Europe and over Indonesia for Asia.

Figure 1.8: Types of Earth orbits*



* See Annex 2 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.[77]

To avoid radio frequency interference, GEO satellites are required to maintain a minimum of two and up to nine degrees of orbital separation, depending on the band they are using to transmit and receive signals, the service they provide, and the field of view of their ground antennas.[78] Thus, only a limited number of satellites can occupy the prime equator (0 degree inclination) orbital path. In the equatorial arc around the continental United States there is room for only an extremely limited number of satellites.

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

Originally, crowding in the MEO region was not a concern, as the only major users were the United States with GPS and Russia with its Global Navigation Satellite System (GLONASS). However, concern is increasing that problems could develop in this area 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.

2012 Developments

Pressure on the radio frequency 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 2012, as did concerns about crowding and interference, which come with increased demand. In the United States debates dragged on over the potential for LightSquared's planned high-speed broadband wireless network to interfere with Global Positioning System (GPS) signals.[80] In mid-February 2012 the U.S. Federal Communications Commission (FCC) revoked its conditional waiver[81] for LightSquared's plan to use L-band frequencies for its network. This decision came a day after the FCC received a letter from the National Telecommunications and Information Administration (NTIA), which stated that there was no practical way to avoid LightSquared's interference with GPS.[82]

LightSquared filed for Chapter 11 bankruptcy protection in May after failing to reach a debt-restructuring plan with creditors "who lost faith in a plan that no longer had government support."[83] However, Congress retained some support for LightSquared and at a 21 September hearing criticized the FCC for its decision.[84] Soon after the hearing LightSquared proposed yet another plan to reduce its impact on GPS signals,[85] although it has always claimed that it adhered to FCC requirements and that a weak GPS signal and poorly designed receivers were the problem.[86] A paper released in mid-October 2012 demonstrated the weakness of GPS signals and a method for attacking them.[87]

Despite the headache associated with LightSquared, the Obama administration continues to search for ways to free up spectrum for commercial, wireless use as part of an initiative to increase the amount of broadband internet access in the United States under the National

Broadband Plan.[88] In March 2012 the NTIA issued a report confirming the possibility of repurposing the 95 megahertz between 1755-1850MHz currently restricted for government use.[89] However, this plan comes with several challenges, such as identifying alternative locations to be used by the government.[90] Similarly, in the 2010 National Broadband plan, the FCC controversially proposed to reallocate portions of the spectrum currently used by weather satellites to commercial users, specifically in the 1675-1720MHz range.[91] In an August 2012 meeting the FCC and NTIA endorsed this decision, but only for the 1695-1710MHz range.[92] The worldwide weather community firmly opposes this plan, arguing it will interfere with their ability to forecast weather and natural disasters.[93]

Similar disputes over spectrum allocation took place in other parts of the world in 2012. An African and Arab initiative to allocate the 700MHz band to wireless services conflicts with the European Union's (EU) Radio Spectrum Policy Programme.[94] In what is called the second digital dividend, the 2012 World Radiocommunications Congress decided on a last-minute addition to the agenda to allocate the frequencies between 694 and 790 MHz—used since 2007 for mobile use for the Americas and Asia-Pacific—for mobile use in Europe, the Middle East, and Africa.[95] This decision "paves the way to a near-global use of harmonized spectrum in the 700MHz band,"[96] but clashes with long-held arrangements in Europe that license use of this frequency band to terrestrial broadcasters.[97]

Increased efforts to reduce unintentional radio frequency interference

Efforts to reduce unintentional interference include Intelsat's Interference Mitigation Initiative, which aims to reduce RFI through training and product quality assurance. By September 2012 more than 1,000 employees and customers around the world had participated in the Intelsat-sponsored Global VSAT Training program.[98] Intelsat was also heavily involved in the successful testing of Carrier ID technology to reduce and mitigate transmission interference during the 2012 Summer Olympics in London.[99] By tagging all uplink signals so that transmission sources are easily and quickly identified, this technology, while not preventing interference,[100] speeds up the mitigation process significantly.[101] Widespread implementation of this technique during the Olympics was a major advance in reducing accidental RFI.[102]

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 meters in diameter).[103] By the end of 2012 there were 9,445 known NEAs, 853 of which were 1 kilometer in diameter or larger—the so-called "civilization-killer" class.[104]

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.

2012 Developments

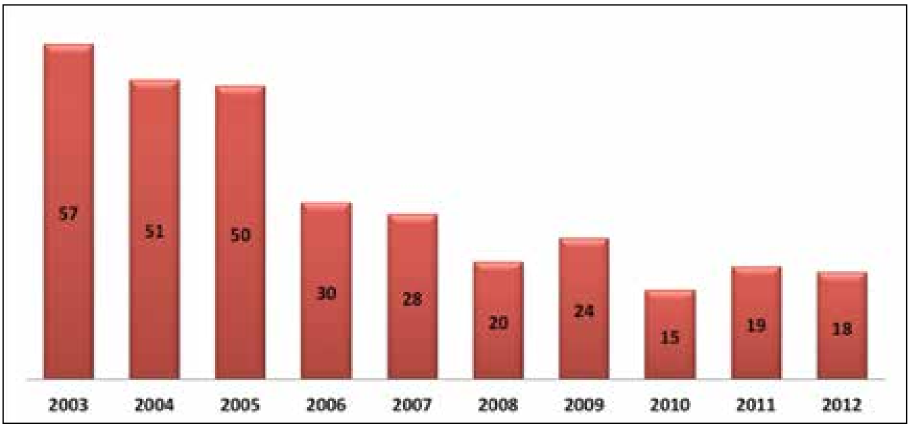
Space agencies, amateur observers produce increasingly accurate assessment of NEO population

In 2012 NASA produced the "best assessment yet of our solar system's population of potentially hazardous asteroids" (PHAs).[105] The observations behind this assessment were gathered by the Wide-field Infrared Survey Explorer (WISE) and provide new detail on the total number of PHAs, their origins, and their potential to harm Earth.[106] The study is part of the NEOWISE portion of the WISE mission, which sampled 107 PHAs to come to conclusions about the whole population. NEOWISE estimates that there are approximately 4,700 PHAs, with a margin of error of plus or minus 1,500. They have located 20-30% of the total estimated population.[107]

Amateur observers and the astronomy community also contributed to NEO discoveries in 2012. Both Spain's La Sagra Sky Survey at the Observatorio Astronómico de Mallorca and the United Kingdom's Faulkes Telescope Project at the University of Glamorgan became part of ESA's SSA Programme this year.[108] These partnerships demonstrate a move toward crowdsourcing the search for NEOs.[109] The Faulkes Telescope Project will assist in discovering and identifying NEOs through amateur observations and educational outreach.[110] This partnership also enables ESA's SSA Programme to access telescope observations through Faulkes' relationship with the U.S.-based Las Cumbres Observatory Global Telescope network, which includes telescopes in Hawaii and Australia.[111]

In 2012 scientists discovered a large asteroid expected to make a very close approach to Earth in 2013.[112] Asteroid 2012 DA14 did in fact narrowly miss Earth on 15 February 2013.[113]

Figure 1.9: Number of large* NEAs discovered by year (2003–2012)[114]



* 1 kilometer in diameter or larger

International awareness of NEO threat and progress in international response continues

As the hunt for NEOs continued in space, the search for an international solution continued on Earth. As a practical or technical solution, two Russian cosmonauts on the ISS installed anti-meteorite panels on 20 August 2012.[115] These protective panels are meant to shield the ISS from micro-meteorites and space debris.[116] This measure was taken after a piece of debris or micro-meteorite struck and damaged a windowpane in the ISS Cupola.[117]

Seeking new deflection concepts, researchers at the University of Strathclyde in Glasgow are developing a constellation of small satellites that would fire solar-powered lasers at an asteroid.[118] This new technique addresses the challenge faced by methods that involve heavy, large spacecraft.[119]

International and cooperative responses to NEO threats made progress in 2012. In January Project NEOShield was established to bring together 13 research and industry partners to examine prevention of NEO impacts on Earth.[120] The effort is being headed by Alan Harris under the auspices of German space agency DLR and is heavily funded by the European Commission.[121] The project is expected to take three-and-a-half years to explore the three most promising asteroid threat-reduction concepts: kinetic impactors, gravity tractors, and the explosive blast-deflection method.[122]

Work continued on an initiative looking at international cooperative solutions to the NEO problem. Action Team 14, part of UN COPUOS, has been working for the past few years on devising a UN "framework for coordinating an international response to potentially dangerous NEOs."[123] Its final report was expected at the February 2013 meeting of the UN COPUOS Scientific and Technical Subcommittee.[124] Action Team 14 has also been helping to organize workshops on specific asteroid threats and to raise awareness of the issue.[125]

Indicator 1.4: Space weather

"Space weather" describes changing environmental conditions in near-Earth space. Explosions on the Sun create "storms of radiation, fluctuating magnetic fields, and swarms of energetic particles."[126] These phenomena travel outward through the solar system with a flow of charged particles called solar wind. When they reach Earth they interact in complex ways with Earth's magnetic field.[127]

Some space weather storms can damage satellites and disrupt cell phone communications systems. Space is filled with magnetic fields, which control the motions of charged particles. Geomagnetic storms and more solar ultraviolet emissions heat the Earth's upper atmosphere, causing it to expand, eventually resulting in increased drag, which causes satellites to slow down and change orbit slightly.[128] This phenomenon requires that LEO satellites be routinely boosted to higher orbits; otherwise, they may eventually fall and burn up in Earth's atmosphere.[129]

As technological advances have produced smaller spacecraft components, "their miniaturized systems have become increasingly vulnerable to solar energetic particles."[130] These particles can cause considerable damage to microchips and affect software commands in satellite computers.[131] When a satellite travels through this energized environment electrical discharges can harm and possibly disable spacecraft components.

Although communications at all frequencies can be affected by space weather, high frequency (HF) radio wave communications are particularly vulnerable because reflection from the ionosphere is necessary to carry HF signals over great distances.[132] Irregularities in the ionosphere caused by space weather can contribute to signal fading as "highly disturbed conditions can absorb the signal completely and make HF propagation impossible."[133] Given that telecommunication companies increasingly depend on higher frequency radio waves that penetrate the ionosphere and are relayed via satellite to other locations, space weather events can impede critical communications, including those used in search-and-rescue efforts and military operations.[134]

2012 Developments

Space weather events continue to affect space operations

The largest radiation storm in nearly a decade occurred on 23 January 2012,[135] forcing some airlines to reroute flights scheduled to fly over the poles where their communications might be threatened.[136] NOAA's Space Weather Prediction Center (SWPC) also received reports of "'soft' or correctable errors on satellite systems" as a result of the storm.[137]

Two solar flares erupted within an hour of each other on the evening of March 6 on the Earth-facing portion of the sun, sending two significant coronal mass ejections rapidly toward Earth.[138] NASA and NOAA warned that the storm could disrupt terrestrial and space-based systems, such as GPS.[139] High-frequency radio blackouts resulted[140] and it is suspected that the storm might have "temporarily knocked American military satellites offline."[141]

Strong radio blackouts occurred on 6 and 12 July 2012 due to solar flares.[142] On 1 October 2012 SWPC observed a strong geomagnetic storm "due to the effects of the [coronal mass ejection (CME)] that arrived at Earth on 30 September."[143] This category of geomagnetic storm is expected to cause surface charging of satellite components, drag on satellites in LEO, and orientation problems.[144]

Progress continues on effectively forecasting space weather events

Beyond tracking satellite and debris, SSA improves our understanding of space weather events. In 2012 progress was made in predicting solar flares more than a day in advance, which will "help protect satellites, power grids and astronauts from potentially dangerous radiation."[145] This progress is based on research that measures the difference in gamma radiation emitted during radioactive atomic decay.[146] As well, the United Kingdom's Met Office announced that the climate and weather model it used would be adapted to include space weather[147] so that it could begin to offer operational space weather forecasts.[148] And interest is growing in developing a commercial market for tailored space weather products and information based on public data.[149]

Indicator 1.5: Space Situational Awareness

Space Situational Awareness (SSA) refers to the technical ability of different spacefaring actors "to monitor and understand the changing environment in space."[150] 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.[151] 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 inasmuch 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 meter 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:[152]

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. Those 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,[153] 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.

2012 Developments

Capabilities

The United States continues to invest in and develop its SSA capabilities

The United States currently operates the world's most expansive and comprehensive space situational awareness capability—the Space Surveillance Network. In 2012 the United States continued to invest in and expand this capability. Despite severe budget constraints, SSA fared well in Congressional budget deliberations.[154]

The U.S. military made progress in 2012 in its S-Band Space Fence, an effort aimed at tracking more and smaller objects in space while also relieving legacy SSA systems.[155] Valued at $6.1-billion over its expected life, the Space Fence will employ two or three geographically distributed ground-based radars. It is anticipated to begin operations in 2017, two years after its initial due date.[156] In February 2012 Lockheed Martin's preliminary system prototype received final approval from the U.S. Air Force (USAF).[157] A few months later, Raytheon's preliminary design review with the USAF was also completed.[158] Lockheed Martin then submitted its final contract proposal to build the Space Fence in mid-November.[159] In September the USAF announced that its first S-Band Space Fence facility would be placed on Kwajalein Island in the Republic of the Marshall Islands.[160] The contract for construction has not yet been awarded, but building is expected to begin in September 2013 and last for four years, with initial operations commencing in 2017.[161]

The USAF Research Laboratory and Boeing announced that they had completed a two-year upgrade of the Advanced Electro-Optical System (AEOS), one of a half-dozen telescopes on Maui that provide SSA.[162] Both AEOS and another upgraded telescope at the facility were declared to have achieved initial operational capability in mid-June. AEOS is the largest telescope owned by the U.S. Department of Defense.[163] On 18 September 2012 defense contractor MacAulay-Brown announced that it had won a contract with the USAF Research Laboratory to conduct research on electro-optical threat warning research, which, inter alia, contributes to SSA.[164]

The JSpOC Mission System is the latest in a 12-year effort to replace and update the legacy IT infrastructure used by JSpOC for its SSA operations.[165] In a 2012 development, Analytical Graphics, Inc. won a contract to provide its SSA Software Suite to the Mission System in a move that is expected to reduce cost and schedule.[166]

Plans to improve SSA capabilities around the world continue in 2012

While its SSN may be the most extensive SSA network in the world, the United States was not the only country to operate SSA capabilities or pursue improvements in 2012. Russia proposed a federal program to "neutralize space threats," including those posed by NEOs and debris.[167] These threats necessitate "significant financial, intellectual and manufacturing resources" and must be countered "through international efforts" according to Vyacheslav Davydov, the head of Russian space agency Roscosmos. The Russian Academy of Sciences will coordinate this program.[168]

The Russian Academy of Sciences also heads the International Scientific Optical Network (ISON), which added two new partners in 2012: Universidad Autónoma de Sinaloa in Mexico and the Research Centre of Astronomy and Geophysics of the Mongolian Academy of Sciences.[169] Additionally, three new ISON facilities began operations: Cosala in Mexico, Khureltogoot in Mongolia, and Kislovodsk in Russia.[170] ISON added 270 newly discovered HEO and GEO pieces of debris to its catalog[171]—over 100 more objects than were discovered in 2011 and over 200 more than were found in 2010.[172]

The future of the European SSA Preparatory Programme was determined at ESA's 2012 Ministerial Council. After 18 months of design and development, ESA's first debris test radar was installed in Spain in mid-October.[173] This test radar will "be used to develop future debris warning services."[174] In September came the announcement of a four-million-euro contract between ESA and France's Office National d'Etudes et Recherches Aerospatiales to develop yet another new test radar for the SSA program, to be based outside Paris.[175] And DLR is developing an "optical observation system with a powerful laser" that can measure small objects in orbit.[176] This laser method was tested successfully in January 2012.[177]

The preparatory phase of the ESA SSA Programme covered the period 2009–2012. Period 2 (2013–2016) was voted on at the November 2012 Ministerial Council of the ESA.[178] This second phase will cover development, testing, and validation activities.[179] The Ministerial Council decided to continue supporting the build-up of an SSA capability in close cooperation with ESA's Member States and European partners, with a focus on activities related to space weather. Activities related to NEO and space surveillance and tracking (SST) will also be pursued, with an emphasis on R&D. Fourteen SSA Participating States take part in space weather activities and nine in activities related to NEO and SST.

Canada experienced a setback in planned improvements to its SSA capability. An Indian launch that will carry Canadian satellites NEOSSat and Sapphire, planned for late 2012, was delayed until 2013.[180]

Amateur observers again demonstrated their ability to contribute to SSA in 2012 when they helped to track the new North Korean satellite and provide information about its flight.[181] Using data gathered from amateurs in South Africa and the United Kingdom, it was determined that the North Korean satellite was tumbling, not fixed toward Earth as originally intended, suggesting that the satellite's stabilizers had malfunctioned.[182] Another indication of malfunction is that no amateur observers have been able to pick up transmissions from the satellite, which was supposed to play "The Song of General Kim Jong-Il."[183]

SSA sharing

Efforts continue to increase SSA sharing among space actors

Other 2012 improvements to SSA were accomplished through international cooperation and data-sharing. By the end of 2012 the United States had 33 official sharing agreements as part of its SSA Sharing Program and was negotiating as many as 10 more with other countries and space entities.[184] These formal agreements are in addition to some 85,000 Space-Track.org accounts with 185 countries.[185] During 2012 USSTRATCOM delivered 20–30 emergency close approach notifications per day to all satellite owner-operators, regardless of formal agreement, as well as orbital data to 90 commercial and foreign entities and 180 U.S. entities.[186] In 2012 USSTRATCOM issued more than 10,000 collision warnings and assisted in 75 avoidance maneuvers.[187] By the end of July 2012, 39 satellites in LEO and four in GEO had been maneuvered because of these warnings.[188]

It was announced in November 2012 that Australia would host two U.S. space surveillance systems, improving the Southern Hemisphere coverage of the SSN.[189] Australia and the United States have decided to forge closer links between their militaries[190] and will work toward basing the DARPA-developed Advanced Space Surveillance Telescope (SST) on Australian soil.[191] The SST is able to detect and track small objects at high altitudes and this Southern Hemisphere placement will expand SSN coverage.[192] The other SSA system will be USAF C-band ground-based radar[193] as per the 2010 Space Situational Partnership agreement between the two nations.[194] On 30 April 2012 the White House announced that the United States and Japan would develop a framework for sharing SSA data "as part of expanded space-related ties."[195]

The United States has also been leading a Combined Space Operations (CSpO) initiative to improve SSA data sharing, among other objectives.[196] Thus far Australia, Canada, New Zealand, and the United Kingdom have joined the United States in this initiative: and it is hoped that more partners will join.[197]

The United States also looked to non-traditional partnerships to expand its SSA capabilities in 2012. DARPA "unveiled a program on 10 November that would enlist private, amateur astronomers' help" through SpaceView.[198] SpaceView is really an equipment-sharing venture, in which the SSN would augment its SSA datasets by purchasing remote access to existing telescopes or by providing a telescope to a selected amateur, with owners free to use the telescopes for their own purposes when not used for SSA.[199]

The coordinated reentry of the failed Phobos-Grunt spacecraft in January 2012 was a significant accomplishment in international SSA cooperation.[200] ESA's Space Debris Office acted as the central coordinating body, with participation by NASA, Roscosmos, and others.[201] The IADC began the comprehensive reentry prediction campaign on 2 January[202] and tracked the spacecraft until it reentered over the Pacific Ocean in mid-January.[203]

In 2012 NOAA (22 May) and NASA (8 August) became the first government agencies to join the Space Data Association (SDA),[204] which is open to all owners and operators of in-orbit satellites. According to then-SDA Chairman Stewart Sanders, these agreements were "particularly gratifying as it shows that we can find a way to engage with commercial/governmental entities while retaining the benefits of the strong legal data protection framework we have put in place for the SDA members."[205] The SDA won two awards in 2012: the Space Risk Management Award at the World Risk Space Forum 2012 and the Innovation in Industry Collaboration on the Safe Use of Space award from the Society of Satellite Professionals International.[206]

Access to and Use of Space by Various Actors

Indicator 2.1: Space-based global utilities

The use of space-based global utilities, including navigation, weather, and search-and-rescue systems, has grown dramatically over the last decade. While key global utilities 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 experimental and thus far 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 2012.

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."

2012 Developments

Navigation systems of various nations continue to evolve

On 12 January 2012 British satellite manufacturer Surrey Satellite Technology Ltd. (SSTL) celebrated the sixth anniversary of signal transmission from its GIOVE-A satellite. In January 2006 Europe's ambitious Galileo satellite navigation program secured vital frequency filings.[28]

The satellite, which was launched on 28 December 2005,[29] was one of two in-orbit testbeds for Galileo. With a design life of 27 months, the satellite was created "to secure the radio frequency filing for the Galileo satellite navigation system with the International Telecommunication Union (ITU), test the critical Galileo payload equipment, and perform tests to characterize the radiation environment of Medium Earth Orbit (MEO)—the region of Earth's orbital space used by navigation satellites."[30]

The "first European satellite launched into the demanding MEO environment," GIOVE-A remained fully operational and was declared "a full mission success" by the ESA in 2008.[31] Surpassing its design life by years, the satellite continued to provide ESA with data about payload performance in 2012.[32]

SSTL is now building the payloads for 14 satellites for ESA, "which will provide the Initial Operational Capability of the Galileo constellation providing navigation services to end-users."[33]

Galileo, which offers real-time positioning services, is expected to be interoperable with the U.S. GPS system and Russia's GLONASS system.[34]

A week-long Cospas-Sarsat task group meeting hosted at ESA's ESTEC technical center in Noordwijk, the Netherlands, began on 27 February 2012 to discuss a major expansion of the Cospas-Sarsat search-and-rescue distress alert detection and information distribution system.[35] At the meeting, representatives from 21 nations, along with the European Commission and the ESA, explored ways in which the Galileo navigation system could be better harnessed to pinpoint distress calls for rapid search and rescue. Testing for the system expansion is expected to be completed by 2015.

The international Cospas-Sarsat satellite relay system—established by Canada, France, Russia, and the United States in 1979—has been used for more than 30 years to detect air and sea distress signals. "Cospas" is a Russian acronym for "Space System for the Search of Vessels in Distress," while "Sarsat" stands for "Search and Rescue Satellite-Aided Tracking."[36]

On 25 February 2012 China successfully launched the eleventh satellite for its indigenous global navigation and positioning satellite system, Beidou (Compass).[37] The satellite, launched from the Xichang Satellite Launch Center in southwestern Sichuan Province, was boosted by a Long March-3C carrier rocket into a geosynchronous orbit.

China began to build the Beidou system in 2000, intent on breaking its dependence on the U.S. Global Positioning System.[38] In 2006 China announced that it would extend Beidou into a global system for military, civilian, and commercial use.[39] The plan was for five satellites in GEO and 30 in MEO. While Beidou now provides only regional coverage, it is expected to evolve into a global navigation system by 2020.[40] The Beidou system started to provide services on a trial basis on 27 December 2011 and is being used to support such activities as transportation, weather forecasting, marine fisheries, hydrological monitoring, and mapping.

Russia plans to spend 346.5-billion rubles (almost US$12-billion) on its Glonass satellite navigation system between 2012 and 2020.[41] In January 2012 Roscosmos and the Ministry of Economic Development and Trade submitted a draft development program for Glonass to the government.[42]

Expenditures include 146.9-billion rubles ($5-billion) for system support and 138.3-billion rubles ($4.6-billion) for development. In 2012 there was a constellation of 31 Glonass satellites in orbit; 24 provided global coverage, while four were in reserve and one was undergoing trials.[43]

By 2020 Russia plans to have 30 satellites in orbit, including six in reserve. To achieve this goal, Russia is planning to launch 13 Glonass-M satellites between 2012 and 2020. Twenty-two new-generation Glonass-K spacecraft are to replace the outdated spacecraft. Eight Proton-M and 11 Soyuz-2.1b carrier rockets are to be constructed.[44]

Australia develops lightweight Earth observation satellite

In July 2012 researchers at the Australian Centre for Space Engineering Research announced the development of a system design for a new spacecraft that weighs about 8 kg, known as the 6U CubeSat.[45] The satellite is expected to be able to perform some of the same commercial Earth-observation missions as microsatellites that weigh approximately 100 kg. For example, the new shoebox-sized spacecraft will enable night imaging and agricultural monitoring missions.

According to the Centre's Dr. Steven Tsitas, the significant size reduction can result in a spacecraft that is 10-times cheaper to produce ($1-million versus $10-million). "The cost may now be low enough to make it politically possible for Australia to establish a sustainable national space program," he said.[46] The original one liter-volume CubeSat was developed by U.S. researchers for educational purposes. The modified 6U version has a greater payload capacity and so can carry advanced instruments and cameras.

Iran launches Earth observation satellite

On 3 February 2012 Iran launched an experimental Earth observation satellite with the Persian name Navid ("bearer of good news" or "best wishes") on a two-month mission. The 50-kg satellite was launched aboard a Safir 1-B rocket.[47] This was Iran's first successful space mission since it failed to put a live monkey in space in September 2011.[48] Iranian Space

Agency officials described the satellite as cube-shaped, approximately 50 cm wide. Navid was controlled by a ground station in each of the cities of Karaj, Tabriz, Qeshm, Bushehr, and Mashhad,[49] and travelled in an elliptical orbit, passing over Iran six times a day. The satellite reentered Earth's atmosphere on 1 April.[50]

Reports indicated that on the same day as the Navid launch, the Fajr (Dawn) satellite was to be launched on Khordad 3. It was described by Iranian officials as "an observation and measurement" satellite weighing 50 kg. It was built by Sa-Iran, a company affiliated with the defence ministry.[51] Its launch was delayed for unknown reasons.[52]

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

* France and the United Kingdom no longer conduct independent launches, but France's CNES manufactures the Ariane launcher used by Arianespace/ESA.

South Africa to launch its first nanosatellite

In August 2012 the Cape Peninsula University of Technology (CPUT) in South Africa announced that a nanosatellite known as ZACUBE-1, weighing 1.2 kg, would be launched in November to collect information about space weather.[53] Funded by the Department of Science and Technology, the satellite is South Africa's and Africa's first nanosatellite.[54] ZACUBE-1 payload is to include a High Frequency (HF) radio beacon, developed in collaboration with the South African National Space Agency (SANSA).[55] The satellite will transmit an HF radio signal that will be received by ground stations at SANSA and CPUT and assist scientists in modeling the ionosphere. According to SANSA, "ionospheric models are crucial towards gaining an understanding of space weather and its impact on communication technology."[56]

The launch of ZACUBE-1 has been delayed until mid-2013. It is to be launched as a secondary payload on a Dnepr vehicle from the Dombarovsky (Yasny Cosmodrome) launch site in Russia.[57]

Meteosat Third Generation Agreement signed at Ministerial Meeting

At the ESA Ministerial Council in Naples in November 2012, Jean-Jacques Dordain, Director-General of ESA, and Alain Ratier, Director General of EUMETSAT, signed an agreement on the Meteosat Third Generation weather satellite system. MTG cooperation was first agreed to at the ESA Ministerial Council in 2008. According to the ESA, this latest agreement "determines the principles of cooperation between the two agencies when establishing the various components of the Meteosat Third Generation system (MTG) and carrying out the related activities."[58]

ESA is to develop the MTG prototype satellite to meet user and system requirements defined by EUMETSAT. ESA also will look after satellite procurement. EUMETSAT is to develop ground control systems and infrastructure, procure launch services, and operate the final system.[59]

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:[60] *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.[61] 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. By the end of 2012 ESA had 20 Member States; the last to join was Poland, which ratified the ESA Convention on 19 November 2012.[62] 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).[63] 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.

Expenditures for major civil space agencies are highlighted below.

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 over 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.[64]

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.[65] 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.[66] Future plans include a permanent human presence on the lunar surface.[67] 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:[68]

- 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.

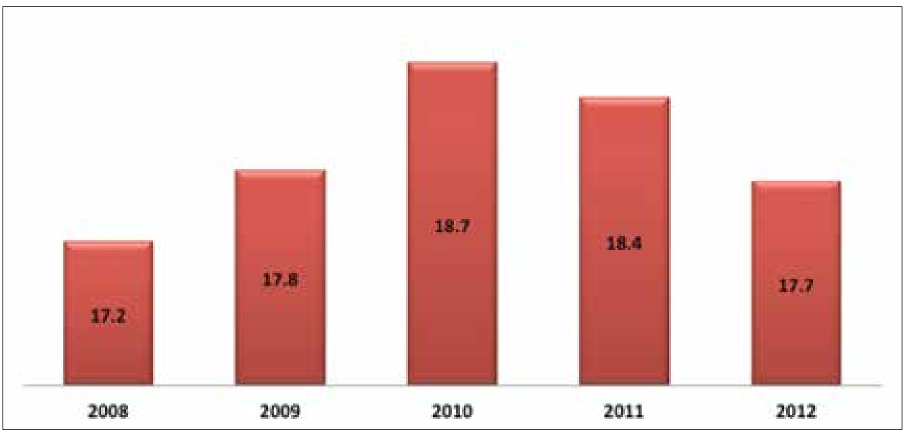
China began developing the Shenzhou human spaceflight system in the late 1990s and completed a successful human mission in 2003, becoming the third state to develop an independent human spaceflight capability.[69] A second mission was successfully completed in 2005, and the third and latest in 2008.

2012 Developments

Changing budgetary allotments for civil space programs

In February 2012 NASA announced that it had requested a budget of $17.7-billion for fiscal year 2013 to support space exploration and technology development. Even in a fiscally constrained environment, NASA expected to continue implementation of the space science and exploration program agreed to by President Obama and Congress, which lays the foundation for ground-breaking discoveries on Earth and in outer space. By 2035 NASA hopes to have reached new destinations, such as an asteroid and Mars.[70]

Figure 2.3: NASA 2008-2012 budget (in $USB)

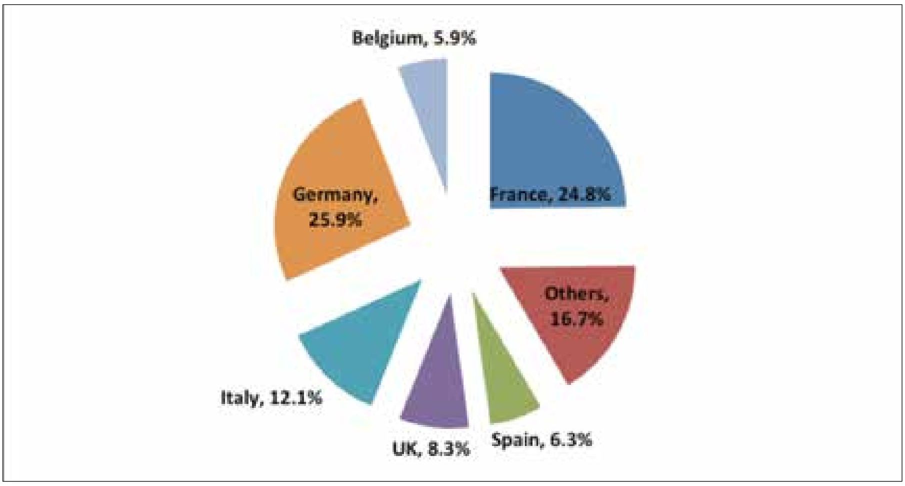


Among budget items are $4-billion for each of space operations and exploration activities, including close-out of the Space Shuttle Program and funding for the International Space Station. Other items include continued work on the Space Launch System; a new heavy-lift rocket to carry astronauts to an asteroid and Mars, with the associated Orion crew capsule; final preparations for Orion's 2014 Exploration Flight Test 1; and preliminary design reviews of major Space Launch System elements. Priority is given to NASA's partnership with the commercial space industry to facilitate crew and cargo transport to the ISS and to developing use of the ISS "to improve life on Earth and help make the next great leaps in scientific discovery and exploration."[71]

In January 2012 officials of the European Space Agency announced that its operational budget for 2012 would remain essentially unchanged from 2011 at 4-billion Euros (approximately $5.2-billion).[72] A decline in contributions from some ESA members had been offset by increased payments by the European Union's executive committee. In "what may be an unprecedented development," the biggest single contributor to the overall budget was Germany, not France.[73]

According to ESA Director-General Dordain, financial problems affecting many European governments had not forced ESA to cancel or substantially modify any of its approved programs.[74] He indicated that the Agency is working to reduce the financial burdens it imposes on contributing governments. ESA aims to cut internal costs—which totaled about 685-million Euros in 2010—by 25% by the end of 2015.[75]

Figure 2.4: Top contributors to ESA's 2012 General Budget* [76]



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

According to the state-run RIA news agency, Russia is significantly boosting its space industry budget over the next seven years. In December 2012 it was reported that Russian Prime Minister Dmitry Medvedev had approved a plan to spend $68.71-billion (2.1-trillion rubles) on developing Russia's space industry between 2013 and 2020.[77] (In each of 2010 and 2011 Russia allocated about $3.3-billion.) According to Medvedev, "The programme will enable our country to effectively participate in forward-looking projects, such as the International Space Station (ISS), the study of the Moon, Mars and other celestial bodies in the solar system."[78]

Increased government spending is expected to partially offset recent setbacks in Russia's space industry. The failure of a Proton rocket after launch in 2012 caused the multimillion-dollar loss of an Indonesian and a Russian satellite. A similar problem had caused the loss of a $265-million communications satellite in 2011. Medvedev criticized the state of the industry in August 2012, saying that such problems were costing Russia prestige and money.[79]

Since the retirement of the space shuttle fleet, NASA has paid Russia approximately $60-million per U.S. astronaut to transport them to the ISS. This arrangement is expected to continue until NASA has a new craft available for this purpose.[80]

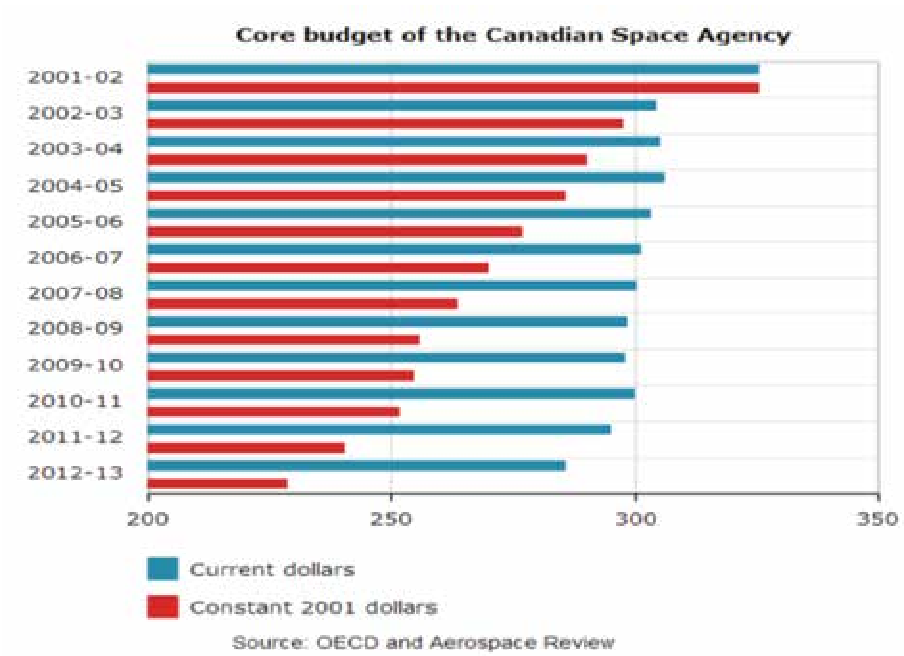
Russia has reportedly fully financed its space programs until 2016, including two Moon expeditions.[81]

The Canadian Space Agency's (CSA) core budget has decreased over the past 10 years, from $325.8-million in 2001-02 to $285.8-million for 2012-13.[82] In 2011-12 the CSA's annual budget was nearly $425-million, but one-third was temporary funding related to the recession-fighting Economic Action Plan and specific projects.[83] CSA expects to cut its budget by $29.5-million by 2014-15 in response to federal government's budget reductions.[84]

The Organisation for Economic Co-operation and Development indicates that countries smaller than Canada, such as Belgium, Israel, and Luxembourg, spend more of their GDP on space than Canada does.[85]

In November 2012—the month before Canadian astronaut Chris Hadfield flew to the ISS—a review of the country's aerospace sector commissioned by the federal government was released. The review, led by former cabinet minister David Emerson, urges Ottawa to boost spending on the development of space technology and to stabilize CSA's core funding over a 10-year period. "Over the last decade, the Canadian space program has foundered," said Emerson. "There's been some lack of clarity around priorities and an uneven performance in the implementation of projects," he added.[86]

Figure 2.5: Canadian Space Agency budget



The 2012-13 budget for the Indian Space Research Organisation amounts to approximately $1.3-billion.[87] Although ISRO's budget has increased every year since 2004-05 when it was $591-million it is still less than 10% of NASA's.[88]

On 29 September 2012 India launched the 3,400-kg GSAT-10 communications satellite—the heaviest it has built—aboard an Ariane-5 rocket. During its 15-year lifespan, the satellite will boost telecommunications, direct-to-home, and radio navigation services, adding 30 transponders to the India's current capacity.[89] This should allow India greater independence from foreign transponders.

India plans to launch an orbiter to Mars in October or November 2013. NASA has agreed to provide "the deep space navigation and tracking support to the mission during the non-visible period of the Indian Deep Space Network," according to a U.S. State Department announcement.[90]

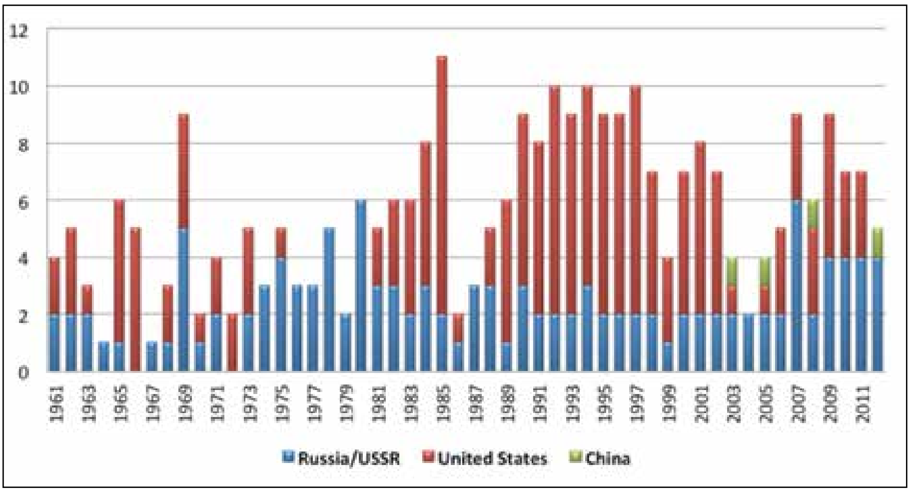
China conducts first manned mission to Tiangong-1 space station

On 16 June 2012 Chinese astronauts or *taikonauts*, including China's first female astronaut Liu Yang, successfully carried out a manned docking with an experimental space module. This mission, China's fifth manned space mission, marks another step in China's drive to build a space station.[91] The three-person crew aboard the Shenzhou 9 spacecraft, which used the Long March 2F carrier rocket,[92] linked with the Tiangong-1 module.

The docking exercise marked the first time China has been able to transfer astronauts between two orbiting spacecraft.[93] During the 13-day mission, the astronauts worked and slept aboard Tiangong 1 which, according to media reports, includes an exercise bike and a video telephone booth.[94]

Rendezvous and docking exercises between the two vessels are seen as important achievements in China's efforts to acquire the technological and logistical skills to run a full space lab that can house astronauts for long periods.[95]

Figure 2.6: Human spaceflight missions by country 1961–2012



Canada renews commitment to International Space Station

On 20 February 2012 CSA President Steve MacLean and Minister of Industry Christian Paradis announced that Canada would renew its commitment to the International Space Station, a project that the country has supported since 1998.[96]

MacLean and Paradis also unveiled two space projects: Microflow and Lab on a CD, which are designed "to accelerate how patients are diagnosed, in space and on earth." They "will use space as a test environment to develop smaller, cheaper, and faster medical technology that can process and analyze medical samples" aboard the ISS.[97]

Lab on a CD is intended to provide real-time diagnostics of infectious diseases at the patient's point of care.[98] It can perform sophisticated genetic analysis of samples in just minutes. This project has funding from CSA and the European Life and Physical Sciences Program.[99] The Microflow is a technology demonstration platform that was brought to the ISS with Canadian Space Agency Astronaut Chris Hadfield in December 2012. It was successfully activated by Hadfield in March 2013.[100]

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.[101] One of the first scientific satellites, Ariel-1, launched in 1962, was the world's first international satellite, built by NASA to carry U.K. 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 U.K. to enable astronauts to conduct experiments onboard the Mir space station.[102] 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 to 1998 there were nine dockings of the U.S. Space Shuttle to the Mir space station, with various crew exchanges.[103] 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. As of June 2013 a total of 134 flights (not including one SpaceX Dragon test flight) had carried components, equipment, and astronauts to the station,[104] which remains unfinished. The flights comprised 89 Russian launches, 37 Space Shuttle launches, two operational flights by the SpaceX Dragon, three Japanese Hypersonic Test Vehicles (HTVs), and three European Automated Transfer Vehicles (ATVs).[105] The ISS is projected to cost approximately $129-billion over 30 years of operation.[106]

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 under Indicator 1.5.

2012 Developments

United States signs data-sharing agreement with Canada; eyes other countries

On 6 June 2012 Greg Schulte, deputy assistant secretary of defense for space policy, indicated in an interview that the United States was seeking more global cooperation in space activities, including data-sharing with various countries.[107] In May 2012 the United States and Canada signed a long-term partnership agreement that will allow the two countries to share surveillance data. The United States is seeking similar agreements with France, Japan, and other countries willing to share data from surveillance satellites.[108]

Schulte and his staff were encouraging U.S. lawmakers to enact export control changes that would allow some of the data-sharing wanted by the United States. As he noted, "Washington has operated largely on its own in space, but the growing number of countries with satellite and space capabilities has changed that."[109]

China deepens cooperation on space activities with various countries

In January 2012 China announced a plan to launch Bolivia's first telecommunications satellite into orbit in December 2013.[110] Named after an indigenous Bolivian hero who led an uprising against the Spanish conquistadors, the Tupac Katari satellite will be launched from China's Xichang Satellite Launch Center.[111] The original agreement was signed in 2010 between the Bolivian Space Agency and the Great Wall Industry Corporation of China. Bolivia should see benefits in education, medicine, and communications.[112] While the satellite is expected to earn about $40-million a year, most of the money will go to China's Development Bank to repay the loan Bolivia needed to fund the project.[113]

In November 2012 China welcomed former Indian President APJ Abdul Kalam and used the occasion to propose that China and India collaborate on a space solar power mission.[114] Officials of the China Academy of Space Technology (CAST) expressed great interest "in partnering the mission with international collaboration for Space based Solar Power initiative," according to V Ponraj, a member of Kalam's delegation. "Wu Yansheng, President of CAST has said his organisation is very much interested to collaborate with India and ISRO on the space mission and would like to establish a formal initiative from both the nations," Ponraj said in a statement.[115]

In recent years, China has signed space cooperation agreements with Argentina, Brazil, Canada, France, Malaysia, Pakistan, Russia, Ukraine, the ESA, and the European Commission. It has established space cooperation subcommittee or joint commission mechanisms with Brazil, France, Russia, and Ukraine.[116]

European Commission and South African National Space Agency in scientific cooperation agreement

On 6 December 2012 the European Commission's Joint Research Centre signed a cooperation agreement with SANSA to use South Africa's "remote sensing technologies to monitor atmospheric, terrestrial and marine environments." The goal is to better understand "the dynamics and evolution of our natural environment."[117] Optimal observation of Earth and the development of technologies and services will support national and international efforts related to disaster risk reduction, early warning, and emergency management.[118]

Hungary, Poland, and Romania launch their first satellites

The maiden launch of ESA's small Vega launcher took place on 13 February 2012.[119] Of the nine satellites it carried into orbit, seven were built by European universities. These ESA-sponsored educational CubeSats included Goliat from Romania, PW-Sat from Poland, and Masat-1 from Hungary.[120] "ESA provided technical expertise and educational support for integrating, testing and preparing the satellites for launch."[121]

Russia offers post-mission rehab to ISS astronauts; suggests longer stays

In March 2012 Roscosmos proposed that NASA astronauts increase their time on the ISS from six months to nine months and eventually one year.[122] Because Europeans and Americans have not experienced such long periods in space, Russia offered to make its medical expertise available to astronauts from partner countries during post-mission rehabilitation.

Roscosmos head Vladimir Popovkin said that foreign astronauts usually return directly to their home countries after ending their ISS missions, which can sometimes cause them problems. He said, "We know how to rehabilitate astronauts…. And so we are ready to use everything we know to help, perhaps, to change the rehabilitation period."[123]

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. The satellite industry is made up of four major segments: ground equipment, satellite services, launch industry, and satellite manufacturing. During 2012 the satellite industry accounted for approximately 62% of total worldwide space industry revenues[124] and 4% of overall global telecommunications industry revenues.[125] Between 2011 and 2012 revenues for the satellite services segments grew 5% to $93.3-billion; satellite manufacturing revenue grew 23% to $14.6-billion; the global launch industry segment grew 35% to $6.5-billion; and ground equipment revenues grew 4% to $54.8-billion.[126]

Figure 2.7: Global satellite industry revenue by year. 2008-2012 (in US$billions)[127]

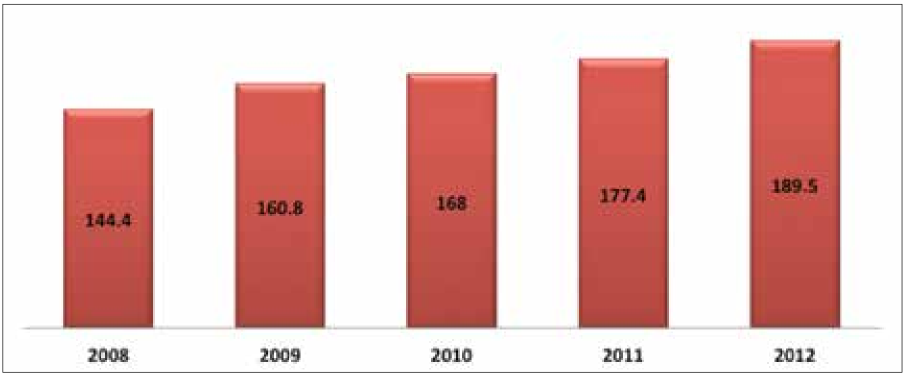
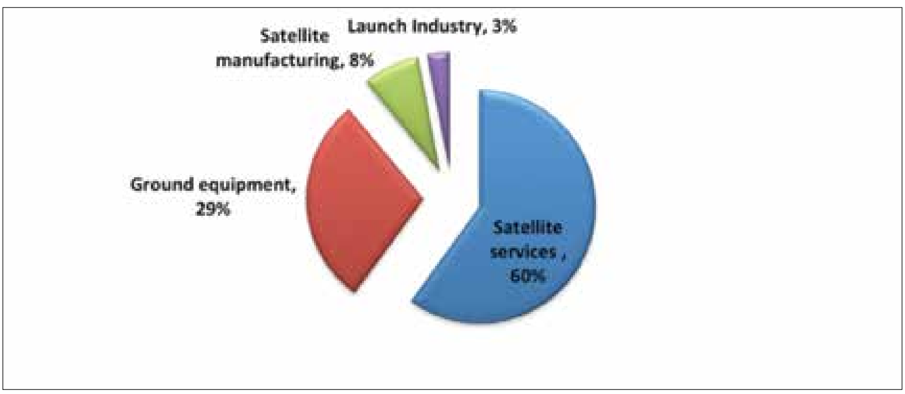


Figure 2.8: Global satellite industry revenue by segment in 2012[128]



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.[129] Satellite industry revenues were first reported in 1978, when Communication Satellite Corporation claimed operating revenues of almost $154-million for 1976.[130] By 1980 it is estimated that the worldwide commercial space sector already accounted for revenues of $2.1-billion.[131] 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.[132] 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.[133] Of the 139 payloads carried into orbit in 2012, 27 provide commercial services and the remaining 112 perform civil government, nonprofit, or military missions.[134] The global commercial launch market continues to be dominated by Russia and Europe, followed by the United States.

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.[135] India has been positioning itself to compete for a portion of the commercial launch service market by offering lower-cost launches.[136] For the first time in 2007 China both manufactured and launched a satellite for another country, Nigeria's Nigcomsat-1.[137]

2012 Developments

Growth in satellite market

Satellite market continues to expand

According to data compiled by the Federal Aviation Administration (FAA) and other sources, in 2012, 23 of 75 orbital launches were global commercial launches,[138] up from 18 commercial launches in 2011.[139] Estimated launch revenues for 2012 were estimated to be $500-million over the previous year for a total of $2.4-billion, with European launch operators seeing a revenue increase of nearly 50%.[140]

On 8 November 2012 Euroconsult released its 15th edition of *Satellites to be Built and Launched by 2021*. This report estimates that there are currently 92 geosynchronous commercial satellites under construction and an additional 75 non-geosynchronous commercial satellites under construction for launch by 2015.[141] Euroconsult predicts that 1,075 satellites will be built for launch between 2012 and 2022.[142] Revenues from these services are predicted to be worth $198-billion, up 36% over the prior ten-year period.[143] Nearly 75% of these commercial satellites will be replacements for aging satellites in geostationary orbit.[144] Forecast International predicts a similar trend in the commercial communication market, estimating that 419 satellites will be produced between 2012 and 2021, with a value of $52.7-billion.[145]

Figure 2.9: Approximate commercial launch revenue by country in 2012 (in US$millions)[146]

SpaceX delivers first commercial payload to ISS

SpaceX made history with the launch of the first commercial cargo contracted by NASA aboard the Dragon space capsule to the ISS.[147] Dragon berthed with the ISS on 10 October 2012, delivering 400 kg (882 lb) of supplies.[148]

While the main mission was successful, one of the nine engines aboard the Falcon 9 launch vehicle was shut down during the first stage after a malfunction was detected.[149] The flight computer adjusted the launch trajectory, which allowed the Dragon to reach the ISS.[150] However, a secondary payload, the prototype for Orbcomm's second generation of satellites, failed to reach the intended orbit.[151] Orbcomm, a commercial satellite communications provider, has contracted with SpaceX for a mid-2013 Falcon 9 launch to place a constellation of eight satellites to provide messaging services, with an additional 18 in 2014.[152] As a result of the lower-than-planned orbit, the satellite was de-orbited on 11 October and an insurance claim was made by Orbcomm for $10-million.[153]

Dragon returned to earth on 28 October with 760 kg of crew supplies, scientific research, and assorted hardware.[154] Under the Commercial Orbital Transportation Services/Commercial Resupply Service (COTS/CRS) program NASA has contracted with SpaceX for at least 12 cargo resupply missions to the ISS through 2016, with the contract worth up to $1.6-billion.[155]

In May INTELSAT and SpaceX entered into the first commercial contract for the Falcon Heavy launch vehicle.[156] The Falcon Heavy, whose first launch is expected in 2014,[157] is designed to deliver 53 metric tons of cargo to LEO,[158] twice as much payload as the Delta 4 Heavy, which is currently the largest rocket in the United States.[159] Terms of the contract were not disclosed but SpaceX has previously expressed expectations that a commercial launch of the Falcon Heavy would cost approximately $100-million.[160]

In December SpaceX won the first two contracts of the USAF Orbital/Suborbital 3 program, valued at $262-million.[161] SpaceX is scheduled to launch NASA's Deep Space Climate Observatory aboard a Falcon 9 in November 2014 and the Space Test Program Satellite aboard the yet untested Falcon Heavy in 2015.[162]

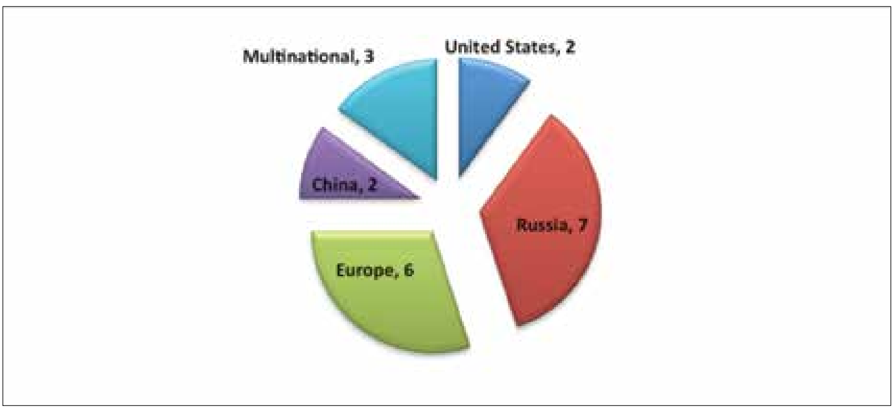
Commercial launch market continues growth

Orbital Sciences is developing the Antares medium lift rocket and the Cygnus advanced maneuvering space vehicle as a partner with NASA under the COTS/CRS program.[163] In October 2012 the Antares first stage test article was moved from the Horizontal Integration Facility at the Mid-Atlantic Regional Spaceport on Wallops Island, Virginia to the launch pad for testing of the launch pad fuel systems.[164] In December 2012 cold flow propellant tests were completed on the launch pad[165] and a subsequent "hot fire" hold down test on the pad was scheduled for February 2013.[166] The maiden launch of Cygnus and Antares occurred in late April 2013.[167]

On 7 October 2012, during the Farnborough Air Show, Virgin Galactic revealed LauncherOne.[168] This rocket is designed to carry small satellites of up to 225 kg into LEO and 100 kg satellites to Sun-Synchronous LEO.[169] The rocket will be launched from WhiteKnightTwo, the company's all-composite, high-altitude, heavy-lift aircraft, from an air drop at an altitude of 15 km.[170] Several customers, including Skybox Imaging, GeoOptics Inc., Spaceflight Inc., and Planetary Resources had representatives present.[171]

Two other leading small satellite manufacturers, Surrey Satellite Technology and Sierra Nevada Space Systems, announced that they would develop small satellite designs to match LauncherOne's performance specifications.[172] The cost of a launch has been set at $10-million.[173]

Figure 2.10: Worldwide commercial launch activity in 2012[174]



Stratolaunch Systems, a venture funded by Paul Allen, is working with Scaled Composites to develop a launch aircraft similar to, but much larger than, VirginGalactic's WhiteKnight.[175] Stratolaunch has purchased two 747-400s, which will be used to create the largest carrier aircraft ever constructed.[176] They will be powered by six 747 engines, have a wingspan of 116 m and weigh over 590,909 kg.[177] The carrier is intended to carry a launch vehicle of up to 222,727 kg[178] and deliver up to 4,545.5 kg into LEO.[179]

Stratolaunch opened a production facility at the Mojave Air and Space Port on 10 October 2012.[180] However, in December SpaceX and Stratolaunch, which were to have provided a modified Falcon launch vehicle, parted ways. Stratolaunch is now partnering with Orbital Sciences to develop a launch vehicle design.[181]

On 18 May 2012 Japan launched its first commercial satellite—a South Korean KOMPSAT-3 Earth observation satellite—aboard an H-IIA rocket.[182] In addition to the South Korean payload, three smaller Japanese satellites were also successfully placed into orbit.[183]

H-IIA launches have been operated by Mitsubishi Heavy Industries (MHI) since 2007, when launch operations were taken over from JAXA.[184] MHI spokesman Kenichi Nakamura expressed MHI's interest in competing in the commercial space launch industry: "With the success of this commercial launch, we hope to build customers' trust and get the next order, entering a business dominated by European Ariane and Russian Proton rockets."[185]

Arianespace conducted 11 flights in 2012, 10 from the French Guiana Spaceport and a Soyuz mission from Baikonur in Kazakhstan.[186] In addition to launching 11 telecommunications satellites,[187] Arianespace launched the ESA Automated Transfer Vehicle Edoardo Amaldi, which delivered seven tons of supplies to the ISS.[188]

In February 2012 Arianespace successfully launched the Vega four-stage launcher—a new vehicle for small to medium-sized payloads (approximately 1,500 kg).[189] The payload consisted of nine spacecraft: the Italian LARES laser relativity satellite, the ALMASat-1 technology microsatellite demonstrator, and seven CubeSats developed by university students.[190]

Arianespace, using the Ariane 5 heavy lift launcher, completed missions for the Galileo satellite constellation, the French and European defense ministries, and EUMETSAT.[191] Chairman and CEO Jean-Yves Le Gall described the year 2012 as "remarkable": "It confirms the interest, effectiveness and availability of our launcher product line—which enables us to launch all satellites, for all of our customers, to all orbits…. In addition, 2012 also marked a yearly record in terms of payload mass placed into orbit, since—for the first time—we have reached a total of nearly 75 tons, of which 20 tons was for the *Edoardo Amaldi* Automated Transfer Vehicle."[192]

Arianespace scheduled 12 launches for 2013, 11 to take place in French Guiana and one Soyuz launch from Baikonour.[193]

Space Tourism

Virgin Galactic SpaceShipTwo reaches milestone

SpaceShipTwo, the Scaled Composites-built vehicle intended to be the world's first commercial spacecraft, reached a milestone in 2012. On 19 December it successfully completed a high-altitude test glide with newly installed components of its hybrid rocket system installed.[194]

Virgin Galactic CEO George Whitesides described the test flight: "Today was a big step closer to first powered flight. We had a variety of systems newly installed on the vehicle. The most important were the components of the rocket system, including all the flight-ready tanks and valves. But we also flew with flight-ready thermal protection materials on the leading edges of the vehicle for the first time."[195]

In May 2012 Virgin Galactic announced that it had received FAA approval for powered test flights.[196] Glide flights resumed in June after an aerodynamic problem was discovered during a test glide in 2011.[197] Hot fire tests of the rocket motor were conducted in January 2013.[198]

The Golden Spike Company plans lunar commercial missions

On 6 December 2012 the Golden Spike Company announced plans to offer commercial scientific and tourist lunar orbital and surface expeditions.[199] Golden Spike has a Board of Directors; Spaceflight, Scientific, and Creative Council; and a Board of Advisors that includes experienced Apollo and Shuttle mission directors, politicians, former NASA employees, and scientists.[200]

Golden Spike plans to sell space expeditions to government agencies, businesses, and individuals with scientific, commercial, tourist, and educational interests.[201] Financial plans include the direct sale of expeditions, media rights, and advertising; sales of returned samples and expedition artifacts; and entertainment products marketing each expedition.[202]

According to CEO Alan Stern, Golden Spike will use existing hardware, infrastructure, and launchers, adapting crew capsules already in development and developing their own spacesuits and landers.[203] The missions would first launch a lunar lander into Earth orbit, using a secondary launch to send the crew into orbit, docking with the lunar lander before heading to the Moon.[204]

By using existing technology, Golden Spike believes it can complete a lunar mission by 2020, with a cost of 7-8 billion USD.[205] Partners listed on Golden Spike corporate materials include Armadillo Aerospace, Space Florida, Northrup Grumman, and United Launch Alliance.[206]

Actress Sarah Brightman next ISS tourist

On 11 October 2012 Sarah Brightman, a recording artist and actress famous for her performances in *Phantom of the Opera*, announced that she had passed the spaceflight medical assessment at the Russian cosmonaut training center near Moscow.[207] A UNESCO ambassador, Brightman wants to use the trip to promote women's education in the sciences and environmental awareness.[208]

Space Adventures has arranged with Roscosmos and the ISS partners for a 10-day trip to the ISS.[209] Alexei Krasnov, head of manned programs at Roscosmos, indicated that the trip would be scheduled for autumn 2015, with a price tag in the tens of millions of dollars.[210] Previous flights have cost over $20-million, according to several past tourists.

Roscosmos head Vladimir Popovkin said, "I have met her, she is all set to fly, but Roscosmos has not yet decided on it. We have a range of possibilities, including sending young cosmonauts to fly. A final decision will be made in the first half of 2013."[211] In May 2013[212] Roscosmos confirmed that Brightman will be on a space flight to the ISS in October 2015.

Commercial Spaceports

Various commercial spaceports under development

In October 2012 the Mid-Atlantic Regional Spaceport (MARS), overseen by the Virginia Commercial Space Flight Authority (VCSFA) and located at the NASA Wallops Island Flight Facility, completed construction on a liquid-fuel launch complex[213] capable of accommodating mid- to heavy-launch vehicles.[214]

MARS Pad 0B was modified to accommodate NASA's Lunar Atmosphere and Dust Environment Explorer mission and the USAF Operationally Responsive Space (ORS-3) mission, both scheduled for mid-2013.[215]

The VCSFA and Orbital Sciences signed a Memorandum of Understanding in September that committed Orbital Sciences to launching 10 Antares missions from the MARS facility, including eight ISS resupply missions.[216]

Virginia Governor Robert McDonnell said, "The Commonwealth's partnership with Orbital will kick off a new era of commercial aerospace activity throughout the Commonwealth.

As the U.S. space program increases its reliance on the commercial sector, these types of partnerships will not only help keep America competitive in the space industry, but will help create much-needed jobs and economic development."[217]

Under the terms of the MoU, the VCSFA owns and operates the non-Antares infrastructure and assets that can be used to provide services to other launch customers.[218] VCSFA Executive Director Dale Nash stated, "MARS is one of only four commercial facilities licensed in the U.S. to launch rockets into orbit. Our partnership with Orbital not only expands our launch capabilities, but demonstrates to the entire space community that Virginia is a leader in the commercial aerospace industry. The VCSFA looks forward to continuing to work with Orbital to support their critical operations at MARS and continue to grow the commercial aerospace industry in Virginia."[219]

Spaceport America is a $209-million facility in Sierra County, New Mexico. It bills itself as "the first spaceport in the world built-from-the-ground-up to host private enterprise, intended to be the launch-pad of the global commercial spaceflight industry and the second space age."[220] It received its FAA launch operations license in 2008 and signed a 20-year lease with anchor tenant Virgin Galactic to provide their corporate headquarters and launch operation facilities.[221] However, while the Spaceport currently identifies four tenants and customers on its website, the facility was mostly empty at the end of 2012.[222] Virgin Galactic's commitment to the facility was uncertain for much of 2012; Virgin Galactic's Whitesides stated that the company would complete their move to Sierra County when "the Spaceport Authority finished the level of the work that it has agreed to provide on our building." He also expressed concern over the lack of other tenants with which Virgin would share costs.[223]

In a February 2013 interview with *Forbes*, Steve Isakowitz, Executive Vice President and Chief Technology Officer at Virgin Galactic, stated, "Virgin Galactic has agreed to start paying rent as a gesture of good faith and in recognition of the near completion of the spaceport terminal. We have been working closely and diligently with New Mexico Spaceport Authority over a number of months to solve the last remaining issues and complete the pre-agreed work, and we expect it to be resolved very soon. We look forward to the facility being fully completed soon and to operating from Spaceport America in the not too distant future."[224]

On 20 September 2012 Florida Lieutenant Governor Jennifer Carroll, chair of Space Florida, requested that NASA transfer 150 acres of land north of the space shuttle launch pads for Florida to develop as a commercial spaceport.[225] A week earlier Space Florida had committed to spending $2.3-million on environmental studies, appraisals, and title searches to begin the necessary work to develop Cape Canaveral Spaceport, a state-owned commercial complex, in an effort to become the third launch site of SpaceX.[226] SpaceX was also looking at sites in Texas and Puerto Rico.[227]

As of 29 January 2013 the 150 acres was still in NASA's control, kept as a buffer zone between the launch area and local communities and to meet the needs of future missions.[228]

In April 2012 Virgin Galactic and Aabar Investments (which holds a 32% stake in Spaceport America)[229] announced the appointment of a Chief Advisor to head the development of Spaceport Abu Dhabi.[230] Aabar Investments, a state-backed investment firm, plans to develop a regional space hub for science and research opportunities, while also creating a space tourism industry.[231]

Commercial Operators

Satellite broadband service expands to commercial airlines

In 2012 in-flight entertainment and internet began a significant expansion. In addition to industry partnerships announced during the year, at the close of 2012 the United States Federal Communications Commission issued a rule that would shorten the approval process for internet services aboard aircraft.[232] Since 2001 companies have been authorized on an ad hoc basis to operate Earth Stations Aboard Aircraft, which communicate with Fixed-Satellite Service geostationary-orbit space stations, providing two-way in-flight broadband services.[233] The new regulatory process allows airlines to test FCC-approved systems to establish a lack of interference with aircraft systems and seek FAA approval.[234]

On 7 September 2012 Intelsat announced that it would provide trans-oceanic internet access around the globe to Gogo, "a leader of in-flight connectivity and a pioneer in wireless in-flight digital entertainment solutions."[235] Gogo will be able to access u-band capacity across four satellites, with coverage on trans-Atlantic and trans-Pacific routes, as well as routes over South America, Asia, Africa, and Australia.[236]

"We believe Intelsat brings to the table a long-term commitment to providing Aero solutions for the aviation market, including the recently announced Intelsat EpicNG, which we expect will allow us to provide the reliable and seamless satellite coverage our current and prospective airline partners must have to meet passenger demand for high-speed Internet access on transoceanic and other international flights," said Michael Small, Gogo's president and CEO.[237]

In December Gogo also reached an agreement with INMARSAT to provide service via INMARSAT's Global Xpress. "With the addition of Inmarsat's Ka-band service, Gogo has the ability to provide the most complete range of solutions, enabling us to service the full-fleet needs of our current and future airline partners—regardless of aircraft size, mission, or location," said Small.[238]

ViaSat, Inc. announced the expansion of Exede Internet, the "fast-growing high-speed consumer broadband service" to serve commercial airlines.[239] ViaSat-1, a Ka-band high-capacity communications satellite, will enable this expansion.[240] The full aircraft system is currently undergoing FAA certification.[241]

According to ViaSat CEO and Chairman Mark Dankberg, "Compared to air-to-ground and traditional satellite in-flight networks, the improved capacity and economics of our Ka-band system enable airlines to finally bring a high-speed home or office Internet experience to passengers. Customer feedback on our Exede home Internet service has been overwhelmingly positive and we're eager to prove that the in-flight experience can be just as good."[242]

Working with partner LiveTV, ViaSat is under contract to provide in-flight internet service on 370 aircraft operated by JetBlue and an unnamed U.S. air carrier by the end of 2015.[243] In September 2012 JetBlue CEO Dave Barger stated, "This system will be designed for the 21st century, not just for today's personal connectivity needs, but with the bandwidth to expand to meet tomorrow's needs as well. In just the three years since we launched BetaBlue, the first commercial aircraft with simple messaging capability, technology has advanced by generations. Rather than invest in current technology, designed to transmit broadcast video and audio, we elected to partner with ViaSat to create broadband functionality worthy of today's interactive personal technology needs."[244]

ViaSat has also expressed interest in partnering with INMARSAT to expand coverage in the Ka-band satellite service.[245]

Analysts and industry predict continued sector growth

In September 2012 the Satellite Industry Association (SIA) released its fifteenth annual "State of the Satellite Industry Report," which estimated global revenue for the satellite industry at $177.3-billion for 2011.[246] Satellite Services revenues grew 6% from 2010 to 2011.[247] Global satellite manufacturing revenues grew 9% to $11.9-billion in 2011, compared to $10.8-billion in 2010.[248] Indeed, the report described growth across nearly every satellite sector; these numbers found close parallels in several reports from Euroconsult.[249]

In the report *Satellite Communications & Broadcasting Markets Survey Forecasts to 2021*, Euroconsult predicted that FSS bandwidth will be worth nearly $15-billion by 2021, with revenue growth of 8% in 2011.[250] Euroconsult estimated that 1,145 satellites will be manufactured and launched from 2011 to 2020 in its 2012 report *Satellites to be Built and Launched by 2021*, with revenues of at least $196-billion.[251] The estimate is for 203 commercial communications satellites in geosynchronous orbit, with a value reaching $50-billion, and an additional 165 satellites in medium- and low-Earth orbits.[252]

Commercial sales of earth observation data are predicted to grow by 12% each year, totaling nearly $4-billion in revenue by 2020.[253] Euroconsult estimated 288 Earth observation satellites from 42 countries will be launched over the next decade.[254]

In May 2012 Euroconsult released the 5th edition of *Satellite TV Platforms, World Survey and Prospect to 2021*, which reported an increase in revenue for satellite pay-TV from $79-billion in 2010 to $90-billion in 2011.[255] Revenues will nearly double by 2021, with the developing world contributing a growing portion.[256] Over the last decade, satellite pay television subscriptions have grown by at least 10% a year and in 2011 subscriptions increased by 16%.[257] Euroconsult predicts nearly 350-million household subscriptions by 2021.[258]

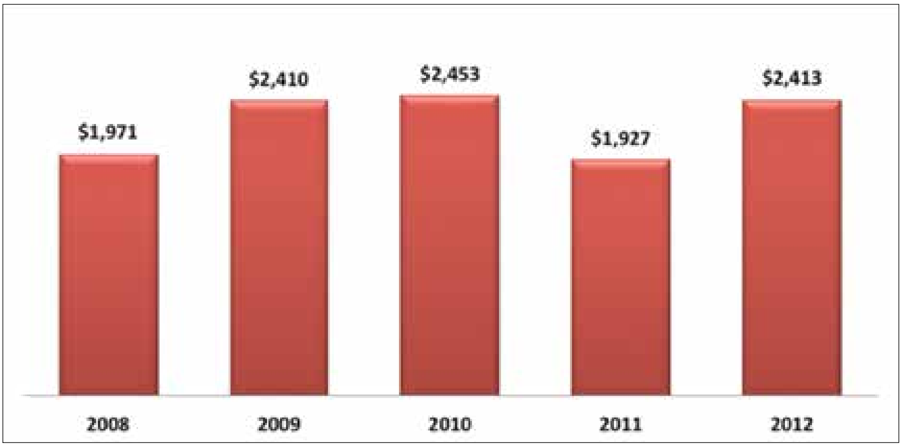
The second edition of Euroconsult's *Maritime Telecom Solutions by Satellite, Global Market Analysis and Forecasts,* which came out in March 2012, forecast a compound annual growth rate of 7% in the number of satellite communications terminals in the global maritime market over the next decade.[259]

According to Wei Li, a Senior Consultant at Euroconsult, "Onboard bandwidth requirements keep growing, driving the maritime market in a direction quite beneficial to satellite communications. Fully integrated IP applications providing Internet access, audio and video streaming, and the integration of ships into corporate networks generate significant capacity demand at sea."[260]

According to Euroconsult, the number of terminals used for global maritime satellite communications grew by approximately 6% in 2011. Revenues increased by more than 7% at the level of the satellite operator.[261] Service provider revenue was estimated at more than $1.4-billion.[262]

In a 1 January 2013 interview with Satellite Today INMARSAT CEO Rupert Pearce discussed investment and growth over the next several years.[263] He viewed Global Xpress as "a key driver for our wholesale revenue growth," and predicted a compound annual growth rate of wholesale revenues of 8-12% percent over 2014-16. He stated that "we aim to be delivering more than $500 million of annual revenues from Global Xpress, which sets the bar quite high for a fast start in 2014."

Figure 2.11: Worldwide commercial launch revenue by year. 2008-2012 (in US$millions)[264]



Companies announce plans to mine asteroids

On 24 April 2012 Planetary Industries announced a commercial venture to develop low-cost robotic spacecraft to explore the estimated 9,000 near-Earth asteroids for potential resource extraction and utilization.[265] They began actively recruiting employees in October.[266]

"Many of the scarce metals and minerals on Earth are in near-infinite quantities in space. As access to these materials increases, not only will the cost of everything from microelectronics to energy storage be reduced, but new applications for these abundant elements will result in important and novel applications," said Peter H. Diamandis, co-founder and co-Chairman, Planetary Resources, Inc., as well as Chairman and CEO of the X Prize Foundation.[267]

Another resource focus is asteroids containing water. "Water is perhaps the most valuable resource in space. Accessing a water-rich asteroid will greatly enable the large-scale exploration of the solar system. In addition to supporting life, water will also be separated into oxygen and hydrogen for breathable air and rocket propellant," said Eric Anderson, the other founder and co-Chairman of Planetary Resources, who also founded Space Adventures, pioneers in space tourism.[268]

On 22 January 2013 a second company, Deep Space Industries, announced their intention to compete in asteroid surveying and resource extraction.[269] The company headed by David Gump intends to develop a fleet of three spacecraft, using off-the-shelf technology, to survey small near-Earth asteroids.[270] They hope to attract $13-million in capital over the next few years.[271]

LightSquared files for bankruptcy

On 14 May 2012 LightSquared Inc. filed for bankruptcy.[272] In January 2011 it had received tentative FCC approval to use airwaves originally intended for satellite spectrum in wireless land-based towers. LightSquared had accumulated nearly $4-billion worth of frequencies, but its technology was found to interfere with GPS signals and the FCC revoked approval in February 2012.[273]

While creditors seek its liquidation, LightSquared has pushed ahead with its broadband plan, seeking to share government spectrum until it sorts out the technical problems of interference in the current bandwidth it holds.[274] On 14 February 2013 the bankruptcy court in Manhattan gave LightSquared until 31 May 2013 to file a plan for reorganization with lender support.[275] Planned restructuring failed and matters are now before the courts.[276]

Indicator 2.5: Public-private collaboration on space activities

Government support

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.[277] 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.[278] 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.[279] A 2006 report commissioned by the FAA indicated that a successful U.S. commercial launch industry is viewed as "beneficial to national interests."[280] Also in 2006 NASA announced the COTS program, designed to coordinate the transportation of crews and cargo to the ISS by private companies.[281] In January 2011 it was announced that NASA would increase its investment in the COTS program, assigning cash payouts for the achievement of specific milestones related to logistical services being developed for the ISS.[282]

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.[283] 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.[284] 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."[285]

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.[286]

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.[287]

Likewise, because certain commercial satellite imagery can serve military purposes, a number of states have implemented regulations on the sector over the years. The 2003 U.S. Commercial Remote Sensing Policy set up a two-tiered licensing regime, limiting the sale of sensitive imagery.[288] In 2001 the French Ministry of Defense prohibited open sales of commercial Spot Image satellite imagery of Afghanistan.[289] Indian laws require the 'scrubbing' of commercial satellite images of sensitive Indian sites.[290] With the Remote Sensing Space Systems Act, which came into force on 29 March 2007, Canada adopted a regulatory regime that gives the Canadian government "shutter control" over the collection and dissemination of commercial satellite imagery and priority access in the event of future major security crises.[291]

2012 Developments

United Kingdom provides financial boost to space sector

In April 2012 the British government announced grants for nearly £6-million to co-fund research and development of commercial products and services using space technology and systems. The grant funding is part of the National Space Technology Programme from the U.K. Space Agency and the Technology Strategy Board.[292] Four major research and development projects by Astrium Ltd., Avanti Communications Ltd., DMC International Imagining Ltd., and Surrey Satellite Technology Ltd. are being supported, with total funding of £11.5-million.[293]

Dr David Williams, Chief Executive of the Space Agency, said, "These initial major projects springing out of the National Space Technology Programme are great examples [of] innovative and ambitious R and D in the U.K. space sector. By investing in these projects, we are securing our future national capability across the range of vital applications and services that space technology can provide."[294]

In November Chancellor of the Exchequer George Osborne announced that ESA headquarters for telecoms satellite monitoring will be located in Harwell, Oxfordshire:[295] "Finally there are the opportunities to be a world leader in satellites and commercial applications of Space. The U.K. space sector, including such companies as Astrium, Inmarsat, and Avanti, already generates £9-billion a year for the economy, and has grown at over 8 per cent per year through the recent difficult economic times. Our ambition is to have a £30-billion industry by 2030."[296] The government is investing an additional £60-million annually in ESA projects, for an annual total of £240-million.

European Defence Agency procures commercial bandwidth

The European Satellite Communications Procurement Cell was awarded a three-year contract by the European Defence Agency to procure commercial satellite bandwidth (C, Ku, and Ka) for European military communications needs.[297] This pilot project, to which France, Italy, Poland, Romania, and the United Kingdom have so far contributed, aims to pool procurement to lower costs, ease access, and improve efficiency in providing communications bandwidth to the armed forces of EU member states.[298]

Astrium Services is an early provider. Its CEO said, "As a commercial company and a pioneer in providing milsatcoms [military satellite communications] to governments and defence ministries, we are very proud to be the first to provide commercial satellite communications to the European Defence Agency through such an innovative scheme. Being European, Astrium Services is fully engaged in making a significant contribution to European defence."[299]

NASA awards contracts, funding to various commercial companies

On 3 August 2012 NASA announced that it had selected three finalists for Commercial Crew Integrated Capability contract funding.[300] The Commercial Crew Program (CCP) is intended to use commercially developed U.S. spaceflight capabilities to bridge the spaceflight gap created by the retirement of the Space Shuttle program.[301] Through commercial spaceflight, NASA hopes to achieve low-cost, reliable transportation to LEO and the ISS.[302]

Boeing, SpaceX, and Sierra Nevada had all received prior funding awards under the Commercial Crew Development second round (CCDev-2).In this round Boeing received $460-million, SpaceX $440-million, and Sierra Nevada $212.5-million,[303] to be funded over 21 months.[304] All three companies plan to have spaceships ready in 2015-2016.[305]

Boeing and Sierra Nevada are each partnering with United Launch Alliance. SpaceX, which has received funding under the Commercial Orbital Transportation System (COTS) program, is developing its system independently.[306]

United Launch Alliance receives contracts for 11 launches from USAF

On 3 December 2012 the United States Air Force announced that it had awarded a contract to Lockheed Martin, Orbital Sciences, and SpaceX for small spacecraft launch services.[307] The Orbital/Suborbital Program is designed to provide new entrants an opportunity for certification to the Evolved Expendable Launch Vehicle program.[308] Since 2006 United Launch Alliance has been the only certified launch operator.[309]

Indicator 2.6: Space-based military systems

Since the beginning of the space age 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 upon 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.[310] 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. By 1 June 2013 there were 206 dedicated military satellites worldwide.[311]

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.[312] 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.[313] 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.[314] Since 2004 Russia has focused on "maintaining and protecting" its fleet of satellites and developing satellites with post-Soviet technology.[315] 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.[316]

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.[317] Beidou may also improve the accuracy of China's intercontinental ballistic missiles (ICBMs) and cruise missiles.[318] China launched the first Compass-M1 test satellite into MEO in 2007.[319] 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, with the 35-satellite system expected to provide global coverage by 2020.[320]

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.[321]

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 sector. 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 these scarce resources also affect the civil and commercial space sectors, they become more acute in the military sector, where they are associated with national security.

Space assets play an important strategic role in the terrestrial military operations of certain states. In most cases, 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. Furthermore, remote sensing satellites have served as a national technical means of verification of 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.

2012 Developments

Military Space Systems in Major Spacefaring Nations

The United States continues to update existing space capabilities

The United States completed 12 successful launches in 2012; one Falcon 9 launch was a partial failure.[322] Eight military space systems were deployed in 2012: three communications satellites, two surveillance satellites, one radar imaging satellite, one navigation satellite, and one technology demonstration satellite.[323]

Intelligence, surveillance, and reconnaissance

The United States launched two surveillance satellites and one radar imaging satellite in 2012. On 3 April the National Reconnaissance Office Launch (NROL)-25 satellite, a radar imaging satellite, was launched on a Delta IV rocket from Vandenberg Air Force Base.[324] NROL-38, a surveillance satellite, was launched on an Atlas V rocket on 20 June; NROL-15, another surveillance satellite, was launched on a Delta IV Heavy rocket on 29 June.[325]

On 16 June 2012 the USAF's second unmanned X-37B spaceplane returned to earth after a 469-day classified mission.[326] The next X-37 mission was successfully launched on 11 December.[327] Almost two years after the launch of its Space-Based Surveillance Satellite, the USAF declared it operational; delays were due to problems with onboard electronics.[328]

In May the United States and Canada signed a five-year agreement to share orbital surveillance data, establishing a framework for negotiating a longer-term deal. The initial SSA data-sharing program took effect on 4 May 2012.[329]

Figure 2.12: U.S. dedicated military satellites launched in 2012[330]

Satellite	Operator	Function	Orbit	Launch date
SMDC-ONE 1.2	U.S. Army Space and Missile Defense Command	Technology Development	LEO	9/13/2012
SMDC-ONE 1.1	U.S. Army Space and Missile Defense Command	Technology Development	LEO	9/13/2012
USA 238	NRO/US Navy	Electronic Surveillance	LEO	9/13/2012
RE	NRO	Remote Sensing	LEO	9/13/2012
USA 237	NRO	Electronic Surveillance	GEO	6/29/2012
USA 236	NRO/USAF	Electronic Surveillance	GEO	6/20/2012
USA 235	USAF	Communications	GEO	5/3/2012
USA 234	NRO	Reconnaissance	LEO	4/3/2012
MUOS-1	DoD/US Navy	Communications	GEO	2/24/2012
USA 233	USAF	Communications	GEO	1/20/2012

Weather

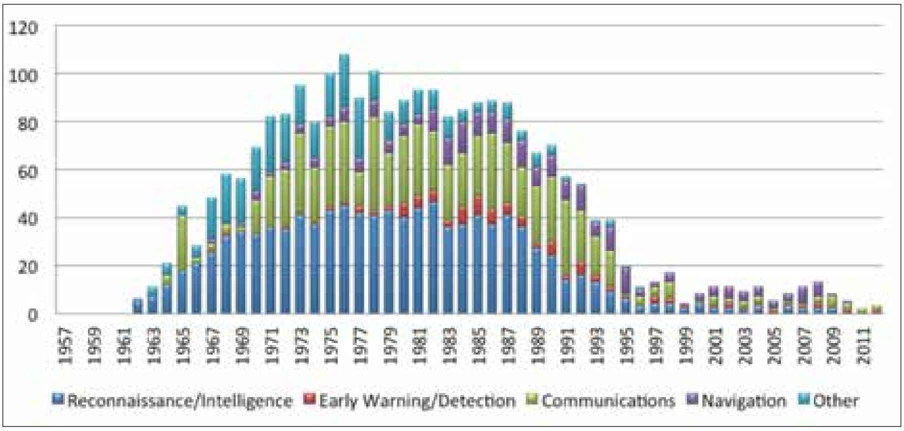
The USAF budget request for FY2014 deferred major development on the next-generation weather satellite programs.[331] Alternatives to the system will be analyzed. Congress provided $123.5-million in 2012 for a follow-on system to the canceled Defense Weather Satellite System.[332]

In February 2012 the NOAA submitted a funding increase of nearly 9% for weather satellites and related activities. NOAA's new polar-orbiting weather satellite system, the Joint Polar Satellite System, will cost $12.9-billion through 2028.[333] To date, NOAA has finalized contracts worth $655-million for this system.[334]

Satellite communications

The United States launched three satellite communications systems in 2012. On 1 January the Wideband Global Satellite Communications (WGS) spacecraft launched on a Delta 4 rocket from Cape Canaveral Air Force Station in Florida.[335] The fourth Boeing WGS spacecraft launched, it is stationed in geostationary orbit. WGS serves communications needs for the U.S. military. Also in 2012 Canada, Denmark, Luxembourg, the Netherlands, and New Zealand agreed to invest a combined $650-million in WGS. The deal enables the purchase of an additional satellite from Boeing and grants these nations access to the full 10-satellite constellation.[336]

Figure 2.13: U.S. dedicated military spacecraft launched by application: 1957–2012[337]



In March Lockheed Martin announced that on-orbit testing of the first Advanced Extremely High Frequency (AEHF) satellite was complete; the satellite was transferred to Vandenberg Air Force Base.[338] On 4 May the second AEHF satellite was launched on an Atlas V rocket from Cape Canaveral. These satellites provide highly secure military communications.[339]

A classified communications satellite, NROL-38, was launched on an Atlas V rocket on 20 June from Cape Canaveral.[340] This relay-data satellite provides real-time data transmission from reconnaissance satellites.[341]

Navigation/GPS

On 4 October 2012 a Delta 4 rocket, launched by United Launch Alliance, deployed the Air Force's third Block 2F navigation satellite for the GPS.[342] This satellite is replacing 19-year-old satellite GPS 2A-21, which operated twice as long as initially expected.[343] During the satellite's release, the rocket's engine suffered a reduced thrust level and the satellite's engine fired longer than usual to make up the shortfall.[344] The current GPS constellation comprises 10 Block 2A spacecraft built by Boeing, 12 Block 2R satellites built by Lockheed Martin, seven modernized 2R spacecraft built by Lockheed Martin, and three Block 2F satellites built by Boeing. The oldest operational satellite is 21 years old.[345]

Launch

The USAF's decisions on acquisitions of launch vehicles can be seen to be promoting both stability and competition among rocket manufacturers. In January 2012 it awarded United Launch Alliance a $1.5-billion firm, fixed-price contract running through June 2014, covering a total of nine launches. [346] But it continued to solicit bids from other launch providers to loft a pair of experimental satellites in 2014 and 2015.[347] Two separate contracts were awarded to SpaceX to launch experimental satellites.[348] In a 27 November 2012 memo Frank Kendall, Under Secretary of Defense for Acquisition, Technology and Logistics, authorized the USAF to purchase up to 50 rocket cores in the next five years, including 36 from United Launch Alliance.[349] The remaining launches are to be awarded on a competitive basis to so-called new entrants in the national security market.[350]

Russia continues to update space capabilities

Navigation/GLONASS

Russia's Global Navigation Satellite System had some financial troubles in 2012. Managers of Russian Space Systems, a major space industry contractor, stole 6.5-billion rubles ($200-million) in federal funds earmarked to maintain and upgrade GLONASS.[351] On 19 November the Russian Federal Space Agency dismissed the head of Russian Space Systems, Yuri Urlichich.[352]

Russia delayed the December 2012 launch of the second GLONASS-K satellite until 2013, citing concerns over the Fregat booster.[353] Russia still plans to have 30 GLONASS satellites in orbit by 2020. Thirteen GLONASS-K satellites are scheduled to be launched between 2012 and 2020.[354]

Figure 2.14: Russian dedicated military satellites launched in 2012[355]

Satellite	Operator	Function	Orbit	Launch date
Meridian-6	Military Space Forces	Communications	Elliptical	11/14/2012
Cosmos 2481	Ministry of Defense	Communications	LEO	7/28/2012
Cosmos 2479	Ministry of Defense	Early Warning	GEO	3/30/2012

Communications and intelligence, surveillance, and reconnaissance

On 30 March 2012 Russia launched Oko early warning satellite Kosmos 2479 on a Proton rocket from Baikonur Cosmodrome. Kosmos 2479 is designed to detect missile launches with an infrared telescope; it is believed to be the last satellite deployed as part of Russia's current early warning system.[356]

Russia launched what was likely a Kobalt reconnaissance satellite into polar orbit on a Soyuz booster on 17 May. The satellite, orbiting between 150 and 300 miles above Earth, carries an optical camera to take photos of military installations and troop movements around the world.[357] On 22 July a Soyuz rocket launched a remote sensing satellite named Kanopus-Vulkan.[358]

A military communications satellite was launched on 14 November on a Soyuz rocket from Plesetsk Cosmodrome. The Meridian satellite is being used to link ground forces, ships, and aircraft in the Arctic and Siberia. This was the first Meridian launch since a Soyuz failure destroyed an identical payload in December 2011.[359]

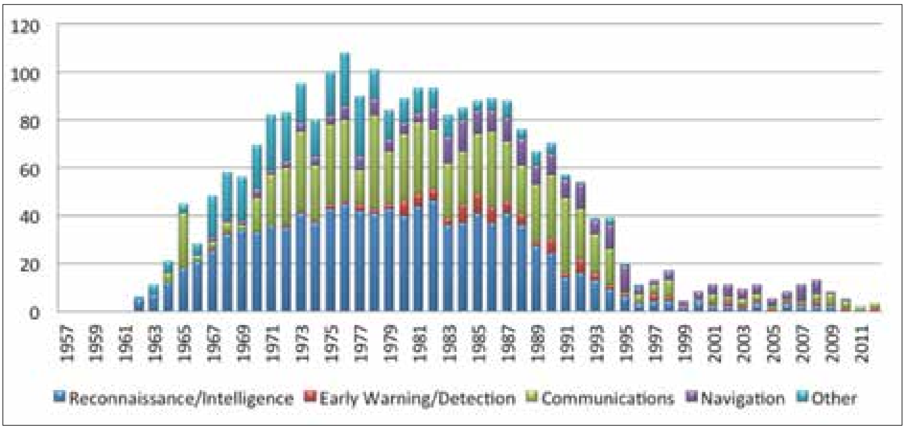
Launch failures

On 6 August 2012 the Breeze-M upper stage of a Proton Rocket failed to place two telecommunications satellites into their proper orbit. The mishap was attributed to a premature shutdown of the Breeze-M stage.[360] The financial loss of the two satellites is estimated at between $100-million and $150-million.[361] The upper stage broke up in Earth orbit on 16 October, producing more than 500 pieces of debris and threatening most objects in LEO.[362]

After the August launch, a top official was fired and all Proton launches were suspended. On 10 September, Prime Minister Dmitry Medvedev called for "collective punishment for producing subpar quality products." He said, "None of the major space powers have had so many failed launches."[363]

On 9 December the Breeze-M upper stage failed to place a telecommunications satellite in a high enough orbit.[364]

Figure 2.15: Russian dedicated military spacecraft launched by application: 1957-2012[365]



China continues deploying space-based military capabilities

In 2011 China had 18 successful launches.[366] On 19 January 2012 China announced a plan to launch 21 carrier rockets with 30 satellites.[367] By the end of 2012 China had placed 28 satellites in orbit in 19 launches.[368] In 2013 the Chinese plan to send about 20 satellites into space.[369]

Navigation

In late December 2011 China activated the first phase of its Beidou/Compass satellite navigation system.[370] The system, developed for both military and civilian uses,[371] gained six satellites during 2012; the first launched on 24 February,[372] second and third on 29 April,[373] fourth and fifth on 18 September,[374] and the sixth on 25 October.[375] After the sixth satellite became operational, China opened up its domestic sat-nav network to commercial use across the Asia-Pacific region. Beidou is aiming for a 70-80% share of the Chinese market in related location services by 2020.[376] The goal is for Beidou to develop into a global navigation satellite network similar to GPS and GLONASS by 2020. To meet this goal, the plan is for Beidou to eventually comprise 35 vehicles, including 27 satellites in MEO, three in inclined geosynchronous orbit, and five in geosynchronous orbit.[377]

Reconnaissance

On 10 May 2012 Yaogan 14, an optical and radar reconnaissance satellite used by Chinese military and intelligence agencies, was launched.[378] It was followed on 29 May by the Yaogan 15 military satellite, believed to be a second-generation synthetic aperture radar satellite.[379] Yaogan 16 was launched on 25 November[380] and is believed to be on a naval surveillance mission. Experts believe the Yaogan 16 payload may include three satellites, as did a satellite mission in March 2010.[381]

On 14 October 2012 China launched Shijian-9A and Shijian-9B demonstrator satellites to test electric propulsion and high precision and high stability control systems.[382] They are to demonstrate satellite reliability and validate high-performance Chinese-made technologies.[383] They feature instruments for Earth observation.[384]

Military communications

On 26 May 2012 China launched the Zhongxing-2A (Chinasat-2A). It provides secure tactical military communications—secured digital data and voice communication—to Chinese military forces.[385]

Data relay

On 25 July 2012 China launched TianLian 1-03, its third data relay satellite, on a Long March-3C carrier rocket.[386] The global data relay network is designed to support near-real-time communications between orbiting spacecraft and ground control; it will complement ground-based space tracking and telemetry stations and ships. The spacecraft can carry multiple telecommunication payloads to provide different services, including fixed communications, national and regional communication, and military communications.[387]

India continues to improve its remote sensing satellites

Navigation

On 28 September 2012 an Ariane 5ECA rocket launched the Indian GSAT-10 communication satellite from the Guiana Space Center. The satellite carried 30 communication transponders as well as a GAGAN payload to augment or fine tune U.S. GPS signals.[388] GSAT-10 will support India's implementation of a satellite-based regional capability to assist aircraft navigation over Indian air space and adjoining areas. [389]

Remote sensing

On 26 April 2012 India successfully launched and placed into LEO RISAT-1, a microwave Radar Imaging Satellite, on a PSLV rocket.[390] RISAT-1 is India's second radar imaging satellite; Israeli-built RISAT-2 was launched in April 2009, prioritized to meet security requirements.[391] The images that RISAT-1 provides will have a variety of applications, from crop forecasting and disaster management to addressing the country's strategic needs. RISAT's high-resolution pictures and microwave imaging could be used for defense purposes as it can look through clouds and fog. [392]

Military and multiuse space capabilities in other countries

Europe moves ahead with development of multiuse space capabilities

Navigation

On 12 October 2012 Europe's second pair of Galileo satellites—designed, manufactured, and tested by Astrium—were successfully launched from the spaceport in French Guiana.[393] The first two satellites were launched on 21 October 2011.[394] The four satellites now make possible testing and validating all aspects of Galileo's design, including the ground infrastructure that will monitor and control the satellites.[395] The remaining 24 satellites in the Galileo constellation will be launched in 2015; six Soyuz rockets will carry two each, while three Ariane 5 rockets will each carry four.[396]

In February 2012 the consortium led by OHB System AG and Surrey Satellite Technology Ltd (SSTL) was selected to build eight more satellites for the Galileo satellite navigation program. SSTL-OHB is already building 14 of the satellites. Once Galileo is complete it will provide real-time positioning, navigation, and timing services that will be interoperable with GPS and GLONASS.[397]

On 9 July 2012 an International Launch Services Proton Breeze M rocket successfully launched SES-5, a telecommunications satellite, into GEO.[398] SES-5 will carry the first L-band payload for the European Geostationary Navigation Overlay Service (EGNOS), which was developed by ESA and the European Commission to help to "verify, improve, and report on the reliability and accuracy of navigation positioning signals in Europe."[399]

Telecommunications

On 19 December 2012 the United Kingdom's Skynet 5D satellite was launched on an Ariane 5 rocket from French Guiana,[400] becoming the fourth in the new generation of Skynet military satellites. The first three in the Skynet series were launched in 2007 and 2008.[401] The Skynet system is operated by Astrium[402] in an arrangement with the British Ministry of Defence; the project has a value of up to £3.6-billion over 20 years and is the United Kingdom's single biggest space project.[403]

Earth observation satellites

On 12 March 2012 Astrium signed a contract with the French Defence Procurement Agency to "continue to be responsible for the ground segment maintenance of the Helios 2 military optical reconnaissance system"—a high-resolution military optical reconnaissance system with two operational satellites.[404] The contract runs to 2018.

The Italian Defense Ministry purchased a high-resolution optical reconnaissance satellite from Israel "as part of an offset package agreed to in exchange for the Israeli Defense Ministry's purchase of Italian trainer aircraft." The transaction is valued at more than $100-million.[405]

Mexico, Brazil to enhance their telecommunications capabilities

On 19 December 2012, in the final Ariane 5 launch of the year, Arianespace launched the Mexsat-3 (also known as Bicentenario) communications satellite from the European Spaceport in Kourou, French Guiana.[406] The satellite, which is expected to generate approximately 3.5 kilowatts of payload power, was based on Orbital Sciences Corporation's GEOStar-2 platform and will carry 12 active extended Ku-band and 12 active extended C-band transponders.[407]

Mexsat-3 is part of a three-satellite order by prime contractor Boeing for the Federal Government of Mexico. The remaining two, Mexsat-1 and Mexsat-2, are scheduled for launch in 2013 and 2014 respectively.[408] On 9 March 2012 International Launch Services announced that it will launch the Mexsat-1 mobile communications satellite, which will be placed into geostationary transfer orbit.[409]

On 10 November 2012 an Ariane 5ECA heavy-rocket placed Europe's Eutelsat 21B satellite and Brazil's Star One C3 commercial telecommunications satellite into orbit. Star One C3 will "provide telecommunications links to a region as far north as Miami and covering the Andean region in addition to the whole of Brazil."[410]

Iran continues to develop its space capabilities despite launch failures

Reconnaissance satellites

There were two unsuccessful attempts to launch the Fajr imagery reconnaissance satellite on or about 23 May 2012 and again in September.[411] Evidence exists of a failed Safir launch on or after 22 September. Photos taken by DigitalGlobe satellites on October 25 show a damaged umbilical tower, scars on the ground of the pad, and a discarded rocket transporter.[412]

New space center

On 2 June 2012 General Ahmad Vahidi confirmed that Iran is building a new space facility to be named after the Islamic Republic's founder Ayatollah Ruhollah Khomeini. The location was not made known.[413]

Israel continues to build space capabilities

On 30 March 2012 Elta Systems, a subsidiary of Israel Aerospace Industries, signed a series of contracts totaling $106-million to supply 3-D fire-control radars, SATCOM network system, air defense and air traffic control radar (AD-STAR) systems, and tactical short-range air defense radar. A $30-million contract will supply the ELK-1891 SATCOM satellite-based network system and the ELK-1894 wideband SATCOM DATA Link system to a foreign customer.[414]

North Korea launches Earth observation satellite

On 13 April 2012 North Korea attempted to launch a rocket;[415] the attempt failed and the rocket quickly broke up and splashed into the Yellow Sea.[416] The second launch occurred on 12 December.[417] It succeeded in putting an object into orbit around the Earth.[418] What was reported to be an Earth observation satellite[419] appeared to tumble in orbit and is likely dead.[420]

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 protection features. A 2004 study published by the U.S. President's National Security Telecommunications Advisory Committee emphasized that the key threats to the commercial satellite fleet are those faced by ground facilities by computer hacking or possibly, but less likely, jamming.[1] 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."[2] 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 communications links require specific electronic protection 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 protection measures.

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.[3] 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.[4] The United States has also recently established a Cyber Command (USCYBERCOM) to be responsible for the military's Internet and other computer networks, which reached Full Operational Capability in 2010.[5]

2012 Developments

United States begins enforcement of ban on distribution of personal GPS jamming equipment

On 15 October 2012 the United States announced new actions to enforce U.S. law prohibiting the marketing, sale, and use of jamming devices in the United States.

Jamming devices are radio frequency transmitters that intentionally block, jam, or interfere with lawful communications, such as cell phone calls, text messages, GPS systems, and Wi-Fi networks. In 2011 the FCC Enforcement Bureau issued two Enforcement Advisories and other educational materials warning "consumers, manufacturers, and retailers … that the marketing, sale, or use of cell, GPS, and other jamming devices was illegal."[6]

In October 2012 the FCC took action against those advertising and selling jammers, specifically on the website craigslist.org. The FCC warned that similar violations will be heavily fined. In 2012 the FCC Enforcement Bureau also set up a Jammer Tip Line that can be used to report the sale and use of jammers and released a Consumer Alert in English, Spanish, and Mandarin Chinese on the illegality of jamming.[7]

High Integrity Global Positioning System (HIGPS) capability prepares for full operational deployment

On 2 October 2012 the Naval Research Laboratory (NRL) awarded Boeing a two-year, $40-million sole-source contract to optimize technology for the Navy's HIGPS, with the goal of full operational capability.[8]

HIGPS uses Iridium's network of 66 satellites in LEO to augment satellite navigation capability provided by stand-alone GPS navigation and guidance. According to Boeing, the developer of HIGPS, it offers "improved navigation, high signal integrity, precision accuracy, and more jam-resistant capabilities."[9] It can position data within centimeters and provide data in remote locations in which GPS signals are normally difficult or impossible to access, during attempts to jam the signal, and when battlefield radiofrequency noise is present.[10]

In 2008 Boeing was awarded a $153.5-million contract for the first phase of the HIGPS project, which was completed in 2011. The 2012 contract will allow optimization of "HIGPS user equipment, reference stations, and the NRL HIGPS operations center to create a mission-ready system to support operational test and evaluation."[11]

Eutelsat to field test anti-jam capability

In response to increased intentional and harmful interference originating from the Middle East, Eutelsat will place an experimental anti-jam capability on satellite Eutelsat 8 West B, scheduled to launch in 2015 and be stationed over the Middle East.[12] A new set of frequency converters—including a power-allocation system that sets power levels on a given channel to actual use, freeing power for other channels—will be placed on the satellite, which is under construction by Thales Alenia Space of France and Italy.

The decision is an outcome of an ESA initiative called the Flight Heritage Program or Atlas, "which seeks to facilitate the transfer of promising new satellite technologies to flight hardware."[13]

Chairman of the Joint Chiefs of Staff recommends establishment of United States Cyber Command (USCYBERCOM) as a unified command

USCYBERCOM, established in 2009 to counter security threats to the Pentagon's information networks, currently exists as a sub-unified command under USSTRATCOM.

In May a U.S. defense source reported that General Martin Dempsey, CJCS, would recommend to Defense Secretary Leon Panetta that USCYBERCOM be elevated to standalone combatant command status.[14]

The move to combatant command status comes after several occurrences in recent years that have made cyber terrorism and warfare an increasing concern at the Pentagon. In 2011 hackers took credit for infiltrating websites of the U.S. Central Intelligence Agency and Senate, Sony, and Citibank. In February 2012 a hacking collective shut down Chinese websites.[15]

In August 2012 Army General Keith Alexander, USCYBERCOM Commander, reported that USCYBERCOM was closer to becoming a unified command, but "it's a long, long process. They're working their way through that. I'm sure it will take some more time."[16]

According to its mission statement, "USCYBERCOM is responsible for planning, coordinating, integrating, synchronizing, and directing activities to operate and defend the Department of Defense information networks and when directed, conducts full-spectrum military cyberspace operations (in accordance with all applicable laws and regulations) in order to ensure U.S. and allied freedom of action in cyberspace, while denying the same to our adversaries."[17]

Indicator 3.2: Protection of satellites against direct attacks

Although less likely than interference with satellite ground stations or communications links, direct interference of satellites by conventional, nuclear, or directed energy weapons is much more difficult to defend against. In this case, the primary source of protection for satellites stems from the difficulties associated with launching an attack of conventional weapons into and through the space environment to specific locations. It is worth noting that, despite recent incidents involving ASATs impacting a country's own spacecraft, no hostile attacks on an adversary's satellite have been documented to date.

The distinct nature of the space environment itself may provide a certain level of protection for space assets. For example, energy weapons must overcome atmospheric challenges and be effectively targeted at satellites, which orbit at great distances and move at very high speeds. Also, the distances and speeds involved in satellite engagements can be exploited to enhance protection. Satellites in lower-altitude orbits are more difficult to detect with space-based infrared sensors because of their proximity to the Earth's atmosphere. The fact that LEO can be reached in a matter of minutes, while GEO takes about a half-day to reach by completing a Hohmann transfer orbit, illustrates the unique protection of dynamics associated with different orbits.[18] Lower orbits are also less predictable because of greater atmospheric effects, such as fluctuations in density in the upper atmosphere, which alter satellite drag.

Higher operational orbits also raise the power demands for terrestrial radars, leaving only optical systems capable of tracking satellites in altitudes beyond 5,000 km. Some military systems are being placed into higher orbits such as MEO or GEO, but orbits are largely dictated by function. Surface finishes and designs optimized for heat dissipation and radar absorption can also reduce the signatures of a satellite and the ability to observe it, further complicating negation targeting efforts. Still, if a hostile space actor has the ability to overcome these defenses, there are few ways to physically protect a satellite against a direct attack.

Efforts to protect satellites from conventional weapons, such as kinetic hit-to-kill, explosive, or pellet cloud methods of attack, assume that it is almost impossible to provide foolproof physical hardening against such attacks because of the high relative velocities of objects in orbit. Once an interceptor has been launched toward a satellite, it has committed a significant amount of its limited fuel to a specific attack strategy. Evasive maneuvers by the targeted satellite can force an interceptor to expend valuable fuel and time in reorienting its line of attack. While such defensive maneuvers require fuel utilization and few satellites carry extra fuel specifically for this purpose, all operational satellites have some fuel allocated to maintaining their orbital positions, known as "station keeping," in case of natural orbital disturbances.

An interceptor is also vulnerable to deception by decoys deployed from a target. For example, an interceptor's radars could be deceived by the release of a cloud of metal foil known as chaff; its thermal sensors could be spoofed by devices imitating the thermal signature of the satellite; or its sensors could be jammed.[19]

Dispersing capabilities, well established in terrestrial conflict, can be applied to satellite operations.[20] Dispersion through the use of a constellation both increases the number of targets that must be negated to affect a satellite system and increases system survivability.

Redundancy in satellite design and operations offers a number of protection advantages. Since onsite repairs in space are not cost effective, satellites tend to employ redundant electronic systems to avoid single point failures. Many GEO communications satellites are also bought in pairs and launched separately into orbit to provide system-level redundancy.

Directed energy weapons can make use of a ground-based laser directed at a satellite to temporarily dazzle or disrupt sensitive optics. Optical imaging systems on a remote sensing satellite or other sensors, such as the infrared Earth sensors that are part of the attitude control system of most satellites, would be most susceptible to laser interference. Since the attacker must be in the line of sight of the target, opportunities for attack are limited to the available territory below the satellite.

2012 Developments

USAF delays decision to deploy disaggregated satellite missions

In November 2012 it was learned that the U.S. Air Force was delaying its decision to pursue the creation of constellations of disaggregated satellites until 2015. General William Shelton, Commander of Air Force Space Command, said that the USAF's Space and Missile System Center is performing studies that will inform the decision.[21]

Disaggregation could make payloads more resilient to enemy attacks by dispersing capabilities on a greater number of smaller craft across a wider expanse of space. The missions most likely under consideration by the USAF for disaggregation are the AEHF series of secure, jam-proof communications satellites and the next generation of weather forecasting satellites. There are currently two operational AEHF satellites, while Lockheed Martin has two more satellites under full-scale construction. Currently, the USAF does not have a weather satellite program in development or production.

Indicator 3.3: 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.[22] 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 Office opened to coordinate the development of hardware and doctrine in support of ORS across the various agencies.[23] 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.[24] 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.[25] In September 2008 Falcon-1 reached orbit on its fourth attempt.[26]

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."[27] 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.[28] The first technology demonstrators built were the X-40 (USAF) and the X-37A (NASA/DARPA).[29] 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.[30] 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.

2012 Developments

ATK awarded DARPA Phoenix contract

"The Phoenix Program is developing technologies to cooperatively harvest and re-use valuable components from retired, nonworking satellites in geosynchronous orbit. The planned repurposing of these satellite components such as antennas represents the potential to create new space resources at significantly less cost."[31]

In August 2012 the Phoenix Program system integrator, the Naval Research Laboratory, identified ATK as the "only responsive source" to modify an existing satellite bus, originally designed by ATK, for the Phoenix mission. The bus "will be capable of supporting, for a minimum of one year, robotic rendezvous and proximity operations, and a grapple-and-repair robotic technology demonstration mission." The bus is to be delivered by October 2014 to the NRL for "Space Vehicle integration and test."[32]

ATK, in partnership with the University of Maryland's Space Systems Laboratory, was also selected by DARPA to develop "robotic servicing tools and software to enable re-use of the antenna and other working components of a nonfunctional satellite."[33]

Robotic Refueling Mission of NASA and CSA performs satellite servicing task from ISS

A joint effort of NASA and the Canadian Space Agency, the Robotic Refueling Mission (RRM) began operations on the International Space Station on 7 March 2012, marking a milestone "in satellite-servicing technology and the use of the space station robotic capabilities."[34] RRM was delivered to the ISS in July 2011.

RRM is "designed to demonstrate the technologies, tools, and techniques needed to robotically service and refuel satellites in orbit, especially those not built with servicing in mind."[35] It employs Dextre, the space station's twin-armed Canadian robot developed by the CSA to perform assembly and maintenance tasks on the exterior of the ISS as an extension of Canadarm2. This marks the first time that Dextre has been used for research and development.[36]

RRM and Dextre were assigned tasks to accomplish over two years. These activities are designed to demonstrate a wide array of servicing capabilities. The goal is "to reduce the risks associated with satellite servicing as well as lay the foundation and encourage future robotic servicing missions."[37] Such future missions could include the repair and repositioning of orbiting satellites. According to Benjamin Reed, Deputy Project Manager of the Satellite Servicing Capabilities Office, "The significance of RRM is that it demonstrates that robotic satellite-servicing technology exists now and it works correctly on orbit."[38]

Initial operational capability declared for ORS-1 satellite

After testing the on-board camera for months, the USAF declared the ORS-1 imaging satellite operational in January 2012. ORS-1 was launched in June 2011 and received "early combatant command acceptance" in September.[39]

Although the ORS program was under financial attack, it seemed that the satellite's fate was secure for the time being. According to the USAF, "The 1st and 7th Space Operations squadrons at Schriever Air Force Base in Colorado will continue to operate ORS-1 to support CENTCOM needs until it is deemed no longer needed or is no longer capable."[40]

In its February 2012 budget request for FY2013 the White House called for the termination of the ORS office. According to a departmental statement, "The Air Force is working to integrate ORS lessons learned into the broader set of space programs, allowing for a more distributed and integrated approach. To do this, rather than have a stand-alone program office, the Air Force will transition the ORS efforts, principles and activities to the [Air Force] Space and Missile Systems Center."[41]

Deployment of small satellites on the rise

On 13 September 2012 an Atlas V 401 launch vehicle built by United Launch Alliance lifted off from Vandenberg AFB with a classified NROL payload. Following the completion of its primary mission the Centaur Upper Stage of NROL-36 was to place 11 Picosatellites or cubesats in orbit.[42]

Don Spencer of ULA said that "the cubesat missions will study space weather and communication, the space environment, debris mitigation, maritime shipping container tracking and spaceflight safety, and orbit refinement."[43]

The Japanese Experimental Module (JEM) Small Satellite Orbital Deployer (J-SSOD) is designed to launch small satellites from the ISS, potentially much more cheaply than from Earth.[44] It uses the JEM Remote Manipulator System, which is like a small robotic arm. In the summer of 2012 the J-SSOD and five CubeSats arrived at the ISS onboard a JAXA transfer vehicle. On 4 October 2012 the J-SSOD deployed the satellites.[45]

The largest satellite, RAIKO, is a two-unit JAXA satellite; it is designed to take photos of the Earth through a fish-eye lens camera and will test a star sensor. FITSAT-1, also a JAXA satellite, will test "a high-speed transmission module for small satellites, using visible light to communicate by high power LED flashes;" its goal is "to transmit data close to 100 times faster than current CubeSats,"[46] The JAXA WE WISH satellite, with an infrared camera that will transmit images to Earth, will promote the use of data from small satellites; it is expected to be popular with local ham operators.[47] The F-1 Cubesat will capture atmospheric changes and might also gather data on ship traffic and forest fires, among other uses.[48] TechEdSat is designed to evaluate Space Plug-and-Play Avionics and test tracking and communication capabilities; it also uses ham radio to transmit information back to Earth.[49]

In July 2012 DARPA awarded six contracts for its Airborne Launch Assist Space Access (ALASA) program, which is designed to produce a rocket that can launch a 100-lb satellite into LEO at a cost of less than $1-million and with no more than 24 hours' notice to integrate the payload.[50] Flight test demonstrations are planned for the period 2013-15.[51] ALASA is designed to launch from an aircraft to improve performance, reduce range costs, and enable more frequent missions. It will be able to launch quickly from virtually any major runway around the world.[52]

The Soldier-Warfighter Operationally Responsive Deployer for Space (SWORDS) launcher is a cooperative project between the Office of the Secretary of Defense, U.S. Army Space and Missile Defense Command/Army Forces Strategic Command, and NASA.[53] In 2012 the Office of the Secretary of Defense approved SWORDS as a Joint Capabilities Technology Demonstration.[54] It is designed to place nanosatellites in precise LEOs when and where they are needed. No longer will these small satellites have to wait months or years to piggyback on larger payloads. "The SWORDS launch vehicle can be transported by C-130 aircraft, and is designed to launch out of multiple ranges, including austere ranges with as little infrastructure as a simple concrete pad."[55] A flight test is planned for summer 2014.[56]

Indicator 3.4: 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).[57] 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.[58]

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.[59] For FY2005 Congress appropriated $14-million for the KE-ASAT program through the MDA Ballistic Missile Defense Products budget.[60] The KE-ASAT program was part of the Army Counterspace Technology testbed at Redstone Arsenal.[61]

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.[62] EKVs use infrared sensors to detect ballistic missiles in midcourse and maneuver into the trajectory of the missile to ensure a hit to kill.[63] With limited modification, the EKV may be used against satellites in LEO.[64] 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.[65]

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,"[66] 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.[67] 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.[68]

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.[69] However, China called the event an experiment, not an anti-satellite test.[70] The U.K., Israel, and India have also explored techniques for exoatmospheric interceptors.[71]

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.[72] 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.[73]

Low-powered lasers have been used to "dazzle" or degrade unhardened sensors on satellites in LEO.[74] 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.[75] This suggests that even a commercially available low-watt laser functioning from the ground could be used to "dazzle" or temporarily disrupt a satellite.[76] 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.[77]

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.[78] This technology is believed by some experts to have potential ASAT capabilities, despite the significant technical and cost challenges it has faced.[79] The program was initiated in 1996 and took 12 years to reach first light, at a cost of $5-billion.[80] The first ballistic missile interception was planned for late 2009[81] and finally occurred in February 2010 when the ALTB system successfully shot down a test ballistic missile.[82]

2012 Developments

Jamming incidents and capabilities proliferate

Middle East and North Africa

Uprisings in the Middle East and North Africa associated with the Arab Spring have prompted some governments in the region to block incoming signals from satellites, in attempts to quell unrest and the ability of citizens to coordinate protests.[83] This practice threatens the business of operators such as Arabsat and Nilesat, which provide broadcasting, broadband, telephone, and Very Small Aperture Terminal service.[84] During the Satellite 2012 Conference in Washington, DC, Arabsat and Nilesat, two of the largest satellite fleet operators based in the Middle East, complained of jamming by regional governments.[85]

Since pro-democracy uprisings began in Libya and Egypt, Ethiopia has reportedly become the source of the jamming of Arabsat satellite transmissions.[86] Several Lebanese channels as well as the Qatar-based Al-Jazeera have been affected.[87] In January 2012 Ethiopia is said to have jammed Eritrean television, jamming its own channels in the process.[88] Eritrea accused China of providing Ethiopia with the technology, training, and assistance to conduct jamming activity.[89]

International operators are also affected. For two weeks in October 2012 Syria and Iran are believed to have jammed the satellite frequencies of 25 international broadcasters, including the BBC, France 24, Deutsche Welle, and Voice of America.[90] It is estimated that the disruption spanned an area from northwestern Europe to Afghanistan.[91] Most global interference in 2012 was traced to Syria, with rising instances of jamming in Bahrain and Iran.[92]

There has been some speculation that Iran has been using concealed satellite jamming technology in flagpoles in addition to satellite-to-satellite jamming techniques.[93] The increase in interference based in Tehran has coincided with the strategic placement of metal flagpoles around the perimeter of the city. These poles decrease in width as they get taller; this is "consistent with the design principles for good omni-directional broadcasting" that can function as a "kill switch."[94]

Iranian satellite-jamming equipment is based in the west of Iran and in Iraqi Kurdistan. There has been increased pressure from international sanctions to drop state-owned Iranian channels to reduce the frequency of jamming. In October 2012 Eutelsat dropped 19 state-owned Iranian channels from its Hotbird satellite. Intelsat reportedly did the same.[95]

Other incidents of jamming occurred in 2012. In January in Bahrain, British technicians began jamming the Islamic Republic of Iran Broadcasting channels on the Hotbird satellite provider.[96] In July Eutelsat formally complained to the ITU and the Government of Saudi Arabia about the jamming of its transponders aboard its Eutelsat 25A communications satellite.[97] Eutelsat claimed that competitor Arabsat, based in Saudi Arabia, was responsible for the jamming, as broadcast disputes arose over the use of Ku-band frequencies.[98]

In February 2012 the ITU "called for governments, broadcasters and satellite operators to work much more closely together in tackling the problem [of jamming] and exert greater pressure on the rogue states that still engage in uplink jamming."[99] As there is currently no pan-African or pan-Middle Eastern authority to prevent illegal transmissions, cooperative agreements are made among the countries that make up each body of operators. However, member states of this consortium continue to jam broadcasts, including their own.[100]

North Korea

In May 2012 South Korea announced that for two weeks beginning in late April, North Korea had jammed its GPS signals, affecting civilian flights in and out of South Korea. North Korea had reportedly jammed signals twice before,[101] but this was the first time there had been such a "widespread effect on civilian flights."[102] The reason for the jamming was not clear, but "it came at a time of high cross-border tensions."[103]

Missile systems pursued by various countries

In January 2013 Lockheed Martin received a $755-million contract from the U.S. Army Aviation and Missile Command for hardware and services associated with the Patriot Advanced Capability-3 (PAC-3) Missile Segment program.[104] The contract included production for the U.S. Army and Taiwan.[105]

"The PAC-3 Missile Segment upgrade consists of the PAC-3 Missile, a highly agile hit-to-kill interceptor, the PAC-3 Missile canisters (in four packs), a fire solution computer and an Enhanced Launcher Electronics System."[106] The PAC-3 missile system was successfully tested in April 2012 at the Utah Test and Training Range, demonstrating the system's ability "to detect, track, engage and destroy a cruise missile target at extended range in an integrated air and missile defense architecture."[107] Raytheon's Rolling Airframe Missile Block 2 conducted successful tests of missile interceptors for ships in February 2012.[108]

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

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

Key:
■ = enabling capability

In April 2012 India tested its Agni-5 missile, which can reach an altitude of 600 km (373 miles) and has a range of 5,000 km (3,100 miles).[109] The head of the Indian Defence Research and Development Organisation proclaimed "fantastic opportunities" in building ASAT weapons and launching satellites on demand. But Saraswat denied plans to develop offensive systems: "India does not believe in weaponization of space. We are only talking about having the capability. There are no plans for offensive space capabilities."[110] This test comes after a missile defense shield test in February 2012. Pakistan has indicated that India's missile program could trigger a new arms race in the region.[111]

In March 2012, in advance of a North Korean missile test, Japan announced that it might use force to bring down the missile if it threatened Japan.[112] In early April Japan deployed missile batteries and dispatched destroyers.[113] Also in response to North Korean threats, in May 2012 South Korea announced its decision to purchase 500 to 600 missiles, including more Hyunmu-3 cruise missiles (range 1,500 km) and Hyunmu-2 ballistic missiles (range 300 km).[114]

In February 2012 Israel and the United States tested their Arrow anti-missile defense system in advance of the delivery of the block 4 Arrow Weapons System to Israel.[115] In May, days after NATO activated the first stage of their missile defense shield, Russia tested an intercontinental missile. Former strategic forces director Viktor Yesin said that "this is one of the … measures being developed by Russia's military and political leadership in response to the US deployment of a global anti-missile system."[116]

Development of directed energy weapons continues

DARPA has a contract with General Atomics to develop and scale the High Energy Liquid Laser Area Defense System (HELLADS)—a directed energy weapon.[117] The HELLADS solid state laser system is designed for tactical aircraft. By 2012 development was in its final stage, with plans to demonstrate the system in 2014.[118] In January 2013 DARPA also announced plans to purchase a second HELLADS system.[119] DARPA plans to also continue funding Lockheed Martin's Aero-Adaptive/Aero-Optic Beam Control program for a self-defense laser designed for a high-speed fighter jet.[120] Likewise, Northrup Grumman continued to work throughout 2012 on the Joint High-Power Solid State Laser (JHPSSL) system, which is capable of producing "three 100kW bursts of power within the first 20 seconds of being switched on."[121]

In November 2012 Russia announced the modernization and refurbishment of their A-60 test bed aircraft by late 2013.[122] The Soviet government began development of the high energy airborne laser system known as the A-60 test bed aircraft in response to the USAF Airborne Laser Laboratory.[123] A new system, the Sokol-Eshelon (Falcon-Echelon) laser, is almost ready for use.[124]

Indicator 3.5: 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 U.K. saw the launch of the Tsinghua-1 microsatellite and companion Surrey Nanosatellite Application Platform to test on-orbit rendezvous capabilities.[125]

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;[126] 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.[127] In January 2009 the Pentagon confirmed that the two MiTEx microsatellites had maneuvered in close proximity to a failing satellite in GEO.[128] This incident raised concerns that the ability to get in such close proximity to another satellite could potentially be used for hostile actions.[129]

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."[130] Sweden has developed the automated rendezvous and proximity operation PRISMA satellites, which were successfully launched in June 2010 from Yasni, Russia.[131] The PRISMA satellite project demonstrates technologies for autonomous formation flying, approach, rendezvous, and proximity operations.[132] 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.

2012 Developments

Orbital rendezvous and docking capabilities still pursued

The U.S. NRL has proposed deploying a suborbital cloud of dust to intercept orbital debris. "The essential idea is that dust, if artificially deployed on orbit in opposite direction to the debris trajectory, can induce an enhanced drag on the debris." The right dust characteristics allow the synchronization of the rate of dust and debris descent.[133] The metallic dust—enough to cover a range of 18 to 31 miles—would eventually fall back to Earth and burn up, with some dust escaping out into space.[134] The plan could go into effect after four or five years of research; effectively removing debris from orbit could take from 10 to 25 years.[135]

In January 2013 Canada's Dextre demonstrated its ability to refuel a mock satellite.[136]

In January 2012 China announced an ambitious launch schedule of 30 satellites, including GPS satellites. Also announced were launches of Shenzhou-9 and Shenzou-10 spacecraft with rendezvous and docking capabilities.[137] This comes after the successful docking of the Shenzhou-8 with the robotic Tiangong 1 space laboratory module in November 2011.[138] The launch of these Shenzhou spacecraft is a key element in China's plans to construct a space station, which is to be completed by 2020.[139]

The Shenzhou-9, a mission that also delivered the country's first female taikonaut to space, successfully docked with the Tiangong-1 spacecraft in June 2012.[140] The initial docking was accomplished through an automated process, with a manual docking attempted with the same spacecraft. [141] The Shenzhou 10 mission is scheduled to launch in 2013.[142]

THEME FOUR

Outer Space Policies and Governance

Indicator 4.1: National space policies and laws

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.

2012 Developments

U.K. Space Agency publishes its Civil Space Strategy

On 10 July 2012 the U.K. Space Agency unveiled its Civil Space Strategy for the four-year period 2012-16 at the Farnborough International Airshow.[10] The strategy, which sets out the agency's framework and priorities, was officially launched by Minister of Universities and Science David Willets. According to Willets, the strategy "focuses on creating new opportunities for industry, bolstering the role of space in the UK's infrastructure and furthering the National Space Technology Programme.[11]

Key areas of growth include:

- international telecommunications and navigation services and applications;
- provision of information systems to support carbon trading;
- systems of space surveillance to alert us to natural and manmade hazards that threaten critical space infrastructure;
- innovative launch systems;
- services to support space exploration; and
- space tourism.[12]

The text of the Civil Space Strategy also highlights the importance to the U.K. Space Agency of working with domestic and international partners to

- assist industry to build new markets in line with the Government's Growth Review objectives;
- identify, and invest in, strategic opportunities to grow the U.K.'s industrial capabilities and economic impact;
- carry out horizon-scanning activities with industry and researchers to identify emerging opportunities;
- invest in programs that demonstrate new services;
- translate investment into down-to-Earth applications.[13]

The Civil Space Strategy is normally published every four years; the 2012 edition is the first since the U.K. Space Agency was established as an executive body with its own budget.[14] Notably, the strategy sets out an ambitious goal of acquiring 10% of the global space market by the year 2030.[15]

Japan eases restrictions on military space development

On 20 June 2012 Japan passed the Partial Revision of the Cabinet Office Establishment Act, which restructured the authority to regulate Japanese space policy and budget, including the governance of the JAXA.[16] Under this legislation, the Space Activities Commission of the Ministry of Education, Culture, Sports, Science, and Technology, which was responsible for the development of Japanese space program, will be abolished. Regulation of space policy and budget will be handed over to the Space Strategy Office formed under the Prime Minister's Cabinet Office. The Space Strategy Office will be supported by a consultative Space Policy Commission of academics and independent observers.[17]

By revoking Article 4 (Objectives of the Agency) of a law that previously governed JAXA and mandated the development of space programs for "peaceful purposes only," the new legislation demonstrates consistency with Article 2 of the 2008 Basic Space Law.[18] In conformity with the principles laid down in the 1967 Outer Space Treaty JAXA is now free to pursue the non-aggressive military use of space.[19]

The new legislation is the culmination of a decade-long process that sought ways to “leverage Japan’s space development programs and technologies for security purposes, to bolster the nation’s defenses in the face of increased tensions in East Asia.”[20] According to some observers, such as Kazuto Suzuki, associate professor of international political economy at the Public Policy School of Hokkaido University, Japan’s space development has been hampered by the peaceful-purposes-only restriction.[21] The new legislation “opens the door to military space development programs with an emphasis on space-based missile early warning.”[22] As Suzuki explains, there is also strong bipartisan political support for Japan to develop and launch its own missile early-warning system to support the nation’s small fleet of Aegis destroyers for upper-tier defense, and its PAC-3 systems for lower-tier defense.[23]

States in the United States enact legislation on spaceflight liability

On 19 April 2012 Colorado Governor John Hickenlooper signed the Spaceflight Entity Limited Liability Bill, SB12-035.[24] The bill, signed at the Colorado Space Industry Luncheon held during the 28th National Space Symposium in Colorado Springs, limits the liability of companies that may eventually undertake commercial flight activities in Colorado. According to the bill, “companies and individuals engaged in creating and retaining these space-related employment opportunities should reasonably expect some degree of protection in the event of an accident that might occur as a result of the inherent dangers of spaceflight.”[25]

With the legal protection afforded by the bill, “gross negligence or where the company reasonably should have known of a dangerous condition on the land, or in the facilities or equipment used”[26] would be the only grounds that could be used to sue a spaceflight company in Colorado. This legislation is expected to promote the space industry in Colorado in the wake of the application by Front Range Airport near Denver to be designated a spaceport by the FAA.[27] This designation would allow spacecraft launched from the airport to take passengers on suborbital flights.[28]

On 21 September 2012 California Governor Edmund G. Brown signed the Space Flight Liability and Immunity Act, Assembly Bill 2243, to boost private space travel industry in the state.[29] This law provides liability protections to compliant companies in the form of immunity privileges for bodily injuries or damages sustained by any spaceflight participant who has acknowledged such risks.[30] According to Governor Brown, “This bill allows commercial space-travel companies to innovate and explore without the worry of excessive liability.”[31]

Under the bill, companies wishing to operate spaceflights must have signed statements from travelers acknowledging that they understand the “inherent risks associated with space flight activity, including death, and also acknowledging that the space flight entity has limited liability for injuries or damages sustained by a participant as a result of these inherent risks.”[32] The legislation was welcomed by the Commercial Spaceflight Federation; president Michael Lopez-Alegria said that “this bill will provide the required liability protections needed for the companies in this developing sector to operate in an efficient and effective manner, while acknowledging that spaceflight is not a risk-free activity.”[33]

U.S. DoD Space Policy Directive and defense strategic guidance issued

On 18 October 2012 the U.S. Department of Defense issued a space policy directive to supplement the 2010 National Space Policy and the 2011 National Security Space Strategy. The directive was intended “to update established DoD space policy and assigned DoD responsibilities for space-related activities in accordance with the National Space Policy, Presidential Policy Directive-4 … and the National Security Space Strategy.”[34] It addressed "the challenges posed in an increasingly congested, contested, and competitive space domain."[35] "Sustainability and stability" as well as "free access to and use of space" were identified as vital to U.S. national interests.[36]

The directive aimed to deter attacks on U.S. space systems by developing international norms of responsible behavior and enhanced "collective security capabilities," and by mitigating the benefits gained by attacking U.S. space systems. The DoD promoted adherence to the U.S. Government Orbital Debris Mitigation Standard Practices in accordance with the National Space Policy. It also announced that it would cooperate "with interagency, international, and commercial partners" in "sharing space situational awareness and flight-safety information,' and expand international cooperation by forging "closer security ties."[37]

The directive notably states that "purposeful interference with U.S. space systems … will be considered an infringement of U.S. rights. Such interference … is irresponsible in peacetime and may be escalatory during a crisis. The United States will retain the capabilities to respond at the time and place of our choosing."[38]

This directive reflects the defense strategic guidance entitled "Sustaining U.S. Global Leadership: Priorities for 21st Century Defense," which was announced by President Obama on 5 January 2012.[39] Like earlier policy documents, it characterized the space environment as "increasingly congested and contested"[40] due to the growing number of spacefaring nations. The guidance emphasized continuing U.S. global efforts "to assure access to and use of the global commons, both by strengthening international norms of responsible behavior and by maintaining relevant and interoperable military capabilities."[41] The effective operation in space and cyberspace was identified as a primary mission for U.S. armed forces. It would be achieved through investment in "advanced capabilities to defend its networks, operational capability, and resiliency in cyberspace and space" and by collaborating with international allies and partners.[42]

United States eases export controls on some satellites and related components

On 18 April 2012 DoD released a report on space export control policy as requested by the Congress.[43] Following a review of risk assessment of U.S. space export control policy, satellites and related items were identified as items that "do not contain technologies unique to the United States military industrial base nor are they critical to national security."[44] Items that could be moved from the U.S. Munitions List (USML) to the Commerce Control List (CCL) include:

- Communications satellites that do not contain classified components;
- Remote sensing satellites with performance parameters below certain thresholds; and
- Systems, subsystems, parts, and components associated with these satellites and with performance parameters below thresholds specified for items remaining on the USML.

CCL controls "provide appropriate visibility into where and by whom the dual-use space components are being used, thus protecting national security by ensuring that foreign space assets containing U.S. components are not used against the United States."[45] According to Acting Under Secretary of Defense for Policy Jim Miller, "this in-depth report shows that the United States can safely modify the export controls placed on satellites and related component technology that are widely available, while maintaining firm control on systems and technologies deemed truly critical to national security."[46]

The review also concluded that the following space-related items should remain on the USML because they contain critical components and technologies that offer the United States a military or intelligence edge in space:

- Satellites that perform a purely military or intelligence mission;
- Remote sensing satellites with high performance parameters;
- Systems, subsystems, parts, and components unique to the above satellite types and not common to dual-use satellites; and
- Services in support of foreign launch operations for USML- and CCL-designated satellites.

The report further recommends that Congress should restore the authority to determine the export control jurisdictional status of satellites and related items to the President. It also recommends that DoD be given authority to apply special export control measures to U.S. companies that provide technical services in support of foreign satellite or launch vehicle development and associated launch operations.

On 18 December 2012 the U.S. Congress finalized the National Defense Authorization Act (NDAA) for 2013, which includes a provision to change commercial satellite export control policy. The NDAA repeals a 1998 law that placed export jurisdiction for all space technology, regardless of sophistication or availability, with the Department of State. The NDAA gives the President authority to remove satellites from the USML. The Executive Branch can now place satellites and related technologies on the CCL as dual-use technologies. This development, signed into law by the President on 3 January 2013, is intended to provide more business opportunities for U.S. aerospace companies.

Figure 4.1: Status of major UN space treaties as of August 2013[47]

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

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 2012 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 (described below), 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.[48] 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.[49] 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[50] and the United States in 2008.[51]

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."[52] 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":[53]

- 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.[54] However, the Moon Agreement has not been widely ratified because of contentions related to lunar exploration.[55] 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.

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.[56] 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."[57] 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.[58]

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 2012 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.[59] 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 commencing in 2012 and to report 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.

Figure 4.2: 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.

2012 Developments

Statements on PAROS delivered at the Conference on Disarmament, but still no Program of Work

On 5 June 2012 the CD deliberated on the prevention of an arms race in outer space (PAROS).[60] Although the CD has been effectively deadlocked for more than 15 years due to its inability to agree on a Program of Work, statements were delivered on PAROS by Finland, the Russian Federation, China, Canada, Kazakhstan, the European Union, Belarus, the Republic of Korea, Indonesia, France, India, the United States, Pakistan, Iran, Japan, and Algeria.[61]

Ambassador Kari Kahiluoto of Finland, in his statement as President of the CD, highlighted the enduring importance of PAROS, which "continues to be seen as one of the core agenda items for the CD and an eventual program of work."[62]

Although there was general consensus among the delegates on the preservation of outer space for peaceful uses and the need for an effective regulatory regime, countries including China, Belarus, Pakistan, and Iran noted that gaps exist in the current legal framework relating to outer space activities.[63] At the same time, there was disagreement over the feasibility of adopting a binding legal instrument to regulate outer space activities. For example, the EU's statement pointed to the lack of verification provisions in the draft Prevention of the Placement of Weapons in Outer Space Treaty (PPWT), which has been championed by both Russia and China. It stated that, "as a matter of Principle, an effective and robust verification system must be an integral part of any further Treaty concerning space security."[64]

In its statement the United States reiterated its longstanding position that it "is willing to consider space arms control proposals and concepts that are equitable, effectively verifiable, and enhance the national security of the United States, partners, and allies. However, we have not yet seen a proposal that meets these criteria."[65] During discussions it was widely acknowledged that, while transparency and confidence-building measures (TCBMs) are critical in preventing the weaponization of outer space, they are no substitute for a legally binding agreement.

COPUOS remains active; Working Group on Long-Term Sustainability of Space Activities holds first formal meetings

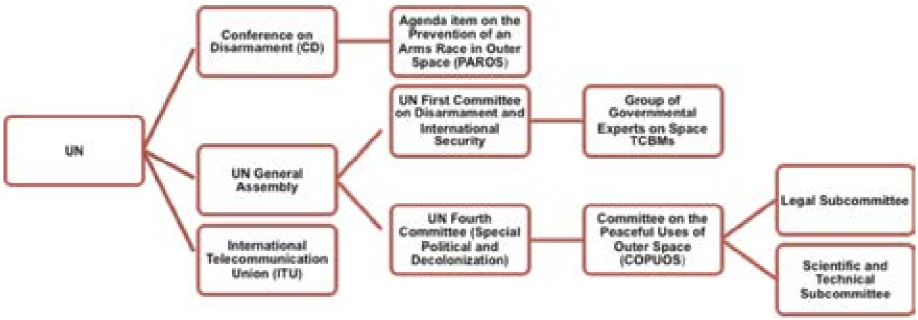
The 55th session of the UN COPUOS was held from 6-15 June 2012 in Vienna under the Chairmanship of Dr. Yasushi Horikawa.[66] To commemorate the fortieth anniversary of the Landsat program, a special panel on the worldwide evolution of remote sensing from space was held on 6 June.[67] During this session, Armenia, Costa Rica, and Jordan applied for Committee membership and Azerbaijan became the newest COPUOS member via UN resolution 66/71.[68]

In February 2012, during the 49th session of the COPUOS Scientific and Technical Subcommittee, the COPUOS Working Group on the Long-term Sustainability of Outer Space Activities (LTSSA) held its first formal meetings under the chairmanship of Peter Martinez of South Africa.[69] The LTSSA Working Group was established by the Scientific and Technical Subcommittee on 18 February 2010; 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 in 2011.

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. Using this information, the Working Group will produce a set of guidelines that could be applied on a voluntary basis by international organizations, nongovernmental entities, and individual states.[70]

Four expert groups were established to expedite the work of the Working Group. Group A will work on sustainable space utilization supporting sustainable development on Earth; Group B on space debris, space operations, and tools to support collaborative space situational awareness; Group C on space weather; and Group D on regulatory regimes and guidance for actors in the space arena.[71]

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



First meeting of UN Group of Governmental Experts on TCBMs in Outer Space Activities convened

The UN Group of Governmental Experts (GGE) on transparency and confidence-building measures in outer space activities held its first meeting from 23-27 July at UN headquarters in New York.[72] The GGE, which had been initially proposed by Russia in 2010, was adopted on 13 January 2011 under UNGA resolution 65/68, with a vote of 183 states in favor and none opposed.[73] Specifically, the resolution requested that the Secretary-General establish, on the basis of equitable geographical distribution, a group of governmental experts to conduct a study commencing in 2012 and report to the 68th session of the UN General Assembly in 2013.[74]

The GGE is made up of 15 experts from the governments of Brazil, Chile, China, France, Italy, Kazakhstan, Nigeria, the Republic of Korea, Romania, the Russian Federation, South Africa, Sri Lanka, Ukraine, the United Kingdom, and the United States. At the first meeting Victor Vasiliev of Russia was elected Chair.[75]

The group considered various issues relating to TCBMs in outer space, including "basic principles; criteria; political, transparency, and operational measures; and consultative mechanisms."[76] Although there have been discussions on the merits of a legally binding treaty, experts were of the view that the measures to be proposed "could be unilateral, bilateral or multilateral and should be voluntary."[77]

The second meeting of the GGE was held in April 2013[78] and the third and final in July.[79]

ITU condemns satellite jamming

After making its first public demand in 2010 that a country stop intentional jamming of satellite broadcasts,[80] the ITU took another public step in 2012 by condemning intentional jamming prohibited by the ITU Radio Regulations.

Eutelsat and Intelsat are the main satellite providers for Persian-language state-run channels in Iran, while Eutelsat is the main provider for broadcasts from outside Iran. According to a Small Media report, these networks can determine the exact origin of satellite jamming by pinpointing the location of jamming frequencies. Eutelsat, which suffers frequent jamming attacks on the Persian-language channels broadcasting from outside Iran, also has a provision-of-service contract to broadcast Iran's Press TV. Consequently, Eutelsat Communications made a new appeal to international regulating authorities to urgently intervene in putting an end to repeated jamming of satellite signals from Iran.[81]

At the World Radiocommunication Conference 2012 (WRC-12), held 23 January-17 February 2012 in Geneva, Switzerland, ITU Member States voted to take greater responsibility in addressing satellite jamming. According to Yvon Henri (Chief, Space Services Department, ITU Radiocommunication Bureau), "WRC-12 reaffirmed that recent and repeated cases of intended harmful interference represent infringements and that Member States under the jurisdiction of which the signals causing this harmful interference are transmitted have the obligation to take the necessary actions."[82] Specifically, Article 15 of the Radio Regulations was revised;[83] it now states, "If an administration has information of an infringement of the Constitution, the Convention or the Radio Regulations (in particular Article 45 of the Constitution and No. 15.1 of the Radio Regulations) committed by a station under its jurisdiction, the administration shall ascertain the facts and take the necessary actions." The ITU also condemned satellite jamming as "contrary to Article 19 of the Universal Declaration of Human Rights."[84]

Article 45 of the ITU Constitution and No. 15.1 of the Radio Regulations prohibit transmissions by Member States that cause harmful interference. ITU Member States, with their ratification of the ITU Convention, are legally bound by intergovernmental treaty to adhere to the ITU Constitution and the Radio Regulations.[85]

The Iranian government has been cautioned numerous times by international regulating bodies, all of which have ordered them to find the source of satellite interference and work to prevent its reoccurrence. In February 2010 the EU called on Iranian authorities to put an end to electronic interference and to cease jamming of satellite broadcasting.[86] However, the EU statement did not outline any punitive actions should Iran refuse to stop jamming and the Iranian authorities have taken no action.

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 dialog on gaps in the international legal framework. For example, the Union of Concerned Scientists drafted a model treaty banning ASATs (1983).[87]

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

2012 Developments

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

In Vienna on 5 June 2012 the European Union kicked off the official multilateral consultation process for its proposed International Code of Conduct for Outer Space Activities.[88] The meeting was attended by 110 representatives from more than 40 countries. A new draft Code was introduced; this new version was the product of bilateral meetings between the EU and various international partners.[89] The UN Institute for Disarmament Research (UNIDIR) participated "to facilitate information dissemination and exchange of views"[90]

A second meeting scheduled for October in New York was postponed[91] until 16-17 May 2013 in Kiev, Ukraine.[92]

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."[93] The latest draft of the Code is based on the following principles:

- the freedom for all States, in accordance with international law, to access, to explore, and to use outer space for peaceful purposes without 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 inherent right of individual or collective self-defence as recognised in the United Nations Charter;
- the responsibility of States to take all appropriate measures and cooperate in good faith to prevent harmful interference in 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 and to take all appropriate measures to prevent outer space from becoming an arena of conflict.[94]

EU-led efforts to develop a code of conduct for space activities received a diplomatic boost in January 2012, when U.S. Secretary of State Hillary Clinton stated 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."[95] She indicated that some features of the code were subject to discussions and negotiations.

Countries such as Australia and Japan have also indicated their support for some version of the Code. In early 2012 Australian Foreign Minister Kevin Rudd indicated 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."[96] 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."[97]

Regional forums tackle space security, cooperation

ESA's Council Meeting at the Ministerial Level met in November 2012 to set the next three-year budget, which closely resembled the previous one. The Ministerial Council also accepted an offer from NASA to provide the Service Module for their Orion crew capsule, based on the European Automated Transfer Vehicle (ATV) design. In response to the competitive launch market, especially the success of SpaceX, the Ministerial Council recommended the development of the upgraded Ariane 5ME launch vehicle, which could accommodate two large satellites.[98]

The Ninth Space Council of ESA and EU Ministers was held on 11 December 2012. In November the EU published a proposal entitled "Establishing appropriate relations between the EU and the European Space Agency."[99] In it the EU describes several problems it has with ESA "relating to ESA's inclusion of non-EU nations in its membership, the way it awards contracts, and the lack of democratic oversight." The EU's executive commission is concerned that "as ESA and the EU move more into security- and military-related space activities, they will need to discuss issues that should not be within earshot of Norway and Switzerland, which are ESA members, and of Canada, an associate ESA member."[100]

The EU objected to the use of EU funds to benefit non-EU ESA members Norway, Switzerland, and Canada, whose participation "poses an obvious problem in general, and an even more acute problem when it comes to security and defence matters."[101] France and Belgium supported the conversion of ESA into an EU agency, while Germany and the United Kingdom were in favor of maintaining the status quo. Most of the other nations present were reluctant to commit to a side.[102]

The Association of Southeast Asian Nations (ASEAN) 2012 Regional Forum, held in December, included a Space Security Workshop, jointly organized by the Vietnamese Ministry of Foreign Affairs and the Australian Department of Foreign Affairs.[103] Representatives of governments and nongovernmental organizations made presentations.

In his remarks at the workshop, Frank Rose, U.S. Deputy Assistant Secretary of State, Bureau of Arms Control, Verification and Compliance, said, "Ensuring the long-term sustainability, stability, safety, and security of the space environment and protecting it for future generations are in the vital interests of the United States, the members of ASEAN, and the entire global community. To do this, however, we must overcome misperceptions and suspicions by taking a step-by-step approach to building confidence and creating understanding through TCBMs."[104] Senior Advisor Ray Williamson of Secure World Foundation, a nongovernmental organization, presented on the technical, policy, and legal issues related to orbital debris removal.[105]

On 5 September 2012 African communications and IT ministers met in Khartoum, Sudan, to consider the creation of an African Space Agency.[106] Sudanese President Omar Hassan al-Bashir called for "the biggest project, an African space agency."[107] He added that having a space agency "will liberate Africa from the technological domination."[108]

According to a working document prepared for this meeting, "a common continental approach will allow the sharing of risks and costs and ensure the availability of skilled and sufficient human resources. It will also ensure a critical size of geographical area and population required in terms of the plan of action for some space applications."[109]

The idea of an African Union Space Agency—or AfriSpace—has gained steam since a September 2010 decision to conduct a feasibility study on creating such an agency.[110] The African Union Commission Strategic Plan 2009-2012 states, "Through the launch of African Union Space Agency, Africa will be able to negotiate better offers for satellite construction, space launches and technology transfer; and share data, scarce facilities and infrastructure much more than individual small countries can do on their own."[111]

UNIDIR hosts 11th annual Space Security Conference

UNIDIR held its eleventh annual conference on space security 29-30 March 2012 in Geneva, Switzerland.[112] Entitled "Laying the Groundwork for Progress," the conference was co-sponsored by Secure World Foundation and had support from The Simons Foundation and the governments of Canada, the People's Republic of China, the Russian Federation, and the United States.[113] The Conference shed light on potential progress while recognizing myriad technical and policy challenges.

While there was general consensus on the need for international cooperation to ensure space sustainability, the complexity of the task was acknowledged. According to the conference report, "the international community is tackling these challenges within the context of several international initiatives, each with its own priorities and perspectives and subject to domestic and technical considerations."[114]

There was considerable discussion on international processes to address issues of space security that "offer different ways forward, from voluntary to legally binding, and cover a range of threats to space security, from orbital debris to space weaponization."[115] Among specific proposals discussed were the draft Treaty on the Prevention of Placement of Weapons in Outer Space, the COPUOS Working Group on the Long-term Sustainability of Space Activities, the UN GGE on transparency and confidence-building measures in space, and the proposed International Code of Conduct for Outer Space Activities.

A Global Assessment of Space Security

C. Jolly

This synthesis chapter provides an overview of the impacts that current and recent trends in space activities are having on space security in early 2013. A number of key indicators are provided.

Foreword

Investing in a space program is no luxury, but a serious undertaking. It brings scientific, technological, industrial, and security capabilities and benefits, often with significant economic returns down the road. Key activities in everyday life—weather forecasting, global communications and broadcasting, disaster prevention and relief—depend increasingly on the unobtrusive use of space technologies. Over the coming decades, space-related applications, such as land-use management, distance education, telemedicine, precision farming, and monitoring of various international treaties, will continue to hold important socioeconomic promise.

In 2006 the Organisation for Economic Co-operation and Development launched its Space Forum in cooperation with the space community. The Forum aims to assist governments, space-related agencies, and the private sector to better delineate the statistical contours of the growing space sector worldwide, while investigating the space infrastructure's economic significance and potential impacts for the larger economy. In early 2013 the Forum included in its Steering Group organizations from Canada, France, Germany, Italy, Norway, the United Kingdom, and the United States, as well as the European Space Agency.

Over the years, while examining the role of space activities and their wider impacts in both OECD and non-OECD countries, the OECD Space Forum has seen several threats to the global space infrastructure become more significant: they include the increasing amount of harmful space debris and growing interference of satellite signals.

In this context, I would like to thank the Space Security Index team for inviting the OECD Space Forum to contribute to this report. Space applications have the potential to make significant contributions in the management of major 21st-century challenges (e.g., environmental and natural resources monitoring, the digital divide). Therefore, one key message to take away from this assessment is that, as a stable space infrastructure is becoming essential to serve our societies' needs, policymakers from spacefaring nations need to take further actions to improve the long-term sustainability of the main orbits that are already used extensively today.

Paris, 5 July 2013
Claire Jolly
OECD Space Forum

Introducing the concept of space security

Considering the concept of "space security" brings many factors to mind, including:

- the physical state of the space environment (e.g., levels of radiation, passage of asteroids);
- the day-to-day functioning and long-term sustainability of space platforms in orbit (e.g., space debris, extreme space weather impacts);
- the malevolent uses of platforms or their sabotage (e.g., frequency interferences, denial of access); and
- the weaponization of space platforms.

The concept of space security for *Space Security Index 2013* is based on the principles enacted in the 1967 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (the Outer Space Treaty). The Outer Space Treaty's overarching notion is to promote an international, secure, and sustainable access to, and use of, space and freedom from space-based threats (see a link to the Treaty's full text at the end of this assessment).

An optimally secure outer space therefore requires that countries and their nationals should pursue their respective space activities without putting at risk the sustainability, stability, and free access to, and use of, space orbits, so that space remains open for all. This ideal outer space regime is, however, being challenged by some current trends in space activities.

How to assess space security?

The concept of space security obviously includes a number of politically charged issues, with strategic considerations and relatively little public information available. But space security also involves an increasing number of civil and commercial operators, sharing facts about their activities and operations, such as incidents in orbit. The sources of information on space security are therefore mixed, with different levels of quality and reliability. Considering these limitations, *Space Security Index 2013* and previous SSI reports provide a useful compilation of information of space security, by presenting a selected number of qualitative as well as quantitative indicators, based on publicly available sources.

This chapter builds on the information collected for *Space Security Index 2013* and other sources, such as work conducted in the OECD's Space Forum, to provide an innovative evaluation of the status of overall space security today. The main question: After examining recent trends, can we determine that, in 2013, countries and their nationals have a "secure and sustainable access to, and use of, space and freedom from space-based threats"?

This is the first time that an analytical piece with a review of longer-term trends has been presented. In previous SSI reports brief and isolated "Space Security Impact" statements provided concise analysis that sometimes failed to show the interdependence of the various aspects of space activities. To do so is a challenging but constructive exercise, as there are many possible angles to consider:

To overcome subjectivity—at least in part—key articles of the Outer Space Treaty are used as a baseline whenever possible; the relevant articles are referenced throughout the text.

The year 2003, when the first SSI report was published, serves as a benchmark against which the situation in 2013 can be evaluated. We can see how some trends have shifted and whether there has been continuity.

Three complementary topics serve to indicate the state of space security: trends in the global space sector affecting the state of space security, technical capacities to deal with natural and manmade threats in orbit, and international cooperation for sustainable use of space orbits. Each topic has icons that use red, amber, and green lights to indicate where attention and progress by national governments, international bodies, and members of the space community are most needed.

This particular assessment remains a qualitative exercise, as some of the trends lack clear quantitative indicators. An ideal approach would be to follow these key trends over time, relying on quantitative indicators whenever possible, and to monitor how they evolve in response to action from policymakers and the private sector.

What is the state of space security in 2013?

Do countries and their nationals today have a "secure and sustainable access to, and use of, space and freedom from space-based threats"?

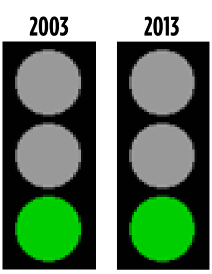
Considering current trends over a decade, my general response would be "yes." An increasing number of countries have access to, and use of, secure space. However, the space environment is becoming ever more risk-prone and the sustainability of space platforms in future decades is increasingly coming into doubt.

Potential military threats, such as access to space negation or destruction of space platforms, are more contentious; several countries are pursuing military space capabilities, which are difficult to assess objectively. In many cases, development of these military space capabilities may be more for deterrence than planned aggression.

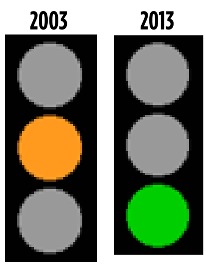
When the growing global importance of a secure and sustainable space infrastructure that provides weather forecasting, environmental and natural resources monitoring, communications, and broadcasting is taken into account, a key message emerges: policymakers from spacefaring nations need to take further actions to improve the long-term sustainability of the main orbits already used extensively today.

1. Trends in the global space sector affecting the state of space security

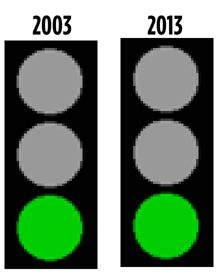
The state of space security is affected by several general trends. Over the decade 2003-2012, four indicators seem particularly relevant: growing access to space by an ever increasing number of actors, the uptake of space applications by more countries, the continuing commercial development of space activities, and increased global military space capabilities. Using the prism of the Outer Space Treaty principles three of these indicators can be seen as positive for space security. The "freedom of access" to space activities by all has never been so true, even if major disparities among countries remain. Freedom of access now includes better access by developing countries to diverse space applications—disaster relief provided by satellite maps and communications—as well as a growing involvement of the private sector and academia in space activities, which brings new commercial opportunities. But freer access to space technologies also features growing military space capabilities of countries around the world, as they can more easily build military or dual-use space systems.



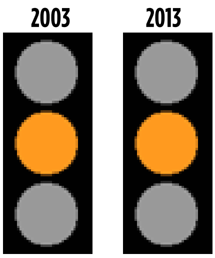
Access to space by an ever increasing number of actors. Paradoxically, the rising number of actors could be seen as a possible threat to space security. Malevolent states and criminal groups could have easier access to space technologies and capabilities, although technology transfer rules still in place in many parts of the world aim to keep sensitive technologies away from such parties. However, the rising number of countries having access to, and use of, space is seen as positive in this particular assessment exercise, if one takes as a baseline the Outer Space Treaty's first article, which declares that space "shall be free for exploration and use by all States…and there shall be free access to all areas of celestial bodies." Limitations to accessing space capabilities remain mainly technical and financial. There were 78 successful space launches in 2012 (a relatively steady number over the past decade), and now more than 50 countries have a satellite in orbit, with more to come in the next couple of years. This demonstrates that an increasing number of countries and their nationals have access to and use of space orbits, despite the many budgetary, technical, and security challenges. Investments have also steadily risen over the past decade, with more than US$80-billion invested in institutional space programs in 2012, and sustained and even increased budgets for a number of OECD and other countries (OECD, 2013).



The uptake of space applications is growing internationally, with positive contributions to environmental sustainability and socioeconomic development. As more countries take part in space activities, competition is growing in different segments of the global space sector's value chains, as demonstrated by recent work conducted at the OECD. As well, more countries are reaping the socioeconomic benefits of past investments. These positive impacts include increased industrial activity, cost efficiencies, and productivity gains in diverse economic sectors, including environmental monitoring, agriculture previsions, and weather forecasting for air transport and shipping. Over the years, several space applications have reached technical maturity, creating new commercial downstream activities that are sometimes far removed from the initial space research and development objectives. For example, the growth of positioning, navigation, and timing applications, which rely on satellite signals, has spurred new commercial markets over the past decade, such as satellite navigation chipsets in smartphones. On the other hand, the dual nature of space applications could be seen as a negative factor for international security, as an increasing number of malevolent groups could be accessing technologies, such as satellite navigation tools that can be easily applied to illegal and military activities. Despite this genuine risk, using again the Outer Space Treaty's Article 1 as a baseline, the growing international uptake of space applications in the past decade all over the world (including developing countries) continues to fulfill the following statement: "The exploration and use of outer space, including the moon and other celestial bodies, shall be carried out for the benefit and in the interests of all countries."



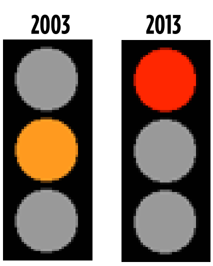
The commercial development of space keeps growing. While space activities were essentially public at the beginning of the space age, the role of private actors has expanded in recent decades. Private actors have successfully exploited, in some markets, technologies that were originally developed in cooperation with, or for, the public sector. A notable case is telecommunication satellites. Moreover, the post-Cold War environment is more conducive to the commercial exploitation of space. Since 2003, in a more open world, space firms have been able to restructure and form new alliances, while the opening of markets has benefited selected segments of the industry. But as demonstrated by the OECD's work on space, space business is not business as usual. Institutional funding remains key for many space activities and even developed space markets are often dependent on institutional customers; defense departments of nations from around the world are often the anchor customers of commercial satellite remote sensing providers. On the other hand, some commercial activities, such as nascent suborbital tourism, may bring new opportunities, but also new challenges in terms of safety and regulations. To promote the development of a vibrant space industry, governments still need to act in a number of areas, including fostering a level playingfield for satellite operators, establishing clear public procurement practices, and encouraging entrepreneurship and innovation by setting up unambiguous rules of the road.



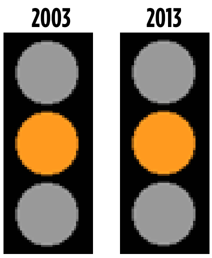
Military space capabilities are growing around the world. Contributing to this trend are an increasing number of technology transfers and a global arms trade that is the largest since the Cold War ended. Although information on military space is scarce and needs to be viewed with caution, the amber indicator is justified by indications that some countries are pursuing space-based negation-enabling capabilities, including directed energy weapons that make use of a ground-based laser directed at a satellite to temporarily dazzle or disrupt sensitive optics, kinetic hit-to-kill systems, and explosive or pellet clouds. These rising capabilities around the world are in line with developments from the early 2000s, when military space capabilities were already appearing in Asia. The Outer Space Treaty discourages military space installations in general; more particularly, article 4 states that "Parties to the Treaty undertake not to place in orbit around the Earth any objects carrying nuclear weapons or any other kinds of weapons of mass destruction [nor] install such weapons on celestial bodies." In 2013 anti-satellite weapon tests are re-emerging, as spacefaring countries develop both defensive and offensive systems.

2. Technical capacities to deal with natural and manmade threats in orbit

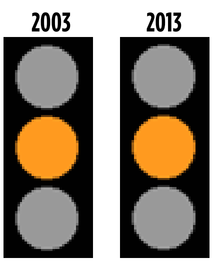
When examining space security, natural and manmade threats to the sustainability of the global space infrastructure come to mind: orbital debris, extreme space weather, and interference of satellite signals. Have these threats increased since 2003 and have national capacities (supported by relevant budgets) grown to tackle these threats? Overall, it is clear that some threats are growing—particularly space debris affecting satellites and the ISS—and that national capacities in space situational awareness are only slowly rising to the challenge.



Orbital debris is becoming a real operational problem. In 2012 several commercial satellite operators and the ISS partners had repeatedly to use space debris-avoidance maneuvers—four for the ISS alone. The number of space objects in the most used orbits is still growing. 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 the result of events such as the Chinese 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. Experts estimate that there are over 300,000 objects with a diameter larger than one cm and several million that are smaller. Even centimeter-size pieces can be highly destructive. The U.S. DoD's Space Surveillance Network currently tracks some 23,000 objects approximately 10 cm in diameter or larger, with a detailed catalog of more than 16,000 pieces of debris. A number of recent satellite failures in orbit (e.g., Envisat, Briz-M) have demonstrated the complexity of securing orbits and the need for more international cooperation to find solutions for the long-term sustainability of key orbits.



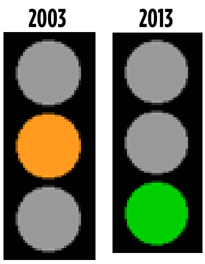
Interference of satellite signals is still a problem. Usually a ground-based threat, interference affects the functioning and reliability of services from many different segments of the orbital infrastructure (broadcasting, communications links, navigation, and positioning). Satellite services are, paradoxically, suffering from their growing popularity. As they are increasingly integrated into a wider information and communication infrastructure, they are engaged in fierce competition for radio-frequency spectrum. Terrestrial networks being put in place in many parts of the world interfere with satellite signal reception; consider the aborted LightSquared development in the United States in 2012. So does the growing intentional jamming of signals by criminal groups and certain governments, resulting in the distortion of GPS signals and satellite communications links. Since 2003 technical developments to alleviate conflicts over bandwidth allocation have taken place. They include shielding, frequency hopping, lower power output, digital signal processing, frequency-agile transceivers, and software-managed spectrum. To circumvent intentional and unintentional interference from third parties, satellite operators and ground-based equipment providers, including Intelsat and Inmarsat, are looking at possible technical solutions with their networks of customers. Such solutions do not resolve all problems (parallel policy, legal, and regulatory approaches are also needed), but contribute to better awareness of the risks by users and providers of space applications.



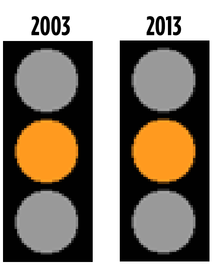
National capacities in SSA as well as research and development on active debris remediation and removal are slowly increasing. Many countries, including the United States, Russia, France, the United Kingdom, and Germany, have developed capabilities in SSA in the past decade. The overarching objective of SSA is to be able to determine the state of the space environment for safe space operations and includes the tracking, cataloging, and screening of objects in space, as well as determining and predicting space weather. Relative progress can be seen over the decade. Space weather extremes are better understood, as academia has become more involved and international scientific exchanges have become more regular. There has been progress in predicting solar flares and more actors are getting involved; for example, the U.K. weather service is to provide space weather warnings. However, the strategic nature of certain SSA research and development programs, with links to missile defense, and budgetary uncertainties in several countries indicate that greater efforts are needed to track space debris, including potentially harmful satellite re-entries. Research and development on active debris remediation and removal continue, but require long-term commitment. For instance, several national departments of defense, space agencies, and companies are pursuing long-term programs to develop new orbital platforms and on-orbit servicing capabilities. Examples include disaggregated satellite missions, the Canadian Space Agency's robotic arms experiments on the ISS, and demonstrations of space rendezvous capabilities. These could benefit space debris remediation and removal over the long term.

3. International cooperation for a sustainable use of space orbits

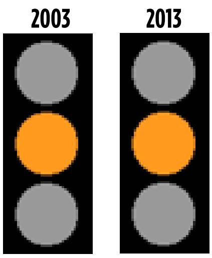
Since the dawn of the space age, international cooperation on space activities has brought major tangible and intangible benefits. Governments have had some success in regulating space activities; the Outer Space Treaty was an achievement in itself in the midst of the Cold War. With an increasing number of space actors, including very diverse nongovernmental bodies such as suborbital tourism companies and universities launching cubesats, the conversation needs to become even more inclusive to promote the sustainable use of space orbits. There are still hurdles; the next indicators show relatively little major progress over a decade. However, dialog has never stopped and continues at international conferences and meetings held at such major bodies as UN COPUOS and the ITU. Although strong national frameworks of policies and regulations should still form the backdrop for space activities in the future, international cooperation will be the only way to tackle such major space security issues as space debris, satellite signal interferences, and NEOs.



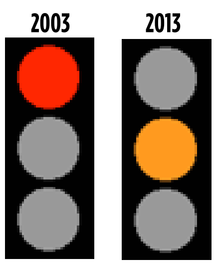
National space laws and regulations provide important new "rules of the road" for space activities. As most analysts believe that the international regime for space activities provides enough flexibility for the continued development of international space activities, national laws and regulations constitute the prime layers for a more transparent governance of space activities. These national layers provide essential guidelines for national actors—public and private—involved in space activities, as well as important information for foreign operators. As mentioned in the Outer Space Treaty, "the activities of non-governmental entities in outer space, including the Moon and other celestial bodies, shall require authorization and continuing supervision by the appropriate State Party to the Treaty" (Article 6), and the States "retain jurisdiction and control over [space] object, and over any personnel thereof, while in outer space or on a celestial body" (Article 8). Over the past decade, the number of space laws has grown significantly, as more governments and private actors have become involved in space activities. In 2012 countries including the United States and United Kingdom enacted new texts providing more clarity on their space activities. The trend to produce space laws and specific regulations has accelerated since the Cold War ended and should continue as more governments realize their need to regulate their country's liability when engaged in space activities. Ongoing debates at international bodies seem to favor the development of soft law and nonbinding rules of behavior in space. No update to existing treaties and the international legal regime for outer space activities is foreseen in the near future.



Dealing with satellite signal interferences at the international level. Article 9 of the Outer Space Treaty states that "if a State Party to the Treaty has reason to believe that an activity or experiment planned by it or its nationals in outer space, including the Moon and other celestial bodies, would cause potentially harmful interference with activities of other States Parties…it shall undertake appropriate international consultations before proceeding with any such activity or experiment." In 2003 the United States and the European Union disagreed over the radio-frequency allocation for the navigation satellite Galileo. This conflict was then seen as an example of potentially enduring competition for a scarce space resource. Since then, more actors have become involved in space activities and new competition for spectrum use has arisen from ground-based telecommunications services. International negotiations remain essential to improving the coexistence of very different systems. As the scope for wireless communications increases, efficient spectrum allocation and orbital allocation will become increasingly important policy and economic issues. In 2012 approximately 3,000 delegates attended the ITU World Radiocommunication Conference. They made some key revisions to the Radio Regulations, the international treaty governing the use of the radio-frequency spectrum and satellite orbits. The ITU continues to play a major political and regulatory role in arbitrating conflicts about radio signal interference (as demonstrated by the 2012 disputes in the Arabo-Persian Gulf); however, governments cannot be forced to strictly apply ITU regulations. The regulatory process should be improved progressively in order to lead to a more efficient use of the spectrum.



Dealing with space debris at the international level. Although space agencies started to discuss the space debris problem in the 1980s, ambitious international plans to mitigate debris began only a decade ago. In August 1995 NASA issued the NASA Safety Standard—guidelines on limiting orbital debris; in September 1996 the United States issued a National Space Policy, describing U.S. intentions to "seek to minimize the creation of space debris." The European Space Agency formed a Space Debris Working Group in 1986; in September 2002 it produced the European Space Debris Safety and Mitigation Standard. Also in 2002 the Inter-Agency Space Debris Coordination Committee, which is charged with coordinating national debris mitigation efforts, issued its first guidelines on limiting debris released during normal space operations, minimizing the potential for in-orbit break-ups, post-mission disposal, and prevention of collisions. More than 10 years later, there is heightened international awareness of the space debris problem, as seen in the NASA/DoD Debris Working Group and ESA's Clean Space program. More conferences and workshops than ever before focus on space debris issues. However, compliance with international debris mitigation guidelines remains uneven, depending on the countries. Work continues at the UN COPUOS Working Group on the Long-Term Sustainability of Outer Space, as well as on the EU's International Code of Conduct for Outer Space Activities. Nevertheless, much remains to be done to engage all the different actors, including emerging spacefaring countries, academia, and the private sector.



Dealing with NEOs at the international level. Near-Earth Objects are comets or asteroids that orbit the sun, closely approaching Earth. International awareness of NEOs is growing, with ongoing research and development at major space agencies, including NASA's NEOWISE program, contributions of amateur observers through the Faulkes Telescope Project, ESA programs, and the biannual Planetary Defense Conference. The Spaceguard Foundation was established in 1996 to coordinate several observatories from around the world that were actively searching for NEOs. In 2003 the theme was not really developed in the first *Space Security Index*. Today, there is more discussion at international forums and scientific conferences on NEOs. However, the NEO threat is not yet as well defined, presented, and recognized internationally as space debris and signal interference.

Further reading

The OECD Space Forum website: http://www.oecd.org/sti/futures/oecdspaceforum.htm.

The Space Security Index reports since 2003: http://www.spacesecurity.org.

The Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies ("the Outer Space Treaty"): http://www.unoosa.org/oosa/SpaceLaw/outerspt.html.

Space Security Working Group Meeting

McGill University
Montreal, Quebec, Canada
12-13 April 2013

Participants

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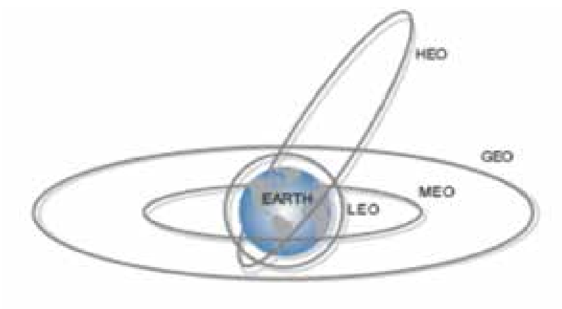
Types of Earth Orbits*



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

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

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

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), at 52.

Working Document Revised Draft

International Code of Conduct for Outer Space Activities*

Preamble

The Subscribing States

Considering that the activities of exploration and use of outer space for peaceful purposes play a growing role in the economic, social, and cultural development of nations, in the management of global issues such as the preservation of the environment, disaster management, the strengthening of national security, and in sustaining international peace;

Noting that all States 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 uses of outer space, in order to meet existing and emerging new challenges;

Further recognising that space capabilities—including associated ground and space segments and supporting links—are vital to national security and to the maintenance of international peace and security;

Recalling the initiatives aiming at promoting a peaceful, safe, and secure outer space environment, through international cooperation;

Recalling the importance of developing transparency and confidence-building measures for activities in outer space;

Considering the importance of the sustainable use of outer space for future generations;

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;

Stressing that the growing use of outer space increases the need for greater transparency and better information exchange among all actors conducting outer space activities;

Convinced that the formation of a set of best practices aimed at ensuring security in outer space could become a useful complement to international law as it applies to outer space;

Reaffirming their commitment to resolve any dispute concerning another State's actions in outer space by peaceful means;

Recognising that a comprehensive approach to safety and security in outer space should be guided by the following principles: (i) freedom of access to space for peaceful purposes; (ii) preservation of the security and integrity of space objects in orbit; and (iii) due consideration for the legitimate defence interests of States;

Conscious that a comprehensive code, including transparency and confidence-building measures could contribute to promoting mutual understandings;

Without prejudice to future work in other appropriate international fora such as the Conference on Disarmament and the United Nations Committee on the Peaceful Uses of Outer Space;

Adhere to the following 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 security, safety and sustainability of all outer space activities.

1.2. This Code addresses all outer space activities 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, in endorsing best practices, contributes to transparency and confidence-building measures and is complementary to the normative framework regulating outer space activities.

1.4. This Code is not legally binding. Adherence to this Code and to the measures contained in it is voluntary and open to all States.

2. General Principles

The Subscribing States decide to abide by the following principles:

– the freedom for all States, in accordance with international law, to access, to explore, and to use outer space for peaceful purposes without 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 inherent right of individual or collective self-defence as recognised in the United Nations Charter;

– the responsibility of States to take all appropriate measures and cooperate in good faith to prevent harmful interference in 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 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

The Subscribing States reaffirm their commitment to the existing legal framework relating to outer space activities. They reiterate their support to encouraging efforts in order to promote universal adoption, implementation, and full adherence to the instruments to which they are parties or subscribe to:

(a) existing international legal instruments regulating 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).

(b) declarations, principles and recommendations, including:

- International Co-operation in the Peaceful Uses of Outer Space 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 in 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);
- 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), and 65/73 (2010);
- the Recommendations on Enhancing the Practice of States and International Intergovernmental Organisations in Registering Space Objects as endorsed in UNGA Resolution 62/101 (2007);
- the Space Debris Mitigation Guidelines of the United Nations Committee for the Peaceful Uses of Outer Space, as endorsed in UNGA Resolution 62/217 (2007).

II. Safety, Security and Sustainability of Outer Space Activities

4. Measures on Space Operations and Mitigation of Space Debris

4.1. The Subscribing States commit to establish and implement policies and procedures to minimise the possibility 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 commit, 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 conducted to reduce the creation of outer space debris or is justified by the inherent right of individual or collective self-defence as recognised in the United Nations Charter or by imperative safety considerations, and where such exceptional action is necessary, that it be undertaken in a manner so as to minimise, to the greatest extent possible, the creation of space debris and, in particular, the creation of long-lived space debris;

– take appropriate measures to minimize the risk of collision; and

– make progress towards adherence to, and implementation of International Telecommunication Union regulations on allocation of radio spectra and orbital assignments.

4.3. In order to minimise the creation of outer space debris and to mitigate its impact in outer space, the Subscribing States commit to avoid, to the greatest extent possible, any activities which may generate long-lived space debris. To that purpose, they commit 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 UNGA Resolution 62/217 (2007).

4.4. When executing manoeuvres of space objects, for example, to supply space stations, repair space objects, mitigate debris, or reposition space objects, the Subscribing States commit to take all reasonable measures to minimise the risks of collision.

5. Promotion of Relevant Measures in other Fora

The Subscribing States commit to promote the development of guidelines for outer space operations within the appropriate international fora, such as the Conference on Disarmament and the United Nations Committee on the Peaceful Uses of Outer Space, for the purpose of protecting the safety and security of outer space operations and the long-term sustainability of outer space activities.

III. Cooperation Mechanisms

6. Notification of Outer Space Activities

6.1. The Subscribing States commit to notify, in a timely manner, to the greatest extent possible and practicable, all potentially affected Subscribing States on the outer space activities conducted which are relevant for the purposes of this Code, including:

- scheduled manoeuvres which may result in dangerous proximity to the space objects of both Subscribing and non-Subscribing States;
- 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 would likely cause potential significant damage or radioactive contamination;
- malfunctioning of space objects which could result in a significantly increased probability of a high risk re-entry event or a collision between space objects.

6.2. The Subscribing States commit to provide the notifications described above to all potentially affected States, including non-Subscribing States where appropriate, through diplomatic channels, or by any other method as may be mutually agreed, or through the Central Point of Contact to be established under section 11. 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 to all Subscribing States.

7. Registration of Space Objects

The Subscribing States commit to register, in a timely manner, space objects in accordance with the Convention on Registration of Objects Launched into Outer Space and to provide the United Nations Secretary-General with the relevant data as set forth in this Convention and in the Recommendations on Enhancing the Practice of States and International Intergovernmental Organisations in Registering Space Objects, as endorsed by UNGA Resolution 62/101 (2007).

8. Information on Outer Space Activities

8.1. The Subscribing States commit to share, on an annual basis, where available and appropriate, information on:

– their space policies and strategies;

– 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.

8.2. The Subscribing States may also consider providing timely information on outer space environmental conditions and forecasts to the governmental agencies and the relevant nongovernmental entities of all space faring nations, collected through their space situational awareness capabilities.

9. Consultation Mechanism

9.1. Without prejudice to existing consultation mechanisms provided for in Article IX of the Outer Space Treaty of 1967 and in Article 56 of the ITU Constitution, the Subscribing States have decided on the creation of the following consultation mechanism:

– A Subscribing State or States that may be directly affected by certain outer space activities conducted by a Subscribing State or States and has reason to believe that those activities are, or may be contrary to the commitments made under 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 risks of damage to persons or property, or of potentially harmful interference to a Subscribing State's outer space activities.

– The Subscribing States involved in a consultation process commit 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 reason to believe that its outer space activities would be directly affected by the identified risk may take part in the consultations if it requests 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 will seek mutually acceptable solutions in accordance with international law.

9.2. In addition, the Subscribing States may propose to create, on a case-by-case basis, independent, ad hoc fact-finding missions to investigate specific incidents affecting space objects and to collect reliable and objective information facilitating their assessment. These fact-finding missions, to be established by the Meeting of the Subscribing States, should utilise information provided on a voluntary basis by the Subscribing States, subject to national laws and regulations, and a roster of internationally recognised experts to undertake an investigation. The findings and any recommendations of these experts will be advisory, and will not be binding upon the Subscribing States involved in the incident that is the subject of the investigation.

IV. Organisational Aspects

10. Meeting of Subscribing States

10.1. The Subscribing States decide to hold meetings biennially or as otherwise decided by the Subscribing States, to define, review and further develop this Code and ensure its effective implementation. The agenda for such meetings could include: (i) review of the implementation of the Code, (ii) evolution of the Code, and (iii) discussion of additional measures which may be necessary, including those due to advances in the development of space technologies and their application.

10.2. The decisions at such meetings, both substantive and procedural, are to be taken by consensus of the Subscribing States present.

10.3. Any Subscribing State may propose modifications to this Code. Modifications apply to Subscribing States upon acceptance by all Subscribing States.

10.4. The results of the Meeting of Subscribing States are to be brought in an appropriate manner to the attention of relevant international fora including the United Nations Committee on Peaceful Uses of Outer Space (COPUOS) and the Conference on Disarmament (CD).

11. Central Point of Contact

A Central Point of Contact to be established by Subscribing States will:

– receive and announce the subscription of additional States;

– maintain an electronic database and communications system;

– serve as secretariat at the Meetings of Subscribing States; and

– carry out other tasks as determined by the Subscribing States.

12. Outer Space Activities Database

12.1. The Subscribing States commit to creating an electronic database and communications system, which should be used exclusively for their benefit in order to:

– collect and disseminate notifications and information submitted in accordance with the provisions of this Code; and

– serve as a mechanism to channel requests for consultations.

12.2. Funding the development and maintenance of the Outer Space Activities Database will be agreed by the Meeting of Subscribing States.

13. Participation by Regional Integration Organisations and International Intergovernmental Organisations

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

– 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 10 to 12 inclusive: 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, 5 June 2012, online: http://eeas.europa.eu/non-proliferation-and-disarmament/pdf/12_06_05_coc_space_eu_revised_draft_working__document.pdf.

Spacecraft Launched in 2012*

Satellite name	Owner	Actor type	Primary function	Orbit	Launch vehicle	Launch date
Mexsat-3	Mexico	Government/ Military	Communications	GEO	Atlas 5 ECA	12/19/2012
Skynet 5D	United Kingdom	Military	Communications	GEO	Ariane 5 ECA	12/19/2012
Göktürk 2	Turkey	Military	Earth Observation	LEO	Long March 2D	12/18/2012
USA 240	USA	Military	Technology Development	LEO	Atlas 5	12/11/2012
Yamal-402	Russia	Commercial	Communications	GEO	Proton M	12/8/2012
Eutelsat 70B	Multinational	Commercial	Communications	GEO	Zenit 3SL	12/3/2012
Pléiades HR1B	France	Government	Earth Observation	LEO	Soyuz STA/ Fregat	12/2/2012
Zhongxing 12	China (PR)	Government	Communications	GEO	Long March 3B	11/27/2012
Yaogan 16A	China (PR)	Military	Remote Sensing	LEO	Long March 4C	11/25/2012
Yaogan 16B	China (PR)	Military	Remote Sensing	LEO	Long March 4C	11/25/2012
Yaogan 16C	China (PR)	Military	Remote Sensing	LEO	Long March 4C	11/25/2012
Echostar 16	USA	Commercial	Communications	GEO	Proton M	11/20/2012
Fengniao 1	China (PR)	Government	Technology Development	LEO	Long March 2C	11/20/2012
Fengniao 1A	China (PR)	Government	Technology Development	LEO	Long March 2C	11/20/2012
HJ-1C	China (PR)	Government	Remote Sensing	LEO	Long March 2C	11/18/2012
Xinyan 1	China (PR)	Government	Technology Development	LEO	Long March 2C	11/18/2012
Meridian-6	Russia	Military	Communications	Elliptical	Soyuz 2-1a	11/14/2012
Eutelsat 48B	Multinational	Commercial	Communications	GEO	Ariane 5 ECA	11/10/2012
Star 1 C3	Brazil	Commercial	Communications	GEO	Ariane 5 ECA	11/10/2012
Luch 5B	Russia	Government	Communications	GEO	Proton M	11/2/2012
Yamal-300K	Russia	Commercial	Communications	GEO	Proton M	11/2/2012
Compass G-6	China (PR)	Military	Navigation/ Global Positioning	GEO	Long March 3C	10/25/2012
Intelsat 23	USA	Commercial	Communications	GEO	Proton/M	10/14/2012
Shijian 9A	China (PR)	Government	Technology Development	LEO	Long March 2C	10/14/2012
Shijian 9B	China (PR)	Government	Technology Development	LEO	Long March 2C	10/14/2012
Galileo IOV-2 FM3	ESA	Commercial	Navigation/ Global Positioning	MEO	Soyuz-Fregat	10/12/2012
Galileo IOV-2 FM4	ESA	Commercial	Navigation/ Global Positioning	MEO	Soyuz-Fregat	10/12/2012
USA 239	USA	Military/ Commercial	Navigation/ Global Positioning	MEO	Delta 4	10/4/2012
Astra 2F	Luxembourg	Commercial	Communications	GEO	Ariane 5 ECA	9/28/2012
GSAT-10	India	Government	Communications	GEO	Ariane 5	9/28/2012
VRSS-1	Venezuela	Government	Remote Sensing	LEO	Long March 2D	9/28/2012

Satellite name	Owner	Actor type	Primary function	Orbit	Launch vehicle	Launch date
Compass M5	China (PR)	Military	Navigation/ Global Positioning	MEO	Long March 3B	9/18/2012
Compass M6	China (PR)	Military	Navigation/ Global Positioning	MEO	Long March 3B	9/18/2012
MetOp-B	Multinational	Government/ Civil	Earth Science/ Meteorology	LEO	Soyuz 2-1a	9/17/2012
Aeneas	USA	Government	Technology Development	LEO	Atlas 5	9/13/2012
Aerocube 4	USA	Commercial	Technology Development	LEO	Atlas 5	9/13/2012
Aerocube 4.5A	USA	Commercial	Technology Development	LEO	Atlas 5	9/13/2012
Aerocube 4.5B	USA	Commercial	Technology Development	LEO	Atlas 5	9/13/2012
CINEMA	USA	Civil	Space Science	LEO	Atlas 5	9/13/2012
RE	USA	Military	Remote Sensing	LEO	Atlas 5	9/13/2012
USA 238	USA	Military	Electronic Surveillance/ Ocean	LEO	Atlas 5	9/13/2012
USA 238	USA	Military	Electronic Surveillance/ Ocean	LEO	Atlas 5	9/13/2012
SMDC-ONE 1.1	USA	Military	Technology Development	LEO	Atlas 5	9/13/2012
SMDC-ONE 1.2	USA	Military	Technology Development	LEO	Atlas 5	9/13/2012
Spot 6	France/ Belgium/ Sweden	Commercial	Earth Observation	LEO	PSLV	9/9/2012
RBSP-A	USA	Government	Earth Science	Elliptical	Atlas 5	8/30/2012
RBSP-B	USA	Government	Earth Science	Elliptical	Atlas 5	8/30/2012
Intelsat 21	USA	Commercial	Communications	GEO	Zenit 3SL	8/19/2012
HYLAS 2	UK	Commercial	Communications	GEO	Ariane 5 ECA	8/2/2012
Intelsat 20	USA	Commercial	Communications	GEO	Ariane 5 ECA	8/2/2012
Gonets M-13	Russia	Commercial/ Government	Communications	LEO	Rokot	7/28/2012
Gonets M-15	Russia	Commercial/ Government	Communications	LEO	Rokot	7/28/2012
MiR	Russia	Civil	Earth Observation/ Technology Development	LEO	Rokot	7/28/2012
Cosmos 2481	Russia	Military	Communications	LEO	Rokot	7/28/2012
TianLian 3	China (PR)	Government	Communications	GEO	Long March 3C	7/25/2012
BKA	Belarus	Government	Remote Sensing	LEO	Soyuz-Fregat	7/22/2012
Canopus-B	Russia	Government	Remote Sensing	LEO	Soyuz-Fregat	7/22/2012
exactView 1	Canada	Commercial	Maritime Tracking	LEO	Soyuz-Fregat	7/22/2012

Satellite name	Owner	Actor type	Primary function	Orbit	Launch vehicle	Launch date
MKA-FKI-1	Russia	Government	Remote Sensing/ Earth Science	LEO	Soyuz-Fregat	7/22/2012
TET-1	Germany	Commercial	Technology Development	LEO	Soyuz-Fregat	7/22/2012
SES-5	USA	Commercial	Communications	GEO	Proton M	7/9/2012
Echostar 17	USA	Commercial	Communications	GEO	Ariane 5 ECA	7/5/2012
Meteosat 10	Multinational	Government/ Civil	Earth Science/ Meteorology	GEO	Ariane 5 ECA	7/5/2012
USA 237	USA	Military	Electronic Surveillance	GEO	Delta 4 Heavy	6/29/2012
USA 236	USA	Military	Electronic Surveillance	GEO	Atlas 5	6/20/2012
NuSTAR	USA	Government	Space Science	LEO	Pegasus XL	6/13/2012
Intelsat 19	USA	Commercial	Communications	GEO	Zenit	6/1/2012
Yaogan 15	China (PR)	Military	Remote Sensing	LEO	Long March 4C	5/29/2012
Zhongxing 2A	China (PR)	Military/ Government	Communications	GEO	Long March 3B	5/26/2012
Nimiq 6	Canada	Commercial	Communications	GEO	Breeze M	5/18/2012
GCOM-1	USA/Japan	Government	Earth Science	LEO	H-II2	5/17/2012
Horyu-2	Japan	Civil	Technology Development	LEO	H2A	5/17/2012
Kompsat-3	South Korea	Government/ Commercial	Earth Observation	LEO	H2A	5/17/2012
SDS-4	Japan	Government	Technology Development	LEO	H-2A	5/17/2012
JCSat 13	Japan	Commercial	Communications	GEO	Ariane 5 ECA	5/15/2012
Vinasat 2	Vietnam	Government	Communications	GEO	Ariane 5 ECA	5/15/2012
Tiantuo 1	China (PR)	Government	Technology Development	LEO	Long March 4B	5/10/2012
Yaogan 14	China (PR)	Military	Remote Sensing	LEO	Long March 4B	5/10/2012
Tianhui 1-02	China (PR)	Government	Earth Observation	LEO	Long March 2D	5/6/2012
USA 235	USA	Military	Communications	GEO	Atlas 5	5/3/2012
Compass M3	China (PR)	Military	Navigation/ Global Positioning	MEO	Long March 3B	4/28/2012
Compass M4	China (PR)	Military	Navigation/ Global Positioning	MEO	Long March 3B	4/28/2012
RISat-1	India	Military	Surveillance	LEO	PSLV XL	4/25/2012
Yahsat-1B	United Arab Emirates	Military/ Commercial	Communications	GEO	Proton M	4/23/2012
USA 234	USA	Military	Reconnaissance	LEO	Delta 4	4/3/2012
Apstar 7	China (PR)	Commercial	Communications	GEO	Long March 3B	3/31/2012
Cosmos 2479	Russia	Military	Early Warning	GEO	Proton K	3/30/2012
Intelsat 22	USA	Commercial	Communications	GEO	Proton	3/25/2012
Compass G-11	China (PR)	Military	Navigation/ Global Positioning	GEO	Long March 3A	2/24/2012

Satellite name	Owner	Actor type	Primary function	Orbit	Launch vehicle	Launch date
MUOS-1	USA	Military	Communications	GEO	Atlas 5	2/24/2012
SES-4	USA	Commercial	Communications	GEO	Proton M	2/14/2012
e-st@r	Italy	Civil	Technology Development	Elliptical	Vega	2/13/2012
MaSat 1	Hungary	Civil	Technology Development	LEO	Vega	2/13/2012
XaTcobeo	Spain	Civil	Technology Development	LEO	Vega	2/13/2012
USA 233	USA	Military	Communications	GEO	Delta 4	1/20/2012

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