SPACE SECURITY 2011

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Edited by Cesar Jaramillo

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Please direct inquires to:
Cesar Jaramillo
Project Ploughshares
57 Erb Street West
Waterloo, Ontario N2L 6C2
Canada
Telephone: 519-888-6541, ext. 708
Fax: 519-888-0018
Email: cjaramillo@ploughshares.ca

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ACRONYMS

3GIRS	Third Generation Infrared Surveillance Program (U.S.)
ABL	Airborne Laser (U.S.)
ABM	Anti-Ballistic Missile
AEHF	Advanced Extremely High Frequency system (U.S.)
AFSSS	Air Force Space Surveillance System
AIA	Aerospace Industries Association (U.S.)
ALTB	Airborne Laser Test Bed
ARMS	African Resources Management Satellite
ASAT	Anti-Satellite Weapon
ASEAN	Association of Southeast Asian Nations
ASI	Agenzia Spaziale Italiana
ATC	Ancillary Terrestrial Component
ATRR	Advanced Technology Risk Reduction
AU	African Union
BMD	Ballistic Missile Defense
BOC	Besoin Opérationnel Commun (Europe)
CALT	China Academy of Launch Vehicle Technology
CASC	China Aerospace Science and Technology Corporation
CBERS	China-Brazil Earth Resource Satellite
CD	Conference on Disarmament
CMB	Cosmic Microwave Background
CNES	Centre National d'Études Spatiales (France)
CNSA	Chinese National Space Administration
COPUOS	United Nations Committee on the Peaceful Uses of Outer Space
COSPAS-SARSAT	International Satellite System for Search and Rescue
COTS	Commercial Orbital Transportation System (U.S.)
CPGS	Conventional Prompt Global Strike
CSA	Canadian Space Agency
CSM	Conjunction Support Message
CSO	Composante spatiale optique (Optical Space Component)
CSpOC	Combined Space Operations Center
DARPA	Defense Advanced Research Projects Agency (U.S.)
DART	Demonstration of Autonomous Rendezvous Technology (U.S.)
DGA	Délégation Générale pour l'Armement (French Agency for Defense Development)
DLR	German Aerospace Center
DMC	Disaster Monitoring Constellation
DOD	Department of Defense (U.S.)
DRDO	Defence Research and Development Organisation (India)
DSCS	Defense Satellite Communications System (U.S.)
DSP	Defense Support Program (U.S.)
EC	European Commission
EELV	Evolved Expendable Launch Vehicle (U.S.)
EGNOS	European Geostationary Navigation Overlay Service

EHF	Extremely High Frequency
EIAST	Emirates Institute for Advanced Science and Technology
EKV	Exoatmospheric Kill Vehicle
ELC	Electronic Systems Command
EMP	Electromagnetic pulse (or HEMP for High Altitude EMP)
EO	Earth Observation
ESA	European Space Agency
ESC	Electronics Systems Center (U.S.)
ESD	Electrostatic Discharge
ESDP	European Security and Defence Policy
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
FOBS	Fractional Orbital Bombardment System (Russia)
FREND	Front-End Robotics Enabling Near-Term Demonstration (U.S.)
GAGAN	GPS and GEO Augmented Navigation (India)
GAO	Government Accountability Office (General Accounting Office until July 2004) (U.S.)
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)
GNSS	Global Navigation Satellite System
GPS	Global Positioning System (U.S.)
GRAVES	Grande Réseau Adapté à la Veille Spatiale (France)
GSLV	Geostationary Satellite Launch Vehicle (India)
GSO	Geosynchronous Orbit
GSSAC	German Space Situational Awareness Center
HAARP	High Frequency Active Auroral Research Program (U.S.)
HAND	High Altitude Nuclear Detonation
HCT	Hall Current Thruster
HEO	Highly Elliptical Orbit
HTV	Hypersonic Test Vehicle
IADC	Inter-Agency Debris Coordination Committee
IADC	Inter-Agency Space Debris Coordination Committee
ICBM	Intercontinental Ballistic Missile
ICESat	Ice, Cloud and Land Elevation Satellite
IGS	Information Gathering Satellites (Japan)
ILS	International Launch Services
Intelsat	International Telecommunications Satellite Consortium
IOC	Initial Operating Capability

IOV	In-Orbit Validation
IRIS	Internet Router in Space
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.)
ITSO	International Telecommunications Satellite Organization
ITU	International Telecommunication Union
JAXA	Japan Aerospace Exploration Agency
JFCC Space	Joint Function Component Command for Space
JHPSSL	Joint High-Power Solid-State Laser (U.S.)
JMS	JSpOC Mission System (U.S.)
JSpOC	Joint Space Operations Center (U.S.)
KSLV	Korean Space Launch Vehicle
LEO	Low Earth Orbit
LRO	Lunar Reconnaissance Orbiter
LTE	Long-Term Evolution
MDA	Missile Defense Agency (U.S.)
MEO	Medium Earth Orbit
MiDSTEP	Microsatellite Demonstration Science and Technology Experiment Program
Milstar	Military Satellite Communications System (U.S.)
MIRACL	Mid-Infrared Advanced Chemical Laser (U.S.)
MiTEX	Micro-satellite Technology Experiment (U.S.)
MSX	Midcourse Space Experiment
MTCR	Missile Technology Control Regime
MUOS	Mobile User Objective System
MUSIS	Multinational Space-based Imaging System (France)
NASA	National Aeronautics and Space Administration (U.S.)
NATO	North Atlantic Treaty Organization
NEA	Near Earth Asteroids
NEC	Near Earth Comets
NEO	Near-Earth Object
NFIRE	Near-Field Infrared Experiment satellite (U.S.)
NGA	National Geospatial-Intelligence Agency (U.S.)
NOAA	National Oceanic and Atmospheric Administration (U.S.)
NPO	Science and Production Association (Russia)
NRL	National Research Laboratory (U.S. Navy)
NRO	National Reconnaissance Office (U.S.)
NSA	National Security Agency (U.S.)
NSAU	National Space Agency of Ukraine
NSP	National Space Policy (U.S.)
NSSO	National Security Space Office (U.S.)

NTM	National Technical Means
ONE	Operational Nanosatellite Effect (U.S.)
ORFEO	Optical and Radar Federated Earth Observation
ORS	Operationally Responsive Space (U.S.)
OST	Outer Space Treaty
OTV	Orbital Test Vehicle (U.S.)
PAROS	Prevention of an Arms Race in Outer Space
PHA	Potentially Hazardous Asteroid
PHO	Potentially Hazardous Object
PLA	People's Liberation Army (China)
PLNS	Pre-Launch Notification System
PPWT	Treaty on the Prevention of the Placement of Weapons in Outer Space, and of the Threat or Use of Force against Outer Space Objects
PSLV	Polar Satellite Launch Vehicle
PTSS	Precision Tracking Space System
QZSS	Quazi-Zenith Satellite System (Japan)
RAIDRS	Rapid Attack, Identification, Detection, and Reporting System
RAMOS	Russian-American Observation Satellite program
RF	Radio Frequency
RFI	Radio Frequency Interference
Roscosmos	Russian Federal Space Agency
SALT	Strategic Arms Limitations Talks
SANSA	South African National Space Agency
SAR	Space-based Radar
SATCOM	Satellite Communications
SBIRS	Space Based Infrared System (U.S.)
SBL	Space Based Laser
SBSS	Space Based Space Surveillance (U.S.)
SDA	Space Data Association
SELENE	Selenological and Engineering Explorer
SHF	Super High Frequency
SMDC	Space and Missile Defense Command (U.S.)
SPR	Space Posture Review
SSA	Space Situational Awareness
SSN	Space Surveillance Network (U.S.)
SSS	Space Surveillance System (Russia)
STSC	Scientific and Technical Subcommittee (UN)
STSS	Space Tracking and Surveillance System (U.S.)
TCBM	Transparency and Confidence-Building Measure
TDRS	Tracking and Data Relay Satellite
TICS	Tiny, Independent, Coordinating Spacecraft Program (U.S.)
TSAT	Transformational Satellite Communications system (U.S.)
TT&C	Tracking, telemetry and command

UCS	Union of Concerned Scientists
UHF	Ultra High Frequency
UNGA	United Nations General Assembly
UNIDIR	United Nations Institute for Disarmament Research
UNISPACE	United Nations Conference on the Exploration and Peaceful Uses of Outer Space
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
WGS	Wideband Global SATCOM
WISE	Wide-field Infrared Survey Explorer
XSS	Experimental Spacecraft System (U.S.)

Space Security 2011 is the eighth annual report on trends and developments related to security in outer space, covering the period January to December 2010. It is part of the broader Space Security Index (SSI) project, which aims to improve transparency with respect to space activities and provide a common, comprehensive knowledge base to support the development of national and international policies that contribute to space security.

The definition of space security guiding this report reflects the express intent of the 1967 Outer Space Treaty that space should be preserved as a global commons to be used by all for peaceful purposes:

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

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

The actions and developments related to space security are assessed according to eight indicators that are organized under three themes:

- The condition of the space environment
  1) The space environment
  2) Space situational awareness
  3) Space laws, policies, and doctrines
- The type of actors in space and how space is used
  4) Civil space programs
  5) Commercial space
  6) Space support for terrestrial military operations
- The status of space-related technology as it pertains to protecting or interfering with space systems, or harming Earth from space
  7) Space systems resiliency
  8) Space systems negation.

Each of the eight indicators is examined in a separate chapter that provides a description of the indicator and its overall impact on space security. A discussion of the prevailing trends associated with that indicator is followed by an overview of key developments throughout the year and an assessment of their short-term effects on the broader security of outer space. In previous editions an additional indicator on space-based strike capabilities was included. Even though speculation continues about the development of space-based strike-weapons (SBSW), the SSI noted an absence of reliably documented SBSW at the time of the report's publication. As a result, the decision was made not to include a chapter on space-based strike capabilities in this year's publication until clear evidence exists that such weapons are being developed or deployed. Readers can consult *Space Security 2010* (www.spacesecurity.org) for background information on space-based strike capabilities.

Last year's cover image, which depicted the first ever collision between two satellites, illustrated the challenges associated with space activities. Conversely, this volume's cover shows the International Space Station, which marked 10 years of continuous operations and uninterrupted inhabitancy in 2010. This exemplifies the benefits that can be derived from international cooperation in outer space. From search-and-rescue operations to weather forecasting, from arms control treaty verification to banking, the world has become increasingly reliant on the benefits derived from space-based technologies. The key challenge is to maintain an environment for the sustainable development of such peaceful applications while keeping outer space from becoming a battlefield congested with debris that restricts its use by all.

A recurring theme in the annual SSI publications has been the inadequacy of the normative regime to regulate space activities and ensure the security of outer space. While there is widespread international recognition that the existing regulatory framework is outdated and insufficient to address the current challenges facing the outer space domain, the development of an overarching normative regime has been painstakingly slow. International space actors have been unable to reach a consensus on the exact nature of a space security regime despite having specific alternatives on the table for consideration — either legally binding treaties, such as the Sino-Russian proposed ban on space weapons (known as the PPWT), or non-binding norms of behavior, such as the European Union's proposed Code of Conduct for Outer Space Activities. The proposals under consideration for a space security regime, which are highlighted in this volume, suggest that multilateral efforts to adopt a legally binding space security treaty are less likely to succeed than non-binding, technical approaches to govern outer space.

As seen in the growing number of public-private partnerships for space operations, the boundaries between civil, military, and commercial space assets are blurring, creating interdependence and mutual vulnerabilities. The fact that space is inevitably becoming more congested each year underscores the need for a comprehensive space security normative regime that not only reflects current threats to space security, but also tackles the emerging legal questions that will inevitably arise as access to orbital slots for satellites, for example, becomes more highly contested.

Although often used as interchangeable concepts, militarization and weaponization of space must be clearly distinguished. While the former is a reality, thus far there is no documented evidence of the latter. The use of space assets for military applications such as reconnaissance, intelligence, and surveillance has been ubiquitous for several years, yet space apparently has remained weapons-free. The development and use of SBSW by any state would likely trigger an uncontrollable arms race. With an ever growing number of spacefaring nations, the implications of such a scenario could be dire.

The need for greater collaboration and data sharing among space actors to prevent harmful interference with space assets is becoming increasingly apparent. Although greater international cooperation to enhance the predictability of space operations is strongly advocated, the sensitive nature of some information and the small number of leading space actors with advanced tools for surveillance have traditionally kept significant data on space activities shrouded in secrecy. But recent developments covered in this volume suggest that there is a greater willingness to share space situational awareness data via partnerships such as the one recently initiated between the United States and Australia. In addition, commercial entities have begun to establish independent surveillance and data-sharing mechanisms, such as the Space Data Association formed by a group of major satellite operators.

Decreasing costs and wider availability of launch technologies could permit the number of spacefaring nations to increase in the coming years. But intensifying space use creates governance challenges in managing space traffic, limiting the indiscriminately destructive potential of increased orbital debris, and distributing scarce resources such as orbital slots and radio frequencies. Already, new actors seeking entrance to a congested space environment are questioning the inherent fairness of the first-come-first-served system, which has been the de facto norm for orbital slot allocations. On a positive note, 2010 broke away from the trend of the three preceding years, in all of which there was a major debris-generating event (anti-satellite test conducted by China in January 2007, destruction of satellite USA-193 by the United States in February 2008, collision of U.S. Iridium and Russian Cosmos satellites in February 2009).

Space Security 2011 does not provide absolute positive or negative assessments of 2010 outer space activities. Instead, it indicates the range of implications that developments could have on the security of space across the various indicators and highlights the difficult challenges faced by policymakers. The Space Security Index project partners hope that this publication will continue to serve as both a reference source and a policymaking tool, with the ultimate goal of enhancing the sustainability of outer space for all users.

Information contained in Space Security 2011 is from open sources. Great effort is made to ensure a complete and factually accurate description of events that is based on a critical appraisal of the available information and consultation with international experts. Strategic and commercial secrecy with respect to space activities inevitably poses a challenge to the comprehensive nature of this report; but many space assets and activities are, by their very nature, in plain view to those with the technical ability to observe them. Increasingly that includes so-called amateurs who make their observations of such space assets as satellites widely available.

Expert participation in the Space Security Index is a key component of the project. The primary research is peer reviewed prior to publication through three processes:

1) Various technical and policy experts are asked to provide critical feedback on the draft research, which is sent to them electronically.
2) The Space Security Working Group consultation is held each spring for two days to review the draft text for factual errors, misinterpretations, gaps and statements about the impact of various events. This meeting also provides an important forum for related policy dialogue on recent outer space developments.
3) Finally, the Governance Group for the Space Security Index provides its comments on 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 in PDF format. Comments and suggestions to improve the project are welcome.

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Timiebi Aganaba, McGill University

Laura Delgado, George Washington University

Catherine Doldirina, McGill University

Diane Howard, McGill University

David McArthur, George Washington University

Brian Weeden, Technical Advisor, Secure World Foundation.

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Gérard Brachet
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Paul Meyer
John Siebert
Dana Smith
Ray Williamson

The Space Environment

TREND 1.1: Amount of orbital debris continues to increase, particularly in Low Earth Orbit (LEO) — Space debris poses a significant, constant, and indiscriminate threat to all spacecraft, regardless of the nation or entity to which they belong. Most space missions 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. Traveling at speeds of up to 7.8 kilometers (km) per second, each piece of space debris may 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 15,000 objects approximately 10 centimeters (cm) in diameter or larger. It is estimated 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 due to national debris mitigation efforts, but has accelerated in recent years due to events such as the Chinese intentional destruction of one of its satellites in 2007.

2010 Developments:

- Software failure leaves Galaxy 15 adrift in the Geostationary Orbit (GEO) belt, but it is eventually recovered
- Cataloged debris field from the 2007 intentional destruction of a Chinese satellite passes 3,000 objects
- Trackable space object population increases by 5.1 per cent
- The U.S. military continues to track and predict atmospheric reentry of space debris

Space Security Impact

Although there were no major fragmentations in 2010, the number of cataloged objects increased by 800, mostly due to the continued discovery and cataloging of debris from major events in 2007 and 2009. Satellites in the critical 800-km Sun-synchronous region are making more maneuvers than ever to avoid collisions. Some debris in LEO will reenter the Earth's atmosphere and disintegrate in a relatively short period of time due to atmospheric drag, but debris in orbits above 600 km will remain a threat for decades and even centuries. Thus, despite growing awareness of the problem and some voluntary mitigation efforts, space debris continues to pose an increasing threat to operational satellites and the long-term sustainability of space activities.

TREND 1.2: Increasing awareness of space debris threats and continued efforts to develop and implement international measures to tackle the problem — Significant debris-generating events as well as improved tracking abilities have encouraged the recognition of space debris as a significant threat. The 2007 Anti-Satellite Weapon (ASAT) test conducted by China, the 2008 U.S. destruction of the failed USA-193 satellite, and the 2009 collision between a Russian and a U.S. satellite have served to underscore the need for effective measures to curb the creation of space debris. Spacefaring states, including China, Japan, Russia, and the U.S., as well as the European Union (EU) have developed debris mitigation standards, and the United Nations (UN) has adopted voluntary guidelines. Most states require residual propellants, batteries, flywheels, pressure vessels, and other instruments to be depleted or made passive at the end of their operational lifetime. All major national debris mitigation guidelines address the disposal of GEO satellites, typically in graveyard orbits 235 km above the GEO orbit, and most seek the removal of dead spacecraft from LEO within 25 years. However, these guidelines are not universally or regularly followed.

2010 Developments:

- Orbital debris continues to have a growing impact on operational spacecraft
- Compliance with international space debris mitigation guidelines is still inconsistent
- International awareness of orbital debris problem increases and progress on solutions continues

Space Security Impact

The increasing awareness of the need for active debris removal, particularly among spacefaring countries, demonstrates that a growing number of actors are taking the problem of space debris seriously. However, continued emphasis on solving the problem at some unknown future point does not build the political will needed to take immediate measures. Slow implementation and enforcement of the Inter-Agency Space Debris Coordination Committee (IADC) and UN debris mitigation guidelines at the national level and continuing reluctance to pursue more stringent measures do not bode well for space security.

TREND 1.3: Growing demand for radio frequency (RF) spectrum and communications bandwidth — The growing number of spacefaring nations and satellite applications is driving the demand for limited radio frequencies and orbital slots. More satellites are operating in the frequency bands that are commonly used by GEO satellites, increasing the likelihood of greater frequency interference. But new technologies are being developed to manage greater frequency usage, allowing more satellites to operate in closer proximity without interference. As well, 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. Current 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.

2010 Developments:

- Drifting Galaxy 15 prompts complicated radio frequency interference (RFI) mitigation plans and causes interference
- Satellite operators continue to report significant harmful RF interference or infringements of RF regulations

Space Security Impact

The relative ease with which intentional or unintentional RFI and signal jamming can occur indicates that the number of RFI or signal jamming events will continue to increase in the future and negatively impact space security. The difficulty in verifying the intentions of a specific RFI or signal-jamming incident and the lack of enforcement measures suggest that the international community will continue to struggle to improve the situation.

TREND 1.4: Increased recognition of the threat from Near-Earth Object (NEO) collisions and progress toward possible solutions — Near-Earth Objects are asteroids and comets in orbits that bring them into close proximity to the Earth. Over the past decade a growing amount of research has started to identify objects that pose threats to Earth and potential mitigation and deflection strategies. Deflection, a difficult process due to the extreme mass, velocity, and distance of any impacting NEO, depends on the amount of warning time. Kinetic deflection methods include ramming the NEO with a series of kinetic projectiles; some experts have advocated the use of nearby explosions of nuclear weapons, which could create additional threats to the environment and stability of outer space and would have complex legal and policy implications.

2010 Developments:

- International awareness of the NEO problem and discussions on solutions continue to increase

Space Security Impact

An understanding of the potential threat posed by NEOs has begun to move from the astronomy community to the broader policy community. Discussions and progress on international detection, warning, collaboration, and decision-making are a positive step for space security, although follow-through is still lacking. The establishment of international governance mechanisms to respond to the NEO threat will likely prove beneficial in other areas of space security.

Space Situational Awareness

TREND 2.1: U.S. space situational awareness (SSA) capabilities slowly improving — The U.S. continues to lead the world in space situational awareness capabilities with the Space Surveillance Network (SSN). Sharing SSA data from the SSN could benefit all space actors by allowing them to supplement the data collected by national assets at little if any additional cost. Still, 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 U.S. to boost conjunction analysis — the ability to accurately predict high-speed collisions between two orbiting objects. A new Space Fence, currently under development, is expected to cost more than US$1-billion to design and procure. The system, with a target completion date of 2015, will likely include a series of S-band radars in at least three separate locations.

2010 Developments:

- U.S. launches orbital space surveillance sensor as part of 20-year plan to improve SSA
- S-Band Space Fence acquisition program moves to the next phase
- U.S. Air Force improves ability to integrate data from different sources for SSA
- Australia funds space debris tracking research and initiates SSA partnership with U.S.

Space Security Impact

The increase in U.S. SSA capabilities, especially tracking and cataloging of objects smaller than 10 cm, significantly improves space security The conjunction warnings issued by the U.S. military have had a significant positive impact on spacecraft operations worldwide, allowing all operators to protect their spacecraft from collisions with space debris. However, the slow progress on SSA data sharing with other countries and satellite operators impedes further improvement for both U.S. SSA and space security.

TREND 2.2: Global SSA capabilities slowly improving — As the importance of space situational awareness is acknowledged, more states are pursuing national space surveillance systems and are engaging in discussions over international SSA data-sharing. Given the sensitive nature of much of the information obtained through surveillance networks and the resulting secrecy that often surrounds it, states are striving to develop their own SSA systems to reduce their reliance on the information released by other space actors such as the U.S. For example, Russia maintains a Space Surveillance System using its early-warning radars and monitors objects (mostly in Low Earth Orbit), although it does not widely disseminate data. Similarly, the EU, Canada, France, Germany, China, India, and Japan are all developing space surveillance capabilities for various purposes. Amateur observations by individuals have also proven to be useful ways to gather and disseminate data on satellites.

2010 Developments:

- Europe continues push to develop its own SSA capabilities
- Commercial satellite operators continue efforts to share data among each other to improve safety
- Hobbyist satellite observers continue to demonstrate their capabilities

Space Security Impact

The European SSA preparatory program and increased data sharing among commercial operators are important contributions to space security. The increase in global SSA capabilities allows for multiple sources of data, improving quality, coverage, and validity. The increase in global capabilities also allows the use of SSA data to monitor activities in space, to increase transparency and confidence among space actors, and, eventually, to serve as a potential verification mechanism for future agreements.

TREND 2.3: International SSA data sharing and cooperation efforts between space actors continue to increase — While the U.S. moderates access to information from its SSN, it has expanded its SSA Sharing Program. In response to the 2009 Cosmos-Iridium satellite collision, the U.S. military announced that in December it would add personnel and resources to enable it to screen up to 800 maneuverable, active satellites for potential collisions, with the eventual goal of screening active payloads on orbit. As part of this development, it would expand the number of outside partners and share data about potential collisions. In addition, commercial entities (such as the Space Data Association [SDA], formed by a group of major satellite operators) have begun to establish independent surveillance and data-sharing mechanisms. The SDA will mainly share data on the positions of members' satellites and information to help prevent electromagnetic interference.

2010 Developments:

- Satellite operators work together to mitigate physical and RF interference from Galaxy 15
- U.S. government continues to expand its SSA Sharing Program

Space Security Impact

As no single space actor can achieve true SSA on its own, increases in data sharing among governments and satellite operators greatly enhance space security. Although more public and universal data sharing would be welcome, the limited sharing done by the U.S. government after the 2009 Iridium-Cosmos satellite collision is a step in the right direction. A positive example of the collective benefits of sharing SSA data is the widely publicized recovery of the Galaxy 15 satellite following a malfunction in 2010.

Laws, Policies, and Doctrines

TREND 3.1: Gradual development of normative framework for outer space activities — The international legal framework for outer space establishes the principle that space should be used for "peaceful purposes." Since the signing of the Outer Space Treaty (OST) in 1967, this framework has grown to include the Astronaut Rescue Agreement (1968), the Liability Convention (1972), the Registration Convention (1979), and the Moon Agreement (1979), as well as a range of other international and bilateral agreements and relevant rules of customary international law. However, the existing regulatory framework is widely considered outdated and insufficient to address the current challenges to space security, which have escalated with more actors and space applications. Furthermore, what began as a focus on multilateral space treaties has transitioned to a focus on what some describe as 'soft law' — non-binding governance tools that include principles, resolutions, confidence-building measures, and policy and technical guidelines — as well as unilateral national regulations.

2010 Developments:
- Shift in U.S. National Space Policy toward increased international cooperation and responsible use of space, but domestic objectives face implementation problems
- Despite initial delay, the U.S. Space Posture Review concludes with the release of the National Space Security Strategy
- The United Nations General Assembly establishes Group of Governmental Experts (GGE) to study transparency and confidence building measures in space
- EU's proposed international Code of Conduct for Outer Space Activities revised and ready for further international consultation

Space Security Impact

The new U.S. National Space Policy (NSP) signals that the U.S. is more open to dialogue and is committed to the responsible use of space. Because the actions and policies of the dominant space actor have a profound impact on the whole space environment, this development is welcome. However, some of the NSP declarations are vague and open to interpretation. The new policy could lead to real changes in the normative framework for outer space activities. However, the international dimension of the policy may have been overemphasized, if the lack of progress at the Conference on Disarmament (CD) and the First Committee is any evidence. Unlike Russia, China, and the EU, which have put forth specific proposals as the basis for further consultation on a multilateral regulatory regime for space activities, the U.S. has not assumed an active role by submitting a proposal of its own for the consideration of the international community.

TREND 3.2: UN Committee on the Peaceful Uses of Outer Space (COPUOS) remains active as a forum for space governance, while CD deadlock persists — A range of international institutions, including the UN General Assembly, the UN Fist Committee, COPUOS, the ITU, and the CD, constitute the key multilateral forums to address issues related to space security. The adoption of a Program of Work at the CD in 2009, after more than a decade of deliberations with no tangible results, could have allowed the CD to move forward on the Prevention of an Arms Race in Outer Space (PAROS) and to further discussions on a legal instrument to regulate space activities. But stalemate quickly resumed its grip. COPUOS remains active, with a principal focus on non-binding, technical approaches to security in space.

2010 Developments:
- The CD could not agree on a Program of Work, reverting to its pre-2009 deadlock
- Progress in COPUOS as a working group emerges to take on the long-term sustainability of outer space activities

Space Security Impact

Renewed deadlock at the CD heightens recognition that the premier disarmament body in the UN system is not the appropriate forum to determine the issue of PAROS. But it also illustrates the larger problem of a near-universal lack of political will to resolve such an impasse. Despite the difficulties, the acknowledgment by COPUOS of the need to liaise more closely with the CD and ITU on issues related to space safety is welcome.

TREND 3.3: Formalized African cooperation in space increases — Recent cooperation agreements on space activities have allowed emerging spacefaring nations from Africa to reap social and economic benefits from space applications. In 2009, after years of discussion, Nigeria, Algeria, South Africa, and Kenya signed a regional cooperation agreement for an African Resources Management Satellite (ARMS) Constellation. Following the launch of the South African National Space Agency in 2010, an inter-agency agreement with the Algerian Space Agency to cooperate in space science and technology was signed. In the same year, African nations requested that the African Union (AU) commission a feasibility study for the establishment of an African Space Agency and the development of an African Space Policy, in cooperation with the Regional Economic Communities, the UN Economic Commission for Africa, and the ITU.

2010 Developments:

- African regional cooperation in space on the rise
- A group of African states seeks to protect the "common heritage" of orbital assets through the International Telecommunications Satellite Organization (ITSO) and the ITU
- Africa considers the establishment of an African Space Agency

Space Security Impact

The implementation of the South African space strategy can serve to spearhead the continent's space initiatives as it will entail the development of private sector space science and technology companies, the development of an export market for South African satellites and space services, and the development of products and services that can respond to the needs of users. On the one hand, this objective will encourage more collaboration with regional international partners. On the other, there may be a risk of unhealthy regional competition in the space domain. This threat may be reduced with the establishment of the African Space Agency, though it may be several years before it is created.

TREND 3.4: National space policies continue to focus on the security uses of outer space, with increased concentration on developing national space industries — Fueled by a technological revolution, the military doctrines of a growing number of states emphasize the use of space systems to support national security. This tendency can be seen, for example, in the increasing development of multiuse space systems, which has led some states — the U.S., certainly, but also Russia, India, and China — to view space assets as critical national security infrastructure. In addition, countries increasingly view their national space industries as a fundamental driver and component of their space policies. A number of nations, including the U.K., Germany, Australia, and the U.S., have made the innovation and development of their industrial space sectors a key priority within their national space strategies.

2010 Developments:

- Mixed signals regarding India's plans to develop an ASAT capability
- National space strategies focus on developing the space industrial sector alongside security objectives
- U.S. export reforms welcomed, but Senate must still consider removal of commercial satellites from Munitions List

Space Security Impact

It is inevitable that major spacefaring states will continue to use space for national security. But they and other states are also increasingly interested in developing a healthy commercial and industrial sector based on space. Tensions could build with the increased use of space for security, the growing competitiveness in the space industry, and heightened awareness of the vulnerabilities and fragility of many space capabilities. So, while linking national space strategies to the industrial sector could bode well for space security by encouraging clear rules, greater transparency, and cooperation, an overreliance on space for national security could lead to a climate of mutual suspicion and mistrust that will ultimately be detrimental to space security.

Civil Space Programs

TREND 4.1: Growth in the number of actors accessing space — The rate at which new states gain access to space increased dramatically in the past decade; this rate is expected to continue as launch costs decrease and some states develop indigenous space technologies. In 2009, Iran became the ninth state to join the ranks of spacefaring nations with independent orbital launch capacities. In addition, more than 60 nations and consortia currently have assets in space that have been launched either independently or in collaboration with others. In 2003, China joined Russia and the U.S. as the only space powers with demonstrated manned spaceflight capabilities, but eventually they could be joined by other states that have expressed an interest in human spaceflight programs. A 2010 report by Euroconsult forecast that more than 1,200 new satellites will be launched in the next 10 years, several of which will be the first for their respective nation.

2010 Developments:

- Various countries prepare or declare launching of their first satellites, mainly with partners
- New launch capabilities are advanced, with mixed results
- National and international space bodies continue to expand and grow in numbers

Space Security Impact

The increasing globalization of space technology has led not only to the diversification of suppliers and customers for space applications, but also to a sharp reduction in entry barriers to the space domain for many nations. As the number of space actors able to access space increases, more parties have a direct stake in the need to ensure the sustainability of space activities and preserve this domain for peaceful purposes. However, more space actors means greater overcrowding of space orbits and greater strain on such scarce space resources as orbital slots and radio frequencies. In a more crowded environment, the risk of accidental interference with space assets goes up. Even though the development of civilian space applications is driven mostly by economic development aspirations and public safety considerations, the spread of launch capabilities could exacerbate regional tensions.

TREND 4.2: Civil space programs continue to prioritize scientific missions and exploration — In recent years, as the social and economic benefits derived from space activities have become more apparent, civil expenditures on space have continued to increase. 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 a growing focus of almost every existing civil space program. Likewise, Moon exploration continues to be a priority for established spacefaring states, such as China, Russia, India, and Japan. New launch vehicles also continue to be developed. Following the cancellation of the Constellation program, the U.S. is focusing on the development of new launchers by private industry rather than NASA. The China Academy of Launch Vehicle Technology (CALT) is continuing 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 ageing Molniya-M launch vehicles currently in service.

2010 Developments:

- Spacefaring states continue to pursue Moon exploration
- Mix of successes and failures in the development of new launch vehicles
- Scientific space missions continue to be developed worldwide
- National space budgets increase slightly

Space Security Impact

Recent events highlight issues that will have longer-term impact. Global space industries face increasing economic and competitive pressures from limited government discretionary spending, existing overcapacity, and new entrants. These pressures on addressable markets, combined with uncertain future plans for space exploration, are leading to increasing costs for major spacefaring countries, which in turn may limit future flight opportunities. At the same time, continued scientific missions and international cooperation increase the level of transparency and contribute to security among spacefaring nations.

TREND 4.3: Steady growth in international cooperation in civil space programs — International cooperation remains a key feature of both civil and global utilities space programs. It enhances transparency into the nature and purpose of certain civil programs that could potentially have military purposes. The most prominent example of international cooperation continues to be the International Space Station (ISS), a multinational effort with a focus on scientific research and an estimated cost of over $100-billion to date. In 2010, the ISS completed 10 years of continuous operations and uninterrupted inhabitancy. 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. Likewise, cooperation agreements enable established spacefaring countries to tackle such high-cost, complex missions as the exploration of Mars by NASA and the European Space Agency.

2010 Developments:

- International Space Station marks 10 years of operations and uninterrupted inhabitancy
- More cooperation agreements on exploration and launchers

Space Security Impact

International civil space cooperation is a positive factor in improving space security, because it helps to build formal and informal ties across the global space community. It can also help groups of nations undertake vast projects in space, such as the International Space Station, which would be too complex and expensive for any one state. Working on challenging bi- and multinational space projects builds confidence for countries at all levels of space development. The relationships and interdependence created through cooperative space projects help foster transparency and allow for a more accurate assessment of the space capabilities of cooperating states.

TREND 4.4: Continued growth in global utilities as states seek to expand applications and accessibility — The use of space-based global utilities, including navigation, weather, and search-and-rescue systems, has grown substantially over the last decade. While key global utilities such as 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 as well. Such systems have spawned space applications such as weather monitoring and remote sensing, which have become almost indispensable. Advanced and developing economies alike are heavily dependent on these space-based systems. Currently Russia, the U.S., the EU, Japan, China, and India have or are developing satellite-based navigation capabilities. Although theoretically interoperable and able to increase the accuracy and reliability of satellite-based navigation, in competition these systems face significant coordination challenges.

2010 Developments:

- Satellite navigation systems around the globe continue to evolve
- Development continues on disaster relief and remote sensing capabilities

Space Security Impact

The development of and reliance on space systems for global utilities support their reliability and give countries a strong incentive to ensure safe and responsible space operations. Progress made on the compatibility and interoperability of space-based communications, Earth Observation and navigation systems will likely have a positive impact on space security. However, increasing competition for radio frequencies represents a potential source of international friction and should be watched closely. Maintaining space for global utilities will likely require greater international cooperation to reduce the risks of orbital debris, protect the spectrum required by space systems, and promote safe and responsible space operations.

Commercial Space

TREND 5.1: The global commercial space industry continues to experience overall growth, but seeks creative solutions to offset probable future downturn — Commercial space revenues have steadily increased since the mid-1990s. 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. Individual consumers are a growing source of demand for these services, particularly satellite television and personal GPS devices. In the face of decreased orders for satellite fleet replenishment, manufacturers and launch providers are looking to the robust demand for new services to facilitate new satellite orders.

2010 Developments:

- New applications in response to Federal Communications Commission (FCC) Ancillary Terrestrial Component regulations could help compensate for downturn
- Significant growth in commercial remote-sensing business
- Top satellite supplier Space Systems/Loral evaluates ways to offset imminent sales decrease

Space Security Impact

The diversification of space applications has an overall positive impact on space security. The development of new products and services lessens dependence upon one facet of commercial activity, thus helping to insulate against fluctuations in specific markets. A great positive impact can be found in the remote sensing sector, which has developed new markets. Increased access to space assets and applications has both positive and negative impact. On the one hand, the pool of stakeholders with a direct interest in preserving space as a peaceful domain is steadily growing. On the other, issues of congestion, competition, and spectrum management become more pressing as commercial space activity increases and could potentially result in friction among providers of commercial services.

TREND 5.2: Commercial sector supporting increased access to space products and services — Lower launch costs for commercial satellites have enabled greater accessibility to space, particularly by developing countries for which the costs related to space access were prohibitively high in the past. A few years ago, Earth-imaging data was only available to a select number of governments. Today any individual or organization with access to the Internet can use these services free of cost through various widely available online mapping applications, such as Google maps. An embryonic private spaceflight industry continues to emerge, seeking to capitalize on new advanced, reliable, reusable, and relatively affordable technologies for launch to suborbital trajectories and low Earth orbit. In 2010, Space X became the first private company to successfully reenter the atmosphere with one of its spacecraft, the Dragon capsule.

2010 Developments:

- Two new services bring high-speed Internet to underserved markets
- Use of small satellites increases, providing a possible new market for dedicated launcher
- Intelsat satellite Galaxy-15 goes adrift following malfunction, reestablishes contact nearly nine months later

Space Security Impact

Developing underserved markets also creates more stakeholders with a vested interest in space security. The malfunction of the Galaxy-15 satellite showed how to responsibly manage an unexpected event that might otherwise have had a detrimental effect on space security. That the satellite corrected according to design has a positive impact upon security. The event also provides the industry with a working model of how to respond to similar problems transparently and collaboratively. The commercial sector's continued development has a positive impact upon access to space, but also comes at the price of congestion. Furthermore, developing regulations for private international corporations, including those venturing into the uncharted realm of space tourism, might be as challenging as regulating state activities in space.

TREND 5.3: Continued government dependency on the commercial space sector develops interactions between public and private sectors — The commercial space sector is significantly shaped by the particular security concerns of national governments. In 2010, the U.S. government released a new National Space Policy, which places great emphasis on maintaining a robust and competitive industrial base in the U.S. and specifically seeks partnerships with the private sector to enable commercial spaceflight capabilities for the transport of crew and cargo to and from the International Space Station. Government regulations of export controls may gradually be influenced by the way in which the controls affect the commercial sector's ability to engage in international cooperation. The joint development of strike systems with possible space applications by the U.S. Air Force and companies such as Boeing is an example of the rising number of military contracts with the commercial sector. The impending retirement of the space shuttle further opens the door for the commercial sector to provide what were formerly government-controlled services.

2010 Developments:

- Changes to U.S. Space Policy affect U.S. space companies and create uncertainty at NASA
- Export credit agency financing makes projects viable
- The European launch sector scrutinizes Arianespace, considers changes in governance and shareholding structure
- ISS partners agree to publish interface standards for interoperable spacecraft docking

Space Security Impact

Increased interaction between the public and private sectors in collaborative space projects has an overall positive impact upon space security. However, this impact is somewhat offset by the uncertainties caused by changes in U.S. Space Policy. Still, these interactions, often more intricate than simple partnerships, better spread the risks among actors and can supply a more cost-effective distribution of public services/public goods. Furthermore, the publication of ISS docking standards provides sustainable access to states and companies beyond the ISS partners, without sacrificing national security. And it potentially increases the number of stakeholders with a vested interest. A negative impact could result if hosted payloads make commercial assets a target, but no such developments in this area are noted for 2010.

TREND 5.4: Commercial space operators gradually embrace cyberspace capabilities — The link between cyberspace and outer space is becoming increasingly important for commercial operators. Exostar, a provider of software applications to the aerospace and defense industries, transitioned from traditional log-in formats to its cloud-based Managed Access Gateway in 2010. The company also announced a new version of its supply chain management application, SCP2, which is expected to improve aerospace and defense supply chain collaboration. Moreover, demand for Cisco's space router during its evaluation period exceeded company projections; the capability will be offered to commercial entities by mid-2011, sooner than originally anticipated. Space routers are intended to manage traffic and process signals aboard spacecraft, while traditional satellite networks rely upon ground-based equipment.

2010 Developments:

- Aerospace e-business platform Exostar providing cloud services to the space industry
- Cisco's Internet Router in Space is an immediate hit

Space Security Impact

The commercial space community is made more efficient by the increased availability of internet services in terrestrial contexts such as cloud services. As the American Institute of Aeronautics and Astronautics notes, the security, availability, and interoperability of such services are an ongoing concern for end-users. Internet routers in space, such as Cisco's IRIS space router, eliminate the need to downlink and uplink data to/from a ground station; thus threats can be minimalized and financial and time costs better managed.

Space Support for Terrestrial Military Operations

TREND 6.1: The U.S. and Russia continue to lead in deploying military space systems — During the Cold War, the U.S. and USSR developed military space systems at a relatively equal pace. At the time of the collapse of the USSR, however, Russian military space spending dropped sharply, while the U.S. expanded its military space capabilities. In recent years there has been a general decrease in the number of military launches by both states. While new systems are being orbited at a slower rate, they have greater capabilities and longevity. The U.S. is not only the biggest spender on military space programs, but is also the state most dependent on space systems. Although the operational status of many Russian space systems is uncertain, Russia is known to be replacing its Soviet-era military space assets. In 2010 it continued to move forward with its Global Navigation Satellite System (GLONASS). By the end of 2010 there were over 165 dedicated military satellites worldwide, with the U.S. operating approximately half and Russia approximately one-quarter.

2010 Developments:

- Despite persistent delays, the U.S. continues to update its systems
- Russia continues to lead in military satellite launches; GLONASS nears full operational capacity

Space Security Impact

Even as reliance on space systems increases, delays, cost-overruns, and other setbacks directly impacted efforts to update systems in 2010. As well, gaps in critical capabilities increase the vulnerability of these systems to attacks by adversaries. On the other hand, the situation creates incentives for both countries to advance policies to reduce the likelihood of conflict in outer space. Over time, growing interest in cooperating with international allies and commercial partners, such as in satellite navigation and military communications, may also reduce such vulnerability and increase interdependence, providing a positive impact on space security.

TREND 6.2: China and India afford increasing roles to space-based military support — China's governmental space program does not clearly distinguish between civil and military applications. Although its space program is officially dedicated to science and exploration, it is believed to provide data to the military (other countries make similar use of their space programs). China operates the Beidou regional navigation system and has expressed its intention of upgrading 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 Medium Earth Orbit (MEO). 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 the Indian Space Research Organisation (ISRO). To secure an independent satellite navigation capability by 2012, India is developing the Indian Regional Navigation Satellite System (IRNSS), which is expected to be made up of seven navigation satellites.

2010 Developments:

- China continues an ambitious launch schedule to complete Beidou/Compass constellation
- China continues to upgrade its satellite systems and sets a new launch record
- India continues to launch dual-use systems and plans to launch dedicated military satellites
- India advances development of a regional satellite navigation system

Space Security Impact

China's and India's increasing dual-use and military space-support activities could have mixed results for space security. On the one hand, the strategic value of space assets increases as actors engaged in competition with each other begin to rely more on space-based support. The development of competing systems, such as individual satellite navigation systems, could result from this dynamic. On the other hand, their increased participation in space also raises the value of policies that reduce the likelihood of conflict in space. The growing roles of these countries as prominent space actors make space security discussions not only beneficial but necessary.

TREND 6.3: More states are developing military and multiuse space capabilities — States such as Canada, China, France, Germany, Japan, Israel, Italy, Australia, 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. Hence, in the absence of dedicated military satellites, many actors use their civilian satellites for military purposes or purchase data and services from other satellite operators. Europe continues to pursue the development of the Galileo navigation system; EU member states exhibit a remarkable predisposition for collaboration in sharing several space capabilities with their partners.

2010 Developments:
- Japan launches "Michibiki" GPS augmentation satellite and considers an indigenous satellite navigation system
- Several countries pursue remote sensing capabilities
- Europe begins awarding Galileo contracts and continues exploring expanded cooperation in military space
- Canada prepares to launch first military satellite, continues expanding multiuse capabilities

Space Security Impact
Increased access to space by more actors reduces the asymmetric vulnerability of those countries that already rely on space assets. However, the proliferation of individual systems increases problems of congestion and may lead to the proliferation of technology that threatens space assets and increases the possibility of conflict. This situation underscores the value of cooperating in enhanced space situational awareness as a way to protect space assets. Budgetary constraints have proven to be a positive motivator for increased cooperation and interdependence, moving some countries to look for ways to improve their access to and use of existing systems without necessarily launching their own. In the case of military systems, however, countries may choose to be less forthcoming about their capabilities or operations in space, thus increasing the risks of uncertainty or confusion.

Space Systems Resiliency

TREND 7.1: Efforts to protect satellite communications links increase, but ground stations remain vulnerable — 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 protection 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. 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.

2010 Developments:
- U.S. Cyber Command (USCYBERCOM) reaches Full Operational Capability
- Rapid Attack Identification, Detection, and Reporting System (RAIDRS) program reaches milestones

Space Security Impact
The establishment of the unified USCYBERCOM gives new focus and integration to U.S. cyber protection, affording a new level of security to its space missions. Enhanced mechanisms to protect cyber networks make space systems more secure against negation attempts, thereby providing a viable alternative to offensive means to defend space assets. Space actors may refrain from interfering with well protected space systems if such attacks seem both futile and costly. However, if USCYBERCOM sets a precedent for offensive cyber action, such capabilities could proliferate. The full operability for RAIDRS Block 10 means that the U.S. will soon have a much improved ability to detect and defend from physical attacks on space assets, which would have a positive impact for space security.

TREND 7.2: Protection of satellites against direct attacks limited but improving — 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 protection measures include system redundancy and interoperability, which have become characteristic of satellite navigation systems. While no hostile ASAT attacks have been carried out, recent incidents, such as the 2007 ASAT test in which China destroyed one of its own satellites and U.S. destruction of USA-193 in 2008 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.

2010 Development:

- U.S. moves forward with STSS, Space Fence

Space Security Impact

In addition to increasing general space situational awareness, the launch of STSS will give the U.S. an increased ability to detect potentially hostile maneuvers against its space assets. The updated version of the Space Fence, with its ability to detect smaller space objects, could decrease the effectiveness of space mines and other attack measures that rely on smallness. Overall, the development of effective surveillance capabilities to detect potential attacks can have a positive impact on space security by increasing the ability of a space system to survive negation efforts, thus helping to ensure secure access to and use of space.

TREND 7.3: Efforts underway to develop capacity to rapidly rebuild space systems following direct attacks, but operational capabilities remain limited — The ability to rapidly rebuild space systems after an attack could reduce vulnerabilities in space. Although the U.S. 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 (Space X), 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.

2010 Development:

- Progress in the research and development of low-cost launch capabilities

Space Security Impact

Moving to cheaper launch capabilities through innovative propulsion, privatization, and miniaturized satellites should allow space systems to become more adaptive in many ways. New technology can be integrated more quickly, and in theory losses due to offensive action could also be more quickly replaced. However, advancements have been slow, and present gains may prove temporary. Cheaper technologies will also be more widely available, making proliferation a concern. More privatization of space launches has the potential to dramatically improve innovation in space systems and save money, thereby facilitating increased access to space. It remains to be seen whether effective controls will be placed on private industry as it moves into space.

Space Systems Negation

TREND 8.1: Increasing capabilities to attack space communications links — Ground segments, including command and control systems and communications links, remain the most vulnerable components of space systems, susceptible to attack by conventional military means, computer hacking, and electronic jamming. Intentional jamming of communications satellites continued in 2010. For example, European satellite signals, including broadcasts of BBC Persian language, Deutsche Welle, and France's Eutelsat have been intentionally jammed from Iran, though it has not been determined that the jamming is state-sponsored. The challenges associated with addressing cases of jamming that are not always easily attributable to one particular actor have been brought to the forefront of space security debates.

2010 Developments:

- European satellite broadcasts continue to be jammed from Iran
- Jamming incidents and capabilities continue to proliferate

Space Security Impact

The technologies used to hack into computer networks and jam satellite communications links are widely available; the relative ease with which such attacks are carried out has a negative impact on space security. Paradoxically, more incidents of jamming and the proliferation of jamming capabilities may also have a positive effect on space security, as they seem to be creating some impetus for more assertive action from the ITU. The proven ability of even minor powers to jam satellite transmissions, including ones used by the U.S. military, should generate increased interest in protecting communications from interference.

TREND 8.2: Ongoing proliferation of ground-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. The U.S., 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 U.S. in 2008) underscore the detrimental effect that such systems have for space security.

2010 Developments:

- Directed energy weapons continue to be developed and tested
- Development of ASAT capabilities considered by some countries

Space Security Impact

The development of directed energy and ASAT weapons has a direct impact on space security. Such capabilities enable an actor to intentionally restrict the secure access to space by others by compromising the physical and operational integrity of space assets. While possession of these capabilities does not necessarily entail their imminent use, it could foster an arms race and hasten the weaponization of space. In any case, the development and testing of anti-satellite capabilities remain highly contentious. Moreover, increasing proliferation of ASAT technology is also likely to be destabilizing at the regional level. India's stated intentions regarding ASAT capabilities, for instance, have already spurred Pakistan to increase its nuclear arsenal.

TREND 8.3: Increased access to space-based negation-enabling capabilities — Space-based negation efforts require sophisticated capabilities, such as precision on-orbit maneuverability and space tracking. Deploying space-based ASATs — using kinetic-kill, directed energy, or conventional explosive techniques — would require enabling technologies somewhat more advanced than those used for orbital launch. 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, or 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. While a number of nations have developed such technologies, there is no evidence to suggest that they have been integrated into a dedicated space-based negation system.

2010 Developments:

- Complex rendezvous capabilities continue to be advanced
- Secrecy surrounds X-37B launch, raising questions about a precise mission and potential capabilities

Space Security Impact

The development of more technologies that allow space-based ASAT capability will force spacefaring nations to incorporate greater protection measures into their spacecraft and invest more in responsive situational awareness. Costs could go up for almost all satellites with any military value, including those funded by private industry. More ominously, the existence of space-to-space ASAT abilities might encourage the weaponization of space for defensive purposes. Fear of such developments could lead to adoption of norms of behavior governing offensive technologies. In some cases, such capabilities have actually fostered transparency; to allay suspicion, nations that are testing rendezvous capabilities freely disclose the nature of their activities.

The Space Environment

This chapter assesses trends and developments related to the physical condition of the space environment, with an emphasis on the impact of human activity in space — such as the creation of space debris, the use of scarce space resources — such as the registration of orbital slots and the allocation of radio frequencies, and the potential threat posed by Near Earth Objects (NEOs).

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. Catastrophic events of both types have created thousands of long-lasting pieces of space debris.[1] The year 2010 broke the trend of the preceding three years, in all of which there was a major debris-generating event. 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 for the first time.

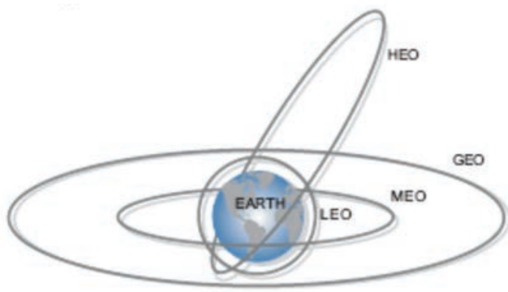
A growing awareness of the impact of space debris on the security of space assets has encouraged space actors to take steps to mitigate the production of new debris through the development and implementation of national and international debris mitigation guidelines, also examined in this chapter.

Earth orbits are limited natural resources. Actors who wish to place a satellite in orbit must secure an appropriate orbital slot in which to do so and secure a portion of the radio spectrum to carry their satellite communications. Both radio frequencies and orbital slots are indispensable tools for all space operations, and in certain orbits their national assignments are coordinated through the International Telecommunication Union. This chapter assesses the trends and developments related to the demand for orbital slots and radio frequencies, as well as the conflict and cooperation associated with the distribution and use of these scarce space resources. This includes compliance with existing norms and procedures developed through the ITU to manage the use and distribution of orbital slots and radio frequencies.

Space Security Impact

Space is a harsh environment and orbital debris represents a growing threat to the secure access to, and use of, space due to the potential for collisions with spacecraft. Because of orbital velocities of up to 7.8 km per second (~30,000 km per hour) in Low Earth Orbit (LEO), debris as small as 10 cm in diameter carries the kinetic energy of a 35,000-kg truck traveling at up to 190 km per hour. While objects have lower relative velocities in Geostationary Earth Orbit (GEO), debris at this altitude is still moving as fast as a bullet — about 1,800 km per hour. No satellite can be reliably protected against this kind of destructive force and, while some satellites and spacecraft have been hardened to withstand minor impacts from space debris, it is considered impractical to shield against objects bigger than a few centimeters.

Figure 1.1: Types of Earth orbits*



* See Annex 2 for a description of each orbit's attributes.

The total amount of manmade space debris in orbit is growing each year and is concentrated in the orbits where human activities take place. LEO is the most highly congested area, especially the Sun-synchronous region. Some debris in LEO will reenter the Earth's atmosphere and disintegrate in a relatively short period of time 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 pose a threat to Earth infrastructure and human lives.

The development of space situational awareness capabilities to track space debris and avoid collisions, covered in Chapter 2, clearly provides significant space security advantages. Efforts to mitigate the production of new debris through compliance with national and international norms, guidelines, standards, and practices can also have a positive impact on space security. Technical measures to efficiently remove debris, once developed and used, could have a positive impact in the future.

The distribution of scarce space resources, including the assignment of orbital slots and radio frequencies to spacefaring nations, has a direct impact on the ability of actors to access and use space. Growing numbers of space actors, particularly in the communications sector, have led to 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.

New measures to increase the number of available orbital slots and frequency bands, such as technology to reduce interference between radio signals, can reduce competition and increase the availability of these scarce resources. Confidence in the sustainability of their use creates a strong incentive for space actors to cooperate in the coordination, registration, and use of radio frequencies and orbital slots. Cooperation in this area can also strengthen support for the application of the rule of law to broader space security issues.

Trend 1.1: Amount of orbital debris continues to increase, particularly in LEO

The U.S. Space Surveillance Network (SSN) is the system that most comprehensively tracks and catalogs space debris, although technological factors limit it to spot checking rather than continuous surveillance, and limit the size of currently cataloged objects to those greater than 10 cm in LEO and much larger in GEO. Currently, the U.S. Department of Defense (DOD) is using the SSN to track more than 21,000 objects approximately 10 cm or larger, of which fewer than 5 per cent are operational satellites.[2] Those objects that can be tracked repeatedly and whose source has been identified are placed in the satellite catalog, currently numbering more than 15,000 objects.[3] It is estimated that there are over 300,000 objects with a diameter larger than 1 cm, and millions smaller.[4]

Two key factors affecting the amount of space debris are the number of objects in orbit and the number of debris-creating launches each year. Growth in the debris population increases the probability of inter-debris collision, which may in turn create further debris. A study by the U.S. National Aeronautics and Space Administration (NASA) has shown that, in LEO, inter-debris collisions will become the dominant source of debris production within the next 50 years. As debris collides and multiplies, it will eventually create a "cascade of collisions" that will spread debris to levels threatening sustainable space access.[5] Additional space debris in LEO could be created by use of ground- and space-based midcourse missile defense systems currently under development, or other weapons testing in space.[6]

Between 1961 and 1996 an average of approximately 240 new pieces of debris were cataloged each year; these new pieces were the result, in large part, 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 system. This decline can be related in large part to international debris mitigation efforts, which increased significantly in the 1990s, combined with a lower number of launches per year. In the 2007-2009 three-year period, an increase in the annual rate of debris production was observed as a result of the aforementioned major debris-creating events occurring in each of these years. Debris events in 2010 resulted in more than 800 cataloged pieces of debris (i.e., 10 cm in diameter or larger), which constitutes a 5.1 per cent increase over 2009.

Collisions between such space assets as the International Space Station and very small pieces of untracked debris are a frequent but manageable problem.[7] While collisions with larger objects remain rare, in October 2010 the ISS had to maneuver to avoid a collision with a large piece of debris, as described below. A U.S. National Research Council study found that within the orbital altitude most congested with debris (900–1,000 km), the chance of a typical spacecraft colliding with a large fragment was only about one in 1,000 over the spacecraft's 10-year functional lifetime.[8]

However, the same study noted that, "although the current hazard to most space activities from debris is low, growth in the amount of debris threatens to make some valuable orbital regions increasingly inhospitable to space operations over the next few decades."[9] Indeed, some experts at NASA believe that collisions between space assets and larger pieces of debris will remain rare only for the next decade, although there is ongoing discussion about this assessment.[10] Incidents of varying severity are noted in Table 1.2 below.

Table 1.2: Unintentional collisions between space objects[11]

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 UARS satellite believed hit by uncataloged debris large enough to create additional debris
2009	Retired Russian communications satellite, Cosmos 2251, collides with U.S. satellite, Iridium 33, part of the Iridium communications constellation.

2010 Development

Software failure leaves Galaxy 15 adrift in the GEO belt, but it is eventually recovered

On 4 April, Intelsat General's Galaxy 15 communications satellite experienced a malfunction in GEO, which left it unresponsive to commands from ground operators.[12] As a result, the satellite could not perform the station-keeping maneuvers required to maintain its orbital slot at 133W over the Pacific Ocean between Hawaii and South America. The gravitational forces from Earth's bulge under the American landmass caused the satellite to slowly drift eastward through the active GEO belt and past other satellites.

Throughout April, Intelsat sent over 200,000 commands to the satellite in an attempt to either turn off its communications payload or maneuver it to stop the drift.[13] All attempts failed and, in early May, Intelsat announced that Galaxy 15 was too close to another active satellite, AMC 11, to attempt further interventions. Intelsat was concerned that the interventions would interfere with AMC 11.

Galaxy 15's communications payload was powered by the satellite's solar panels. As long as the panels remained pointed at the Sun, the satellite had electrical power to retransmit any C-Band broadcasts it picked up. The satellite's ability to keep its antennas pointed at the Earth and solar panels pointed at the Sun depended on the function of its momentum wheels. Without periodic commands from the ground, these momentum wheels would eventually saturate and the satellite would be unable to maintain its attitude pointing. Intelsat originally predicted this "loss of Earth lock" would happen in late July or early August.[14] However, this estimate was revised repeatedly as time went on.[15]

On 29 December, Intelsat announced that it had regained full control of Galaxy 15.[16] The satellite's onboard battery had fully drained on 23 December, which caused the system to perform a software reset and restored ground control. The satellite was placed in safe mode, which prevented its payload from receiving or transmitting any signals. On 13 January 2011, Intelsat announced that it would be moving Galaxy 15 to an orbital slot at 93W for a full systems checkout.[17] After that, the satellite could be put back into service in its original slot.

On 20 April, Orbital Sciences, the company that built the satellite, suggested that the malfunction could have been caused by severe space weather.[18] On the day of the failure, the U.S. National Oceanographic and Atmospheric Administration's (NOAA) Space Weather Prediction Center released a space weather advisory warning bulletin that detailed significant solar activity.[19] However, on 13 January 2011, Intelsat announced that a failure review board had concluded that the malfunction was caused by an electrostatic discharge (ESD) event, and ruled out solar activity as the trigger.[20] The ESD caused a software glitch, which resulted in the satellite's inability to accept commands.

2010 Development

Cataloged debris field from the 2007 intentional destruction of a Chinese satellite passes 3,000 objects

In October, NASA announced that more than 3,000 pieces of trackable debris (>10 cm in diameter) from the intentional destruction of the Chinese Fengyun-1C weather satellite in January 2007 had been officially cataloged.[21] In January 2011, four years after the event, more than 95 per cent of this debris was still in orbit, where much of it is expected to remain for several more decades.[22] The debris from the destruction of the Fengyun-1C represents more than one-fifth of all cataloged objects below 2,000 km.[23]

Table 1.3 below lists the Top 10 breakups of on-orbit objects. These events, six of which occurred in the last decade,[24] account for one-third of all cataloged objects currently in Earth orbit. The two satellites involved in the February 2009 collision — the Russian Cosmos 2251 and the American Iridium 33 — are second and fourth on the list.

A complete listing of the 2009 breakups can be found in Figure 1.3 below.

Table 1.3: Top 10 breakups of on-orbit objects[25]

Common name	Launching state	Year of breakup	Altitude of breakup (km)	Total cataloged pieces of debris*	Pieces of debris still in orbit*	Cause of breakup
Fengyun-1C	China	2007	850	2,841	2,756	Intentional Collision
Cosmos 2251	Russia	2009	790	1,267	1,215	Accidental Collision
STEP 2 Rocket Body	U.S.	1996	625	713	63	Accidental Explosion
Iridium 33	U.S.	2009	790	521	498	Accidental Collision
Cosmos 2421	Russia	2008	410	509	18	Unknown
SPOT 1 Rocket Body	France	1986	805	492	33	Accidental Explosion
OV 2-1 / LCS-2 Rocket Body	U.S.	1965	740	473	36	Accidental Explosion
Nimbus 4 Rocket Body	U.S.	1970	1,075	374	248	Accidental Explosion
TES Rocket Body	India	2001	670	370	116	Accidental Explosion
CBERS 1 Rocket Body	China	2000	740	343	189	Accidental Explosion
			Total:	**7,903**	**5,172**	

* These totals only include trackable debris (generally >10 cm)

2010 Development

Trackable space object population increases by 5.1 per cent

After a year of significant increase in the total space debris population, 2010 saw only a few minor debris-generating events. By the end of 2010, the U.S. SSN had cataloged 15,899 large and medium objects (>10 cm in diameter) in orbit.[26] This number represents an increase of 809 objects or 5.1 per cent over the number at the end of 2009. The previous one-year increase in trackable debris had been 2,347 objects, or 15.6 per cent.

In early February, the Chinese Yaogan 1 remote sensing satellite (object 2006-015A) experienced a minor fragmentation in its 630-km operational orbit, which resulted in seven new pieces of cataloged debris.[27] Two of those pieces were unusually large, with diameters of approximately two meters.[28] Three of the small pieces reentered the Earth's atmosphere in 2010; the remaining five pieces are expected to stay in orbit for decades.[29]

On 10 June, a large Breeze-M propellant tank (object 2009-042C) from a Russian launch vehicle experienced significant fragmentation in LEO. The 1.3-metric-ton tank had been left in a 400 km x 35,570 km geotransfer parking orbit during the launch of the Asiasat 5 satellite on 11 August 2009.[30] At the time of the explosion, the tank's orbit had degraded to 95 km x 1,500 km and the tank was close to atmospheric reentry. The SSN cataloged 88 pieces of debris, all of which reentered the Earth's atmosphere by the end of December 2010.[31]

On 13 October, a Russian Breeze-M upper stage (object 2008-011B) experienced minor fragmentation in its geotransfer parking orbit.[32] The launch vehicle had suffered a malfunction during the 1998 launch of the AMC-14 satellite, which provides satellite television services for Dish Network. Although AMC-14 was able to maneuver on its own into the GEO belt, the malfunction left the upper stage in a highly elliptical orbit with a significant amount of residual propellant, which is usually consumed during launch. The fragmentation resulted in 10 cataloged pieces of debris, all of which are expected to remain in orbit for decades.[33] However, the high altitude and the Breeze-M's elliptical orbit make consistent tracking of small pieces of debris difficult.

On 1 November, the upper stage (object 2010-057B) of a Chinese Long March 3C rocket experienced a minor fragmentation in its 160 km x 35,780 km highly elliptical geotransfer orbit.[34] The event appears to have occurred shortly after the rocket separated from its payload, a Chinese Beidou G4 navigation satellite. Although approximately 50 pieces of debris were detected by the SSN, as of January 2011, none had been cataloged.[35]

On 24 November, a defunct U.S. NOAA weather satellite (object 1988-089A) experienced minor fragmentation in its 835 km x 850 km LEO orbit.[36] Five pieces of debris have been cataloged from this event.[37] Three previous NOAA spacecraft of the same TIROS-N series have experienced similar fragmentation events, each releasing a few pieces at least a dozen years after launch, for unknown reasons.[38]

On 23 December, a piece of debris (object 2007-005E) from the 2007 launch of the Japanese IGS 4A and 4B remote sensing satellites experienced a minor fragmentation.[39] The launch had resulted in the unusually high number of 12 pieces of debris left in orbit, all of which had decayed in 2007 and 2008, with the exception of object 2007-005E.[40] The SSN initially detected 10 new pieces of debris from the December 2010 event, cataloging three.[41]

A complete listing of the 2010 breakups can be found in Table 1.4 below.

Table 1.4: Summary of 2010 debris events[42]

Parent object	Country	Date	Estimated number of pieces*	Cataloged number of pieces**	Lifespan of pieces
Yaogan 1	China	Feb 2010	8	8	decades
Breeze-M tank	Russia	21 June 2010	hundreds	89	6 months
Breeze-M R/B	Russia	13 Oct 2010	tens	9	decades
CZ-3C R/B	China	1 Nov 2010	50	1	1,000+ years
NOAA-11	U.S.	24 Nov 2010	2	2	centuries
H-2A debris	Japan	23 Dec 2010	6	3	months/years

* As initially reported by the SSN
** As of 15 February 2011

Figure 1.5: Total cataloged on-orbit population by launching state[43]

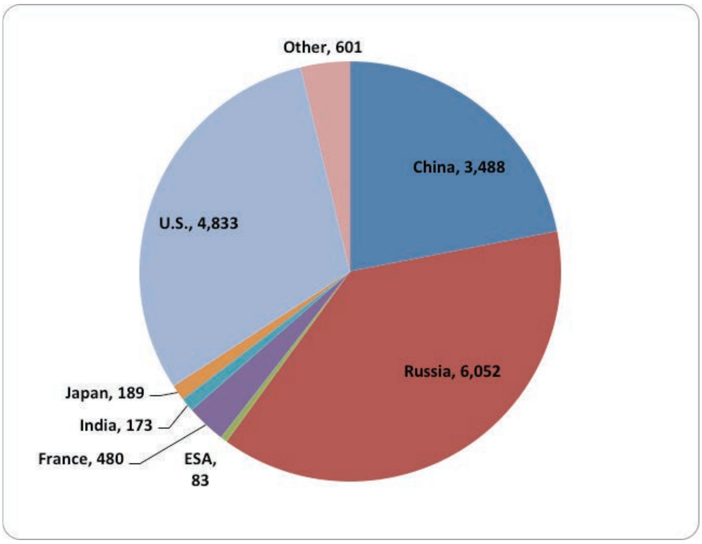
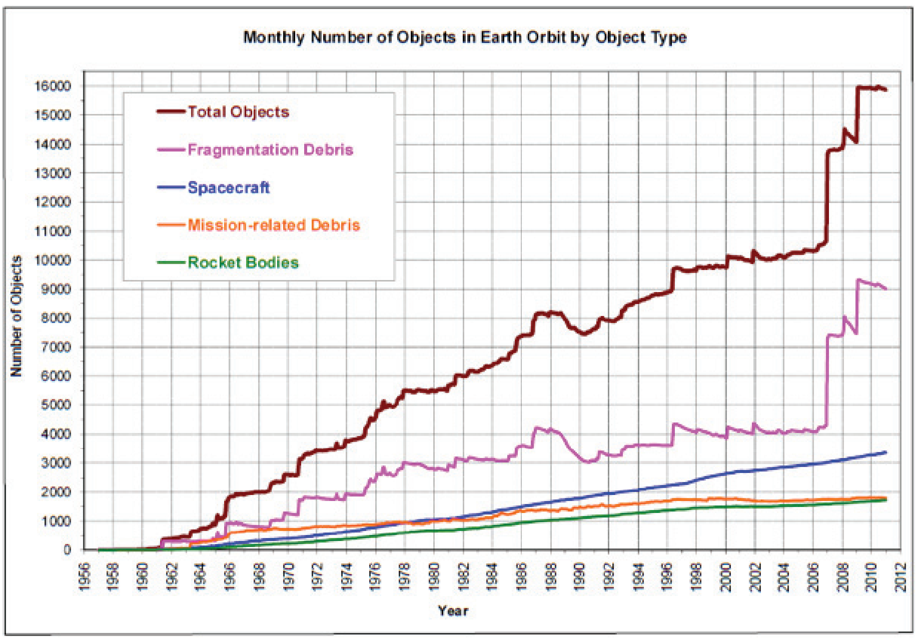


Figure 1.6: Growth in on-orbit population by category[44]



This chart displays a summary of all objects in Earth orbit officially cataloged by the U.S. Space Surveillance Network. "Fragmentation debris" includes satellite breakup debris and anomalous event debris, while "mission-related debris" includes all objects dispensed, separated, or released as part of the planned mission.

2010 Development

The U.S. military continues to track and predict atmospheric reentry of space debris

During 2010, the Joint Space Operations Centre (JSpOC) used tracking data from the SSN to predict the atmospheric reentry of 382 objects in the satellite catalog.[45] Of these, 369 were uncontrolled reentries and 13 were controlled. The uncontrolled reentries accounted for a total mass of approximately 60 metric tons.[46] There were no reported incidents of damage or injury from these reentries.

Space Security Impact

Although there were no major fragmentations in 2010, the number of cataloged objects increased by 800, mostly due to the continued discovery and cataloging of debris from major events in 2007 and 2009. Satellites in the critical 800-km Sun-synchronous region are making more maneuvers than ever to avoid collisions. Some debris in LEO will reenter the Earth's atmosphere and disintegrate in a relatively short period of time due to atmospheric drag, but debris in orbits above 600 km will remain a threat for decades and even centuries. Thus, despite growing awareness of the problem and some voluntary mitigation efforts, space debris continues to pose an increasing threat to operational satellites and the long-term sustainability of space activities.

Trend 1.2: Increasing awareness of space debris threats and continued efforts to develop and implement international measures to tackle the problem

Growing awareness of space debris threats has led to the development of a number of efforts to decrease the amount of new debris, beginning at the national level. NASA first issued guidelines on limiting orbital debris in the August 1995 NASA *Safety Standard 1740*. In December 2000, the U.S. government issued formal orbital debris mitigation standards for space operators. These standards were developed by DOD and NASA. In 2004, the U.S. Federal Communications Commission (FCC) imposed requirements for satellite operators to move geostationary satellites at the end of their operating life into "graveyard orbits" some 200 to 300 km above GEO, and in 2005 new rules went into effect requiring satellite system operators to submit orbital debris mitigation plans.[47] In 2008, NASA published the first edition of the *Handbook for Limiting Orbital Debris*, which presents the scientific background for debris mitigation procedures.[48]

The European Space Agency (ESA) initiated a space debris mitigation effort in 1998. The *ESA Space Debris Mitigation Handbook* was published in 1999 and revised in 2002.[49] Also in 2002, ESA issued the European Space Debris Safety and Mitigation Standard[50] and issued new debris mitigation guidelines in 2003. As well, the European Union's (EU) proposed Code of Conduct for Outer Space Activities, the latest draft of which was still the subject of international consultations by the end of 2010, calls on states to "refrain from intentional destruction of any on-orbit space object or other harmful activities which may generate long-lived space debris."[51]

The Inter-Agency Space Debris Coordination Committee (IADC) was formed in 1993 as an international forum aimed at harmonizing the efforts to address the problem posed by orbital debris among various space agencies. As of 2010, the IADC is made up of ASI (Agenzia Spaziale Italiana [Italy]), CNES (Centre National d'Etudes Spatiales [France]), CNSA (China National Space Administration), CSA (Canadian Space Agency), DLR

(German Aerospace Center), ESA, ISRO (Indian Space Research Organisation), JAXA (Japan Aerospace Exploration Agency), NASA, NSAU (National Space Agency of Ukraine), Roscosmos (Russian Federal Space Agency), and the United Kingdom Space Agency.

While there are differences among national debris mitigation guidelines, they are broadly consistent. For example, all national guidelines address issues related to the minimization of debris released during normal operations. Most states require residual propellants, batteries, flywheels, pressure vessels, and other instruments to be depleted or made passive at the end of their operational lifetimes.[52] All major national debris mitigation guidelines address the disposal of GEO satellites, typically in graveyard orbits some 235 km above GEO, and most seek the removal of dead spacecraft from LEO within 25 years.[53]

The Scientific and Technical Subcommittee of the United Nations Committee on the Peaceful Uses of Outer Space (UN COPUOS) began discussions of space debris issues in 1994 and published its Technical Report on Space Debris in 1999. In 2001, COPUOS asked IADC to develop a set of international debris mitigation guidelines, on which it based its own draft guidelines in 2005.[54] In 2007, these guidelines were adopted by UN COPOUS and endorsed by the UN General Assembly as voluntary measures with which all states are asked to comply.[55] The soon-to-be-released EU Code of Conduct also calls on signatories to reaffirm their commitments to the UN COPUOS space debris mitigation guidelines.

Table 1.7: UN COPUOS Space Debris Mitigation Guidelines[56]

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.

The progressive development of international and national debris mitigation guidelines has been complemented by research on technologies to physically remove debris, such as electromagnetic "tethers" that could help to safely de-orbit non-operational satellites or debris.[57] However, a 2006 IADC report concluded that, while "electrodynamic tethers have strong potential to become effective mitigation measures…various problems are still to be solved before this technique can be practically adopted."[58] Currently, natural decay due to atmospheric drag remains the only feasible way to remove debris, although research into this area continues.

2010 Development

Orbital debris continues to have a growing impact on operational spacecraft

During the almost nine months that Galaxy 15 was adrift in the active GEO belt (see Trend 1.1) another 15 operational satellites were forced to maneuver to minimize the chance of physical or electromagnetic interference with it[59] and avoid collisions.

In late October, the ISS was forced to maneuver to avoid a potential collision with a piece of large space debris (object 1991-063G) from NASA's Upper Atmospheric Research Satellite

(UARS),[60] which had also shed four pieces in November 2007.[61] On 25 October, 10 days before the piece of debris was predicted to reenter the Earth's atmosphere, it was deemed to have a greater than 1-in-10,000 chance of colliding with the ISS the following day. The ISS maneuvered approximately two hours before the predicted time of closest approach on 26 October. The ISS usually maneuvers several times a year to avoid close approaches with space debris, although these maneuvers are combined with required orbit-raising maneuvers when possible.

NASA also reported that, in 2010, seven collision avoidance maneuvers were conducted by five of its satellites: Terra, Cloudsat, Landsat 5, Aura, and Landsat 7.[62] All orbit at an altitude of approximately 720 km, which is the most densely populated region. In 2009, six NASA satellites made a total of seven collision avoidance maneuvers.[63] ESA reported that it had conducted nine collision-avoidance maneuvers in 2010 to protect its operational satellites.[64] The French space agency CNES reported that the 17-18 satellites it protects had performed 13 collision-avoidance maneuvers in 2010.[65]

Speaking at the annual United States Strategic Command (USSTRATCOM) Strategic Space Symposium in Omaha, Nebraska in November, Lieutenant General Larry James said that, on average, the JSpOC sends out 190 conjunction warnings per week to satellite owner/operators around the world. Based on these warnings, active satellites are performing an average of three maneuvers a week to minimize the chances of colliding with another object. This is a significant increase from the 32 maneuvers reported between February and December of 2009.[66]

During the 4th International Association for the Advancement of Space Safety Conference in May, Dr. William Ailor from the Aerospace Corporation presented a new report that quantified the cost impact of space debris on space operations.[67] Entitled "Space Debris and the Cost of Space Operations", the report specifically estimated the costs associated with maintaining three types of satellite constellations in 850-km Sun-synchronous orbits from 2010 to 2030 due to increased amounts of space debris. The report found that the cost of maintaining a small constellation of robust, short-lived, government-owned satellites would increase by 5 per cent over the 20-year period, compared to the costs of maintaining the same constellation in today's debris environment. The cost of maintaining a large constellation of cheaper, long-lived commercial satellites would increase by 26 per cent.

2010 Development

Compliance with international space debris mitigation guidelines is still inconsistent

During 2010, four satellites from the Globalstar constellation were reorbited to post-mission disposal orbits above 2,000 km.[68] Between 1998 and 2000, 52 Globalstar satellites were launched to create a LEO constellation that provided satellite phone and low-speed data services.[69] Of these, most have reached their operational end-of-life, and 14 have been reorbited above 1,600 km in accordance with U.S. and some international debris mitigation guidelines.[70] However, the Inter-Agency Space Debris Coordination Committee (IADC) guidelines do state that deorbiting of spacecraft is always the first priority. Reorbiting should only be considered when deorbiting is not possible, and spacecraft reorbited out of LEO should be left above 2,000 km.[71]

NASA conducted a series of 20 maneuvers during June and July to move its Ice, Cloud, and land Elevation Satellite (ICESat) from its operational 600-km orbit to a 200 km x 280 km disposal orbit. The satellite was then passivated and uneventfully reentered the atmosphere approximately six weeks later. NASA also conducted a series of 12 maneuvers in June to move its first Tracking and Data Relay Satellite (TDRS-1) to a disposal orbit above the protected GEO region. The remaining fuel was then expended to passivate the satellite.

NASA also reported that it has placed two rocket stages in high perigee geosynchronous transfer orbits after launching payloads into GEO. These transfer orbits are above the protected LEO region and below the protected GEO region, and thus minimize the risks of orbital collision as well as risks posed to people and property on Earth from reentry.

An annual European Space Agency (ESA) report on the geosynchronous region stated that at least 16 satellites reached end-of-life in 2010. Of these, only 11 were properly disposed of in accordance with IADC guidelines. Four satellites were not placed in high enough orbits, and thus have a chance of interfering with the active GEO belt in the future. One satellite, operated by Turkey, appears to have been abandoned in the protected GEO zone.

2010 Development

International awareness of orbital debris problem increases and progress on solutions continues

In April, the Institutes of Air and Space Law at McGill University and the University of Cologne held an International Interdisciplinary Congress on Space Debris in Cologne, Germany.[75] The event followed up on a May 2009 Congress in Montreal, Canada. The 2010 event brought together 30 experts in engineering, policy, law, and science to develop recommendations for dealing with the problem of space debris.[76] The recommendations were released in early 2011.

On 28 June, the Obama Administration unveiled the new U.S. National Space Policy, which called for greater international cooperation and encouraged/urged U.S. leadership to tackle the problem of space debris. The National Space Policy emphasized the importance of the long-term sustainability of outer space to U.S. national interests. It called for continued development and adoption of national and international space debris mitigation guidelines, and directed NASA and the Secretary of Defense to pursue research and development of technologies and techniques to remove orbital debris. (For further information on the U.S. National Space Policy see Chapter 3.)

Over the course of 2010, three meetings focused on the issue of active removal of orbital debris. In April, the International Science and Technology Center organized a Space Debris Mitigation Workshop in Moscow.[77] The event brought together 50 scientists and engineers from 10 countries to discuss the space debris problem, debris mitigation, and methods of removing debris from orbit.[78] On 22 June, the French national space agency hosted the first European Workshop on Active Debris Removal in Paris. More than 120 participants from 10 European countries, Canada, Japan, and the U.S. gathered to promote European awareness and highlight potential commercial opportunities.[79]

In October, the Secure World Foundation, in partnership with International Space University and Beihang University, held the 2010 Beijing Orbital Debris Mitigation Workshop at the Beihang campus.[80] The 50 participants, including students and faculty from universities in the U.S., Europe, Japan, Russia, and China, discussed orbital debris removal and related issues.[81] This event was noteworthy as the first on orbital debris removal to include significant Chinese participation.

The European Union proposal for a Code of Conduct on Outer Space Activities was released in an updated form in October 2010, after approval by the Council of the European Union.[82]

The goal of the voluntary Code is to enhance the security, safety, and sustainability of all outer space activities, and is open to all states. The Code contains proscriptions to minimize the possibility of accidents and harmful interference, limit the creation of space debris and its impact on operations, and increase notification and information on space activities.[83]

In November, the RAND Corporation released a report on dealing with space debris,[84] which pulled lessons from comparable environmental mitigation scenarios in other domains, including the Deepwater Horizon oil spill in the Gulf of Mexico. It concluded that while space debris is a problem, there is still much work to be done before active debris removal is an economically feasible solution.[85] It also suggested that the U.S. Comprehensive Environmental Response, Compensation, and Liability Act of 1980, in which a special trust fund known as the Superfund was established to clean up environmental contamination on Earth, could be a viable model for orbital debris cleanup.

Space Security Impact

The increasing awareness of the need for active debris removal, particularly among spacefaring countries, demonstrates that a growing number of actors are taking the problem of space debris seriously. However, continued emphasis on solving the problem at some unknown future point does not build the political will needed to take immediate measures. Slow implementation and enforcement of the IADC and UN debris mitigation guidelines at the national level and continuing reluctance to pursue more stringent measures do not bode well for space security.

Trend 1.3: Growing demand for radio frequency (RF) spectrum and communications bandwidth

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 U.S. 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. It is U.S. policy to reserve the Ultra-High Frequency, X-, and K-bands (240-340 megahertz, 8-12 GHz, and 18-27 GHz, respectively) for the U.S. military.[86]

Most satellite communication falls below 60 GHz; thus actors are competing for a relatively small portion of the radio spectrum, with competition particularly intense for the segment of the spectrum below 3 GHz.[87] Additionally, the number of satellites operating in the 7-8 GHz band, commonly used by GEO satellites, has grown rapidly over the past two decades.[88] Since many satellites vie for this advantageous frequency and ever closer orbit slots, there is an increased risk of accidental signal interference.

Originally adopted in 1994, the ITU Constitution[89] governs international sharing of the finite radio spectrum and orbital slots used to communicate with, and house 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."[90] Military communications are exempt from the ITU Constitution, though they must observe measures to prevent harmful interference. It is observed that "interferences from the military communication and tracking systems into satellite communications is on the rise,"[91] 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. Current receivers have a higher tolerance for interference than those created decades ago, reflecting the need for increased frequency usage and sharing.[92] Significant research is also being 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.

Today, 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. The simplest way to reduce such interference is to ensure that all actors have access to reasonable and sufficient bandwidth. To this end the U.S. DOD released a portion of the military-reserved spectrum from 1.710-1.755 GHz to the commercial sector for third-generation wireless communications.[93]

Bilateral efforts are also under way to harmonize radio frequency utilization. In 2004, the U.S. and EU agreed to major principles over frequency allocation and interoperability between the U.S. GPS and the EU Galileo navigational system;[94] details were finalized in 2007 for a common GPS-Galileo civilian signal, allowing for interoperability of the two systems while also maintaining the integrity of the U.S. military signal.[95]

Orbital slots

Today's satellites operate mainly in three basic orbital regions: LEO, MEO (Medium Earth Orbit), and GEO (see Figure 1.1). As of 30 April 2011, there are approximately 966 operating satellites, of which 470 are in LEO, 64 in MEO, 398 in GEO, and 34 in Highly Elliptical Orbit (HEO).[96] HEO is increasingly being 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 GPS. Most communications and some weather satellites are in GEO, as orbital movement at this altitude is synchronized with the Earth's 24-hour rotation, meaning that 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 U.S. lies between 60° and 135° W longitude because satellites in this area can serve the entire continental U.S.;[97] these desirable slots are also optimal for the rest of the Americas. Similar desirable spots exist over Africa for Europe and over Indonesia for Asia.

GEO satellites must generate high-power transmissions to deliver a strong signal to Earth, due to distance and the use of high bandwidth signals for television or broadband applications.[98] 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.[99] Thus, only a limited number of satellites can occupy the prime equator (0 degree inclination) orbital path. In the equatorial arc around the continental U.S., there is room for only an extremely limited number of satellites. To deal with the limited availability of orbital slots, the ITU Constitution states that radio frequencies and associate 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.[100] However, in practice the orbital slots in GEO are secured on a first-come, first-served basis.

Equitable treatment has been further compromised by a rash of early registrations with the ITU, often of so-called "paper satellites," combined with ITU revenue shortfalls and disputes over satellite network filing fees. "At one time there were about 1300 filings (applications) for satellite networks before the ITU and about 1200 of them were for paper satellites."[101] Filing fees for ITU cost recovery grew from about $1,126 in 2000 to $31,277 in 2003, resulting in patterns of non-payment and tensions between satellite operators and the ITU. The fee schedule, which links charges to the complexity and size of a filing, was most recently updated in 2008. While there is a flat fee of $570, fees can reach almost $60,000 for complex requests requiring extensive coordination.[102] Additional measures to reduce unnecessary registrations include a requirement for satellites to be brought online within seven years of a request, a requirement for the provision of advanced publication information at the time of filing to verify the seriousness of intention, and payment of filing fees within six months.[103]

Originally, crowding in the MEO region was not a concern, as the only major users were the U.S. and Russia with their GPS and GLONASS navigation satellite constellations. However, concern is increasing that problems could develop in this area when Russia adds more satellites and if both China and the EU make good on plans for constellations of their own. The ITU does require that these constellations all have their operational frequencies registered, but does not stipulate specific orbital slots. All four of these systems 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.

2010 Development

Drifting Galaxy 15 prompts complicated radio frequency interference (RFI) mitigation plans and causes interference

The on-orbit malfunction of Galaxy 15 (see Trend 1.1) left the satellite with the ability to keep its payload pointed at the Earth and its solar panels pointed at the Sun, and did not affect the ability of its C-Band communications payload to receive or transmit. This meant that the satellite could still act as an "open microphone" and retransmit any C-Band signals it received on its uplink frequencies as it drifted through the GEO belt.

Galaxy 15 drifted past the first operational satellite, AMC-11, between 23 May and 7 June. AMC-11 receives digital programming from cable-television channels in North America and retransmits the programming to cable television networks all over the U.S. On 17 May, SES, the operator of AMC-11, announced a plan to minimize the chance that Galaxy 15 would create electromagnetic interference with AMC-11.[104] The plan, which was developed with Intelsat's cooperation, included moving AMC-11 to the far eastern side of its orbital box as Galaxy 15 drifted through from the west. As many customers as possible were transferred to other SES satellites, and the SES-1 satellite was maneuvered into position on the western side of AMC-11's box so that it could take over broadcast duties from AMC-11 if needed.

Once Galaxy 15 had drifted past the middle of the box, and in the middle of the night while traffic was at a minimum, AMC-11 was quickly maneuvered around it to the eastern side of its box. Meanwhile, customers were told to reduce the power of their uplink signals to as low as five watts per channel to minimize interference caused when Galaxy 15 rebroadcast their signal.[105] The plan worked and Galaxy 15 caused no apparent interference or outage.[106]

On 9 December, it was reported that Galaxy 15 had potentially caused an outage with the SES-1 satellite located at 101W.[107] The SES-1 satellite relays data from a number of NOAA weather satellites in orbit to stations on the ground for processing. Interference from Galaxy 15 caused service interruptions with NOAA's Advanced Weather Interactive Processing System, resulting in the inability to generate severe weather bulletins across the U.S. for a number of hours.[108] To help minimize this interference, signals were rerouted through another uplink station located in Hawaii, outside of Galaxy 15's uplink footprint, until it had passed by SES-1's orbital box.[109]

2010 Development

Satellite operators continue to report significant harmful RFI or infringements of RF regulations

The annual report to the 56th Meeting of the International Telecommunication Union's Radio Regulations Board reported that for calendar year 2010, the Board received 119 reports of harmful interference or infringement of the Radio Regulations.[110] Twelve of these — double the number reported in 2009 — involved space services. Table 1.8 summarizes these reports.

Table 1.8: Summary of 2010 reported RFI events[111]

	No. of cases*	Cases impacting safety services**	Space services	Terrestrial services
2010 Total	66	26	12	54
2009 Total	55	21	6	49

* Normally one case corresponds to a single frequency, except when an administration communicates a report concerning multiple frequencies that are grouped together as one single case.

** Includes cases concerning interference with any radio communication service used permanently or temporarily for the safeguarding of human life and property

Space Security Impact

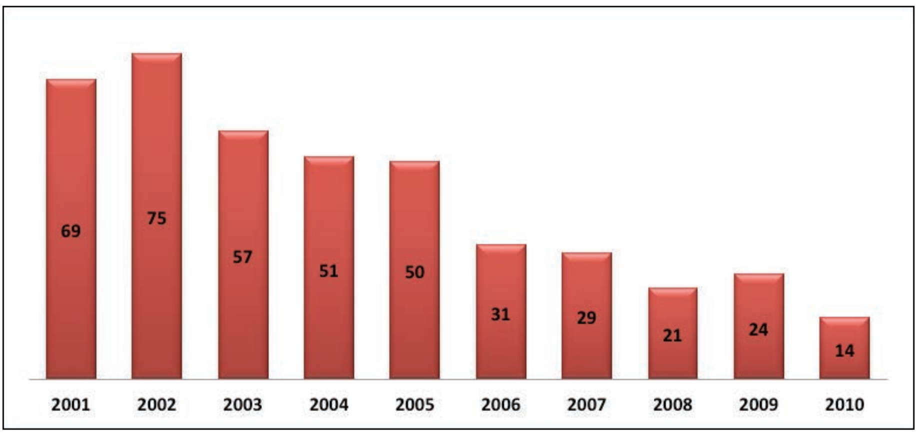
The relative ease with which intentional or unintentional RFI and signal jamming can occur indicates that the number of RFI or signal-jamming events will continue to increase in the future and negatively impact space security. The difficulty in verifying the intentions of a specific RFI or signal-jamming incident and the lack of enforcement measures suggest that the international community will continue to struggle to improve the situation.

Trend 1.4: Increased recognition of the threat from NEO collisions and progress toward possible solutions

Near Earth Objects 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 (PHA) instead. A PHA is defined as an asteroid whose orbit comes within 0.05 astronomical units of the Earth's orbit and has a brightness magnitude greater than 22 (approximately 150 m in diameter).[112]

Initial efforts to find threatening NEOs focused on the so-called "civilization-killer" class, which are NEOs 1 km in diameter or larger. In 1998, NASA agreed to undertake a survey to discover 90 per cent of these objects by 2008. Of the estimated 1,100 objects in this class, NASA tracks approximately 80 per cent.[113] In 2003, a NASA Science Definition Team published a report that recommended the search be extended to include all NEOs down to 140 m in diameter.[114] Impacts of this class of objects would have the potential to wipe out regions of the Earth's surface. Discovery of these objects, along with those over 1 km in diameter, would identify around 90 per cent of the risk the Earth faces from NEO collisions.[115]

Figure 1.9: Number of large* NEAs discovered by year (2001-2010)[116]



* 1 kilometer in diameter or larger

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. These are objects approximately 45 m in diameter, one of which caused the Tunguska explosion in Siberia in 1908. Researchers estimate that there are over 700,000 NEOs of this size, of which approximately three per cent are estimated to pose some sort of threat of impact.[117] Although objects of that size cause much less damage, they impact the Earth at a much higher frequency than kilometer-sized objects.

Technical research is ongoing into ways of mitigating a NEO collision with the Earth. This is proving to be a difficult challenge due to the extreme mass, velocity, and distance of any impacting NEO. Mitigation methods are divided into two categories depending on how much warning time there is for a potential impact event. If the warning times are in the order of years or decades, there are several mitigation methods that could potentially be used, consisting of constant thrust applications to gradually change the NEO's orbit over time. If warning times are relatively short, then only certain kinetic methods can be applied. Kinetic deflection methods may 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 and 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.

As of July 2011, there are 8,037 known NEAs, 828 1 km in diameter or larger.[118] The number of NEOs is expected to jump to over 10,000 in the next 15 years, requiring international decision-making on those objects that present a threat. As a result, focus is now shifting toward governance for NEO detection and mitigation.

2010 Development

International awareness of the NEO problem and discussions on solutions continue to increase

On 15 October, the Director of the Office of Science and Technology Policy in the White House sent a formal letter to both houses of Congress that outlined U.S. government activities, procedures, roles, and responsibilities in responding to the NEO impact threat.[119] The letter detailed historical, current, and future NEO detection and tracking programs and compliance with Congressional direction.[120] It also detailed the domestic and international notification procedures in the event a threatening asteroid is detected, and the emergency response procedures to mitigate an impact.

At the end of October, a workshop was held at the ESA offices in Darmstadt, Germany, to discuss NEO deflection mission planning and operations.[121] The event was organized by the Secure World Foundation and the Association of Space Explorers in cooperation with ESA. The workshop brought together technical and policy experts from several national space agencies and focused on the interagency communication and coordination necessary to deflect threatening asteroids. A workshop report summarized the group's recommendations, which were presented to the UN COPUOS Action Team 14 on NEOs.[122]

In November it was reported that the U.S. DOD was still working on providing data collected by military satellites on bolides to the NEO science community.[123] Military satellites designed to detect missile launches and explosions can also detect asteroids entering the Earth's atmosphere. The data on asteroid impacts is unclassified and in the past was provided to the NEO science community, but such information sharing ceased several years ago. The Chief of Space and Cyberspace Operational Integration stated that work is still ongoing to determine how best to share the bolide data, and where the resources to do so will come from.[124]

Space Security Impact

An understanding of the potential threat posed by NEOs has begun to move from the astronomy community to the broader policy community. Discussions and progress on international detection, warning, collaboration, and decision-making are a positive step for space security, although follow-through is still lacking. The establishment of international governance mechanisms to respond to the NEO threat will likely prove beneficial in other areas of space security.

CHAPTER TWO

Space Situational Awareness

This chapter assesses trends and developments related to the technical ability of different spacefaring actors "to monitor and understand the changing environment in space."[1] 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.[2] Also assessed in this chapter are the growing international efforts made to improve the predictability of space operations through data sharing.

A subset of Space Situational Awareness (SSA) is space surveillance — information about the locations of objects in Earth orbit. There is no international space surveillance mechanism, but efforts to create one date from the 1980s. In 1989, France proposed the creation of an international Earth-based space surveillance system consisting of radar and optical sensors to allow the international community to track the trajectory of space objects. Such an initiative could complement the U.S.-Russian agreement to establish the Joint Center for the Exchange of Data from Early Warning Systems and Notification of Missile Launches.[3] In the absence of an international surveillance system, countries are establishing independent capabilities, with a limited degree of information exchange.

Driven by Cold War security concerns, the U.S. and the USSR were pioneers in the development of space surveillance capabilities. Today, a growing number of space actors are investing in space surveillance to facilitate debris monitoring, satellite tracking, and NEO detection, although this is also a key enabling technology for space systems negation, since tracking and identifying targeted objects in orbit are prerequisites to most negation techniques.

At present the U.S. Space Surveillance Network (SSN) is the primary provider of space surveillance data. Although the U.S. maintains the most capable space surveillance system, Russia continues to have relatively extensive capabilities in this area, and China and India have significant satellite tracking, telemetry, and control assets essential to their civil space programs. The satellite intercepted by China on 11 January 2007 was tracked and targeted using such indigenous surveillance technology.

Space-based surveillance, first demonstrated by the U.S. with the Space Visible Sensor experiment that was decommissioned in 2008,[4] is being pursued through the Space Based Space Surveillance (SBSS) system, which has been described as "a constellation of optical sensing satellites to track and identify space forces in deep space to enable defensive and offensive counterspace operations."[5] The $823.9-million program is designed to collect real-time data and track satellites that are orbiting from LEO to a higher position,[6] using satellites equipped with "an optical telescope that is highly responsive to quick tasking orders, allowing it to shift from target to target quickly in space."[7] SBSS will be able to track every satellite in GEO at least once every 24 hours using its two-axis, gimbaled visible light sensors.[8] After several delays, the first SBSS satellite was placed in orbit on 25 September 2010.

Space Security Impact

Improved SSA capabilities can have a positive impact on the security of outer space inasmuch as SSA can be used to predict and/or prevent harmful interference with the assets of spacefaring states. In an increasingly congested domain, with new civil and commercial actors gaining access every year (see Chapter 4), 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 space activities, which can reinforce the overall stability of the space regime.

However, the positive impact that SSA has on space security must be qualified by the fact that currently advanced SSA capabilities are not widely available and, therefore, space actors must rely on the information provided by those states with advanced SSA — most notably, the U.S. Moreover, while militaries and intelligence agencies used to be the primary users of SSA data, the number and diversity of civil and commercial actors that would benefit from SSA data has grown substantially since the end of the Cold War and will likely exert mounting pressure for cooperative approaches to SSA and increased data sharing.

Sharing SSA data could benefit all space actors, as it would allow them to supplement the data collected by national assets for little or no additional economic cost. Still, there is currently no operational global system for space surveillance, in part because of the sensitive nature of surveillance data. This is why the U.S. moderates access to information from its SSN.[9] 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 expand its SSA Sharing Program, as described below.

Improved SSA could also have a detrimental effect on the security of outer space. Besides being a vital tool for preventing 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 collide with, not the exact nature of that object.

Trend 2.1: U.S. SSA capabilities slowly improving

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 Air Force Space Surveillance System or Space Fence is the oldest component of the SSN and consists of three transmitters and six receivers spread across the southern U.S. It provides the greatest number of observations of any sensor in the network and is capable of making five million detections each month of objects larger than a basketball to an altitude of 10,000 km.[10] A new S-Band Space Fence, whose current phase of development is described below, is expected to cost more than $1-billion to design and procure.[11] The system, with a target completion date of 2015, will include a series of S-band radars in at least three separate locations.[12] Many of the other SSN sensors also do double duty as missile warning radars.

The sensors that make up the SSN can be grouped into three categories:[13]

Dedicated: The primary mission of these Air Force Space Command sensors is space surveillance.

Collateral: These Air Force 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 more than 21,000 manmade objects in Earth orbit. Those objects that can be tracked repeatedly and whose source has been identified are placed in the satellite catalog, currently numbering more than 15,000 objects. A low accuracy version of this catalog is publicly available at the Space Track website,[14] but the data is not sufficiently precise to adequately support collision avoidance. The U.S. Air Force 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 Air Force 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. But while some operators would like direct access to orbital data, there is some reluctance to release it widely.[15] For instance, regulations for the CFE program restrict the sharing of surveillance information with a non-U.S. government entity to agreements in which "providing such data analysis to that entity is in the national security interest of the United States."[16]

In recent years there has been increased impetus in the U.S. to boost conjunction analysis — the ability to accurately predict high-speed collisions between two orbiting objects. However, this will necessitate certain changes in the way space objects are monitored by the Department of Defense (DOD). At the time of the Iridium collision, approximately 140 spacecraft were being monitored for potential collisions and the Joint Space Operations Center (JSpOC) had five operators supporting a single position for conjunction prediction.[17]

To conduct more effective collision avoidance, more personnel and computing equipment are needed. According to Lt. Gen. Larry James, former commander of the Joint Functional Component Command for Space at Vandenberg Air Force Base, collision analysis of roughly 1,300 satellites — including approximately 500 that are not maneuverable — would require as many as 20 more people than were available at the time of the Cosmos-Iridium collision.[18]

2010 Development

U.S. launches orbital space surveillance sensor as part of 20-year plan to improve SSA

In November, the U.S. Air Force's Space Command announced that it has a 20-year plan to improve U.S. SSA capability.[19] Lieutenant Colonel Richard Benz of Space Command's Directorate of Plans and Requirements said that they were also working with U.S. Strategic Command and the National Security Space Office to better define requirements for SSA capabilities and systems.[20]

The first step in the plan was the launch of the Space Based Space Surveillance (SBSS) Block 10 satellite on 25 September from Vandenberg Air Force Base in California.[21] The launch had been delayed almost two years from its original date of December 2008, with an entire program cost of $823-million. The Block 10 satellite is considered a "pathfinder" for follow-on satellites and the eventual creation of an SBSS constellation. The launch vehicle placed the satellite into a 630-km, Sun-synchronous orbit and was designed to have a seven-year lifespan.[22]

The 1,100-kg Block 10 satellite contains a 30-cm telescope mounted on a 2-axis gimbal and connected to a 2.4-megapixel sensor.[23] This enables it to detect and track objects in orbit around the Earth, primarily in the Medium Earth Orbit (MEO) and GEO region, as well as space launches and maneuvers in space.[24] Because the sensor is located in space, it is not susceptible to the daytime and weather restrictions placed on ground-based optical sensors, and it can track every spacecraft in GEO orbit at least once a day.[25] The satellite is operated by the Satellite Operations Center at Schriever Air Force Base in Colorado.[26]

Previous to the SBSS Block 10, the only U.S. military satellite in space dedicated to visible tracking of space objects was the Midcourse Space Experiment (MSX) satellite. Launched as a Ballistic Missile Defense Organization experiment in 1996, MSX had provided space surveillance capabilities since October 2000 and was decommissioned in December 2008.[27] Compared to MSX, the SBSS Block 10 satellite has greater sensitivity, detection speed, and detection probability, and can provide 10 times as many observations.[28] The FY2011 DOD Budget Proposal includes $186-million for SBSS.[29]

In September, the U.S. military announced that another satellite, the Space Tracking and Surveillance System Advanced Technology Risk Reduction (STSS ATRR) satellite, demonstrated the ability to detect and track another satellite in orbit.[30] The STSS ATRR satellite is part of a demonstration program for an eventual constellation of STSS satellites operated by the Missile Defense Agency (MDA) with the primary mission of detecting and characterizing missile launches through all phases of flight. In November, it was announced that the MDA was transferring operational command and control of the STSS ATRR satellite to Air Force Space Command following the conclusion of the missile defense portion of the satellite's mission.[31] The transfer will allow Space Command to use the satellite as an SSA sensor.

2010 Development

S-Band Space Fence acquisition program moves to the next phase

The U.S. Air Force acquisition program to build and deploy the S-Band Space Fence reached a new milestone in late 2010. Electronic Systems Command (ESC) awarded three $30-million contracts to Lockheed Martin, Northrop Grumman, and Raytheon to develop more detailed proposals for an eventual Space Fence system.[32] In early 2011, ESC was to award two 18-month contracts worth up to a total of $214-million to develop preliminary design reviews.[33] In 2012, a final contract will be awarded to complete the S-Band Space Fence by 2015.

The S-Band Space Fence program is planned to replace the existing VHF Space Fence, known as the Air Force Space Surveillance System (AFSSS), which the Air Force inherited from the Navy in 2004.[34] The new fence will operate at the much higher frequency S-Band, enabling it to track objects as small as a few centimeters in diameter. And, unlike the AFSSS, which consists of three transmitting and five receiving stations located across the southern U.S., the S-Band Space Fence will consist of up to three receiver-transmitter pairs located around the globe.

2010 Development

U.S. Air Force improves ability to integrate data from different sources for SSA

The 3rd Space Operations Squadron, located in Colorado Springs, Colorado, announced that it had successfully put in place the capability to send the operational status of satellites in the Wideband Global Satellite Constellation to the JSpOC in California in real time.[35] Historically, the operational status of satellites has only been known by its satellite operators. The ability to transmit status information to the JSpOC in California, where it can be integrated with other satellite constellations and space surveillance data, constitutes a significant improvement in SSA for the U.S. military.

In October, Raytheon announced that it had won a $3-million contract to develop a prototype sensor architecture that would integrate Air Force Space Command space surveillance sensors and MDA sensors into a single sensor network.[36] Currently, those missions have two different networks of sensors, most of which cannot be linked to the other network. Integrating the networks would allow for less replication of capabilities and improve both SSA and the ability to track and intercept ballistic missiles.

In a keynote speech at the USSTRATCOM Strategic Space Symposium in Omaha, Nebraska, in November, Lieutenant General Larry James said that work continued on development of the JSpOC Mission System (JMS) to attain "21st century command and control capability," but Phase 1 deployment has been postponed from Spring 2010 to Spring 2011. The JMS is slated to replace the current, outdated SPADOC 4C and CAVENET computer systems used in the JSpOC for SSA. The FY2011 DOD Budget Proposal includes $132-million for the JMS and estimates almost $670-million for the program through FY2015.[37] James also said that work is proceeding on integrating space with cyber and intelligence capabilities. In total, the FY2011 budget proposal request for SSA programs is $426-million, a significant increase over the $238-million spent in FY2010.[38]

2010 Development

Australia funds space debris tracking research and initiates SSA partnership with U.S.

In July, Australian company Electro Optic Systems was awarded a $4-million grant from the Australian Space Research Program to develop a laser-based space debris tracking system.[39] It is working with an international consortium that includes institutions in the U.S. and Germany. The consortium's goal is to develop a system to automatically track space debris much more accurately than is currently possible with ground-based radars, which are the primary means to track data for small objects in LEO.[40] The consortium hopes the project will lead to a network of lasers around the world to track space debris.

In November, the U.S. government announced a partnership with Australia to improve SSA capabilities.[41] A Fact Sheet released by the Australian government said that the partnership was a result of the initiatives put forward in Australia's 2008 Defence White Paper, which emphasized the need for improved SSA.[42] The Fact Sheet also states that the partnership includes joint U.S.-Australian efforts to use existing sites in Western Australia for SSA, sharing of SSA information, and collaboration on science and technology.[43] It is likely that one of the three S-Band Space Fence sites will be located in Western Australia to provide much-needed Southern Hemisphere coverage for the U.S. SSN.

Space Security Impact

The increase in U.S. SSA capabilities, especially tracking and cataloging of objects smaller than 10 cm, significantly improves space security The conjunction warnings issued by the U.S. military have had a significant positive impact on spacecraft operations worldwide, allowing all operators to protect their spacecraft from collisions with space debris. However, the slow progress on SSA data sharing with other countries and satellite operators impedes further improvement for both U.S. SSA and space security.

Trend 2.2: Global SSA capabilities slowly improving

Russia is the only other state with a dedicated space surveillance system, the Space Surveillance System (SSS). The system relies mainly on the country's network of early warning radars, as well as more than 20 optical and electro-optical facilities at 14 locations on Earth.[44] The main optical observation system, Okno (meaning "window"), which began operations in 1999, is located in the mountains near the Tajik city of Nurek, and is used to track objects from 2,000-40,000 km in altitude.[45] The space surveillance network also includes the Krona system at Zelenchukskaya in the North Caucasus, which includes dedicated X-band space surveillance radars.[46] The SSS has significant limitations due to its limited geographic distribution: it cannot track satellites at very low inclinations or in the Western hemisphere, and the operation of Russian surveillance sensors is reportedly erratic.[47] The network as a whole is estimated to carry out some 50,000 observations daily, contributing to a catalog of approximately 5,000 objects, mostly in LEO.[48] While information from the system is not classified, Russia does not have a formal process to widely disseminate space surveillance information.[49]

Table 2.1: Russia's early warning system land-based radars[50]

Radar station	Radars	Year built
Olenegorsk (RO-1)	Dnestr-M/Dnepr	1976
Olenegorsk (RO-1)	Daugava	1978
Mishelevka (OS-1)	Dnestr (space surveillance)	1968
Mishelevka (OS-1)	two Dnestr-M/Dnepr	1972-1976
Mishelevka (OS-1)	Daryal-U	non-operational
Balkhash, Kazakhstan (OS-2)	Dnestr (space surveillance)	1968
Balkhash, Kazakhstan (OS-2)	two Dnestr-M/Dnepr	1972-1976
Balkhash, Kazakhstan (OS-2)	Daryal-U	non-operational
Sevastopol, Ukraine (RO-4)	Dnepr	1979 [1]
Mukachevo, Ukraine (RO-5)	Dnepr	1979 [1]
Mukachevo, Ukraine (RO-5)	Daryal-UM	non-operational
Pechora (RO-30)	Daryal	1984
Gabala, Azerbaijan (RO-7)	Daryal	1985
Baranovichi, Belarus	Volga	2002
Lekhtusi	Voronezh-M	2006
Armavir	Voronezh-DM	2009-2010

France and Germany also use national space surveillance capabilities to monitor debris. France's Air Force operates the Grande Réseau Adapté à la Veille Spatiale (GRAVES) space surveillance system, which has been fully operational since 2005. The system is capable of monitoring approximately 2,000 space objects, including orbital debris, in LEO up to 1,000 km, and follows more than a quarter of all satellites, particularly those that France considers threatening and those for which the U.S. does not publish orbital information.[51] France has cited the necessity of developing this system to decrease reliance on U.S. surveillance information and to ensure the availability of data in the event of a data distribution blackout.[52]

The German Defense Research Organization operates the FGAN Tracking and Imaging Radar. The antenna, with a diameter of 34 m, carries out observations in the L- and Ku-bands and can see objects as small as 2 cm at altitudes of 1,000 km.[53] In 2009, Germany inaugurated the German Space Situational Awareness Center (GSSAC) in Uedem, with a mission to coordinate efforts to protect German satellites from on-orbit collisions.[54] Included are the five satellites in the SAR-Lupe radar imaging constellation. German officials indicated that the GSSAC would rely heavily on U.S. SSA data until the new European program could get under way, but that data from the GSSAC would be made available to international bodies.[55]

The ESA maintains information in its own Database and Information System Characterising Objects in Space (DISCOS), which also takes inputs from the U.S. public catalog, Germany's Tracking and Imaging Radar (TIRA) system at the Research Establishment for Applied Science near Bonn, and ESA's Space Debris Telescope in Tenerife, Spain. The TIRA system — which can detect debris and determine orbit information for objects as small as 2 cm at 1,000 km — has a 34-meter dish antenna operating in L-band for debris detection and tracking.[56] DISCOS contains information on launch details, orbit histories, physical properties, and mission descriptions for about 33,500 objects tracked since Sputnik-1, including approximately 7.4 million records in total.[57] The Space Debris Telescope, a 1-m Zeiss optical telescope, focuses on observations in GEO and can detect objects as small as approximately 15 cm.[58] According to ESA, during GEO observation campaigns with the Space Debris Telescope, approximately 75 per cent of detections are objects not contained in the U.S. space surveillance catalog.[59] Other optical sensors in Europe, including three Passive Imaging Metric Sensor Telescopes operated by the U.K. Ministry of Defence, the Zimmerwald 1-m telescope at the Astronomical Institute of the University of Berne in Switzerland, and the French SPOC system and ROSACE telescope, contribute to debris surveillance in GEO.[60] In 2010, ESA announced plans for a satellite tracking campaign using existing European capabilities as the basis for a European SSA system, as described below.

Table 2.2: Space surveillance capabilities[61]

Country	Optical Sensors	Radar Sensors	Orbital Sensors	Global Coverage	Centralized Tasking	Catalog	Public Data
Amateur observers	■			□	□	□	■
Bolivia*	■						
Canada	■		[□]				
China	■	■					
European Union	■	■			[□]	[□]	
France	■	■					
Georgia*	■						
Germany		■					
Great Britain	■	■					
Japan	■	■					
India	■						
Norway		■					
Russia	■	■			■	□	
South Africa	■						
Spain*	■						
Switzerland	■						
Tajikistan*	■						
Ukraine	■						
United States	■	■	[□]	□	■	■	□
Uzbekistan*	■						

■ = Full capability
□ = Some capability
[□] = Under development
* Part of the International Scientific Optical Network (ISON)

Space surveillance is an area of growth for China. Since joining the IADC in 1995, China has maintained its own catalog of space objects, using data from the SSN to perform avoidance maneuver calculations and debris modeling.[62] Prior to the launch of the Shenzhou V in 2003, as part of the country's manned spaceflight program, it was revealed that the spacecraft had a debris "alarm system" to warn of potential collisions.[63] In 2005, the Chinese Academy of Sciences established a Space Object and Debris Monitoring and Research Center at Purple Mountain Observatory, which employs researchers to develop a debris warning system for China's space assets.[64] To support its growing space program, China has established a tracking, telemetry, and command (TT&C) system consisting of six ground stations in China and one each in Namibia and Pakistan, as well as a fleet of four Yuan Wang satellite-tracking ships.[65] These assets provide the foundation for space surveillance, but are believed to have limited capacity to track uncooperative space objects. China is believed to have phased array radars that can track space objects, but little is known about them or their capabilities.

Since 2004, Japan has operated a radar station in Okayama prefecture dedicated to the observation of space debris. The Kamisaibara Spaceguard Center radar can detect objects as small as one meter to a distance of 600 km, and track up to 10 objects at once.[66] Two optical telescopes at the Bisei Astronomical Observatory — a 0.5-m tracking telescope and a 1.01-m reflecting telescope capable of viewing objects as small as 30 cm[67] — are dedicated to space debris surveillance in GEO.

The Canadian military's Sapphire satellite, which will be the largest part of the Canadian Space Surveillance System, is also intended to contribute space-based surveillance data to the U.S. SSN. Initially scheduled to be launched in 2011 by Indian Polar Satellite Launch Vehicle #20,[68] following delays in India's launch manifest[69] Sapphire is now tentatively scheduled to launch in the second quarter of 2012. Once Sapphire is launched, the system is expected to provide SSA information on objects located 4,000-40,000 km from Earth.[70]

2010 Development

Europe continues push to develop its own SSA capabilities

In March, the European Conference on Space and Security in Madrid, Spain, focused on SSA as a top priority of European space activities, along with the Global Monitoring for Environment and Security (GMES) program.[71] Both are seen as key to ensuring the availability of key services provided by space assets, which are vital to Europe's economy and security.

In July, the European Space Agency contracted a Spanish company, IndraEspacio S.A., to design a phased array radar system for the future European SSA system.[72] The $6.4-million contract was awarded as part of ESA's three-year SSA Preparatory Programme, and includes design, development, and installation of a small-scale demonstrator version of the final radar and surveying of a suitable site for the final radar in an ESA Member State. IndraEspacio will also be responsible for developing the final radar's transmitter, while the Fraunhofer Institute for High Frequency Physics and Radar Techniques in Wachtberg, Germany, develops the radar receiver.[73]

In December, ESA announced plans for a satellite tracking campaign using existing European capabilities that will form the basis of the early SSA system.[74] The tests were to run through February 2011 and involve facilities in the U.K., Sweden, Cyprus, Switzerland, and Spain. This activity will contribute to the preparation of the proposal for a continuation of European SSA activity. A decision on the next phase is expected at the 2012 ESA Council at the ministerial level.

2010 Development

Commercial satellite operators continue efforts to share data with each other to improve safety

In July, the Space Data Association (SDA) announced initial operations of its Space Data Center. The SDA is a non-profit association of satellite operators created to facilitate the controlled, reliable, and efficient sharing of SSA data to improve the safety of satellite operations. The SDC combines information on the location and operation of participants' satellites with other sources of SSA data and provides safety-related services to participants. The initial operating capability announced in July included automated conjunction assessment for 126 satellites in GEO, and provided participants with web-based access to this information.[76] Full capability for the Space Data Center was expected in the first quarter of 2011, and is to include radio frequency interference mitigation, automated warnings of possible collisions, and avoidance maneuver planning assistance for participating satellite operators in all orbital regimes.[77]

2010 Development

Hobbyist satellite observers continue to demonstrate their capabilities

In late May, it was announced that hobbyist satellite observers had successfully located the U.S. Air Force X-37B spacecraft.[78] Launched on 23 April, the X-37B is an unmanned, reusable space plane intended to demonstrate reusable space technologies and automated reentry and landing. Although the launch itself was unclassified, the U.S. Air Force did not publish the X-37B's orbital location in its public Space Track online catalog, and declined to disclose what it would be doing on orbit or where.[79] Hobbyist observers in Canada, South Africa, and elsewhere around the world coordinated their activities to find and confirm the location of the X-37B in 401 km x 422 km orbit at 40 degrees inclination.[80]

On 24 August, the hobbyist satellite observers reported that the X-37B had conducted a set of two maneuvers starting on 9 August, and that the space plane was in a new orbit of 420 km x 445 km by 19 August.[81] The change in orbit meant that the X-37B now covered the same location on the Earth's surface every six days instead of every four days, possibly corresponding to a surveillance mission.[82] In late August, a new application for the Apple iPhone and Android mobile phones predicted when the X-37B would be over a ground observer.[83]

On 30 August, analyst Brian Weeden published an article that detailed a series of maneuvers by a Chinese satellite to rendezvous with another Chinese satellite in LEO.[84] The maneuvers were initially detected by a Russian hobbyist observer, who was quoted in the Russian media.[85] Mr. Weeden used orbital data from the U.S. military's public Space Track catalog to determine that the Chinese SJ-12 satellite had conducted a series of maneuvers between 12 June and 16 August to rendezvous with the Chinese SJ-06F satellite, and that the two satellites may have bumped.

On 11 November, Dr. Wang Ting, a postdoctoral student at Cornell University, released the "What's Up" Google Earth layer.[86] The program combines information from the Union of Concerned Scientists' Satellite Database and the U.S. military's public Space Track satellite catalog for display in Google Earth. With the layer installed, individual space objects, constellations, and the entire catalog can be visualized in Google Earth. Historical orbital information, including maneuvers, can also be seen for individual satellites.

Space Security Impact

The European SSA preparatory program and increased data sharing among commercial operators are important contributions to space security. The increase in global SSA capabilities allows for multiple sources of data, improving quality, coverage, and validity. The increase in global capabilities also allows the use of SSA data to monitor activities in space, to increase transparency and confidence among space actors, and, eventually, to serve as a potential verification mechanism for future agreements.

Trend 2.3: International SSA data sharing and cooperation efforts between space actors continue to increase

There has been an increased recognition in recent years that the effectiveness of SSA 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. Following the collision, Lt. Gen. Larry James, then commander of Joint Function Component Command for Space (JFCC Space), said that "as events like the February 2009 collision between the Iridium and Cosmos satellites show, space situational awareness, and the sharing of that information with owners and operators in a position to take action is crucial."[87]

In response to the collision, the U.S. military announced that it would add personnel and resources to enable it to screen up to 800 maneuverable, active satellites for potential collisions, with the eventual goal of screening active payloads on orbit.[88] As part of this development, it would expand the number of outside partners and 'push' them information about potential collisions. The U.S. military also announced that it was transferring oversight of its CFE program from Air Force Space Command to U.S. Strategic Command, changing its name to SSA Sharing Program. The transition was complete on 22 December 2009.[89] Any entity that becomes a partner in the SSA Sharing Program must enter an agreement under which it may not transfer any data or technical information obtained through the program to a third party without explicit consent by the U.S. government.[90] Requests for data sharing with third parties are assessed on a case-by-case basis, using an Orbital Data Request.[91]

The conjunction assessment criteria utilized in the framework of the SSA Sharing Program is as follows:[92]

- For an active satellite above LEO, JFCC Space will notify the owner/operators if it is predicted that their satellite will approach within 5 km of another orbiting object in the next 72 hours.
- For an active satellite in LEO, JFCC Space will notify the owner operator if it is predicted that their satellite will approach within 1 km (overall miss distance) of another orbiting object AND within 200 m in the radial direction in the next 72 hours.

In addition to the U.S. SSA Sharing Program, other efforts are under way that exemplify the growing importance afforded to effective data-sharing mechanisms among space actors. Europe is making progress on various aspects of both national and European SSA. In January, the Joint Air Power Competence Center, a NATO think-tank, issued a Space Operations Assessment report that emphasized the need for NATO to better integrate space into military operations and called for SSA data sharing.[93] In December, it was reported that

France had begun work on an improved version of its GRAVES ground-based radar, which was originally conceived of as only a technology demonstrator.[94] Germany was also planning to set up an operational SSA center near its national airspace control facility in 2010.[95]

According to French Air Force Brigadier General Yves Arnaud, at a French-U.S. Space Cooperation Forum in November 2009, SSA and data sharing were priority agenda items. At the same event, Air Commodore David Steele from the Royal Australian Air Force stated that the U.S. and Australia were exploring an SSA data-sharing partnership, which might include basing future U.S. sensors in Australia, to provide much needed Southern Hemisphere coverage.

In 2009, the U.S. and Russia announced a renewed effort to establish a Joint Data Exchange Center to share information on space and missile launches,[96] and the establishment of a Pre-Launch Notification System (PLNS). After the original agreements for the center, designed to promote confidence between the U.S. and Russia over space and missile launches, were signed in 2000, the effort had stalled.

In its report following the 2010 plenary session, UN COPUOS noted that no mechanism existed for sharing information among all states and it was "essential for all states to actively contribute to the work under this item."[97]

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 created the Space Data Association (SDA).[98] The not-for-profit entity was established in the Isle of Man to serve as a central hub for sharing data among participants. The SDA issued a Request for Proposal to solicit bids on a contract to provide the infrastructure and data-sharing services. Several other commercial satellite operators have indicated support for the SDA and may join at a later date.[99] The SDA will mainly deal with sharing data on the positions of participation members' satellites and information to help prevent electromagnetic interference. In 2010, the SDA announced initial operations of the Space Data Center, as described below.

2010 Development

Satellite operators work together to mitigate physical and RF interference from Galaxy 15

Fifteen satellites conducted avoidance maneuvers to minimize the chance of physical or electromagnetic interference with Galaxy 15 during the almost nine months that the malfunctioning satellite was adrift in the active GEO belt.[100] Because Galaxy 15 was a large object, it could be tracked accurately and satellite operators were able to predict its drift path and keep other active satellites out of the way (see Trend 1.1).

In some cases, these maneuvers were more precise than anything else attempted before. The AMC-11–Galaxy 15 mitigation plan (see Trend 1.3) called for AMC-11 to be maneuvered to within 0.2 degrees of the uncontrolled Galaxy 15, 10 times closer than the spacing normally kept between satellites in GEO to prevent electromagnetic interference.[101] In early July, Galaxy 15 passed by a cluster of four Intelsat satellites, again without causing physical or electromagnetic interference.[102] The key to success in all cases was close coordination between Intelsat and the other satellite operators and sharing of the most accurate SSA data possible on the objects' positions.

2010 Development

U.S. government continues to expand its SSA Sharing Program

In July, USSTRATCOM implemented a new Conjunction Support Message (CSM) for participants in its SSA Sharing Program. Entities that sign a data-sharing agreement with USSTRATCOM will receive the new CSM for any close approach that threatens one of their satellites that is being monitored by the JSpOC.[103] The CSM contains information on both objects involved in the conjunction, including some covariance information that was not disclosed previously. This additional information allows satellite operators to more precisely calculate the probability of a collision and plan a potential avoidance maneuver.[104]

By the end of 2010, USSTRATCOM had signed data-sharing agreements with 19 commercial satellite operators.[105] These agreements allow for two-way data flow between USSTRATCOM and partners, including more detailed information on potential collisions contained in the CSMs. In a keynote speech at the November USSTRATCOM Strategic Space Symposium in Omaha, Nebraska, Lieutenant General Larry James said that the JSpOC screening service was assisting with an average of three satellite maneuvers per week. James also stated that throughout 2010, more than 64 satellites were maneuvered to avoid potential on-orbit collisions as a result of information and services provided by USSTRATCOM.

Space Security Impacts

As no single space actor can achieve true SSA on its own, increases in data sharing among governments and satellite operators greatly enhance space security. Although more public and universal data sharing would be welcome, the limited sharing done by the U.S. government after the 2009 Iridium-Cosmos satellite collision is a step in the right direction. A positive example of the collective benefits of sharing SSA data is the widely publicized recovery of the Galaxy 15 satellite following a malfunction in 2010.

CHAPTER THREE

Laws, Policies, and Doctrines

This chapter assesses trends and developments related to national and international space laws, multilateral institutions, national space policies, and military space doctrines.

International space law has gradually expanded to include, inter alia, the 1967 Outer Space Treaty (OST), the 1968 Astronaut Rescue Agreement, the 1972 Liability Convention, the 1975 Registration Convention, and the 1979 Moon Agreement. These treaties establish the fundamental right of all states to access space, as well as state responsibility to use space for peaceful purposes. They also prohibit national appropriation of space and restrict certain military space activities, such as placing nuclear weapons or weapons of mass destruction in outer space.

This chapter also assesses trends and developments related to the multilateral institutions that address matters related to space activities, such as the United Nations Committee on the peaceful Uses of Outer Space (COPUOS), the Conference on Disarmament (CD), and the UN General Assembly (UNGA). While COPUOS tends to focus on commercial and civil space issues, the CD primarily addresses military space challenges through its agenda item on the Prevention of an Arms Race in Outer Space (PAROS). The ITU addresses matters related to the allocation of space resources such as orbital slots and radiofrequencies.

The development of national space policies has been conducive to greater transparency and predictability of space activities insofar as these policies delineate the principles and objectives of space actors with respect to the access to and use of space. They provide the context within which national civil, commercial, and military space actors operate. It is important to note that, despite the ongoing development of military space applications, for the most part, states continue to emphasize international cooperation and the peaceful uses of space in their national space policies.

This chapter also examines the relationship between national space policies and military space programs. Reflecting the fact that space is increasingly being used to support military operations, some space actors also have designated national military space doctrines that support the development of military space applications such as navigation, communications, intelligence, surveillance, reconnaissance, and meteorological capabilities.

Space Security Impact

The existence of international policy instruments to regulate space activities has a direct impact on space security since they establish key parameters for space activities such as the right of all countries to access space, prohibitions against the national appropriation of space and the placement of certain weapons in space, and the obligation to ensure that space is used for peaceful purposes. International space law can improve space security by restricting activities that infringe upon the ability of actors to access and use space safely and sustainably, or that result in space-based threats to national assets in space or on Earth. When followed, space policy helps promote the predictability and transparency of space activities among different stakeholders and helps to overcome problems of collective security. Current national legislation and international space law also play an important role in establishing the building blocks for the development of a more robust, up-to-date regulatory regime on space activities that fills the voids and addresses the shortcomings of the existing space security normative architecture.

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. Member states can peacefully discuss, for instance, solutions to potential disagreements over the allocation of scarce space resources, and develop new international law that reflects the evolving challenges of an ever more complex and congested domain. Ongoing discussion and negotiation within these forums also help to enhance transparency and confidence among spacefaring nations. 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.

The relationship between policy and space security varies, depending on whether or not a specific policy or doctrine promotes the secure and sustainable use of space by all space actors. The policies of some spacefaring nations emphasize the need for international cooperation in space, which enhances transparency and builds confidence among different stakeholders. Such international cooperation frequently supports the diffusion of space capabilities, not only increasing the number of space actors with space assets, but also creating a greater interest in maintaining the peaceful and equitable use of space.

On the other hand, national space policies and military doctrines may have adverse effects on space security if they promote policies and practices that constrain the secure use of space by other actors or advocate space-based weapons. States that remain ambiguous on these points could also stimulate the development of policies, doctrines, and capabilities to counterbalance what a peer may, with a lack of evidence to the contrary, perceive as a threat. Furthermore, military doctrines that rely heavily on space can push other states to develop protection and negation capabilities to protect valuable space systems. At the same time, making these doctrines and policies public also promotes transparency and can help to make the behavior of spacefaring states more predictable.

Trend 3.1: Gradual development of normative framework for outer space activities

The international legal framework that governs the use of outer space includes UN treaties, customary international law, bilateral treaties, and other space-related international agreements, which have gradually become more extensive since 1967. What began as a focus on multilateral treaties, however, has transitioned to a focus on what some describe as 'soft law', which refers to a range of non-binding governance tools including principles, resolutions, confidence-building measures, and policy and technical guidelines.

The UN Charter establishes the fundamental objective of peaceful relations among states, including their interactions in space. 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.[1]

Outer Space Treaty (OST)

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 space security normative regime.

Lack of definitional clarity in the OST presents several challenges for space security. The OST does not specify where airspace ends and outer space begins. This issue has been on the agenda of both the Legal and the Scientific and Technical Subcommittees of COPUOS since 1959 and remains unresolved.[2] The dominant view is that space begins at 100 km above the Earth, but some states continue to disclaim the need for the establishment of such a boundary.[3]

The implications of the OST's notion 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.[4] However, space assets have been developed extensively to support terrestrial military operations, and the position maintained by the U.S., that "peaceful" in the context of the OST means "non-aggressive," has generally been supported by state practice.[5] Article IV of the OST has been cited by some to advance the argument that all military activities in outer space are permissible, unless specifically prohibited by another treaty or customary international law.[6] Others contest this interpretation.[7] While space actors have stopped short of actually deploying weapons in space or attacking the space assets of another nation from Earth, anti-satellite (ASAT) weapons have been tested by some states against their own satellites — most recently by China in 2007[8] and the U.S. in 2008.[9]

There is also no consensus on a definition for "space weapon." Various definitions have been advanced around the nature and scientific principle of weapons, place of deployment, and the location of targets. As well, there have been debates about whether weapons used against space assets but not placed in space, such as ground-based ASATs and anti-ballistic missile weapons, constitute space weapons.[10] For the full text of the Outer Space Treaty, see Annex 3.

Liability Convention

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."[11] 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. The Convention has been used in only one settlement, when Canada received $3-million in compensation from the Soviet Union for cleanup following the 1978 crash of Cosmos-954, which scattered radioactive debris over a remote part of the country.[12] 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 when it is a small piece that has not been cataloged.

The Liability Convention stipulates that states parties are responsible for the activities of their national and nongovernmental entities. Under the provisions of the OST and the Liability Convention, the "launching state" is the state that launches or procures the launching of an object into outer space and the state from whose territory or facility an object is launched. However, the commercialization of space-related services is challenging the applicability of the Liability Convention. For example, the growing number of private commercial actors undertaking space launches is blurring the definition of the term "launching state," since a satellite operator may be officially registered in one state, have operations in another, and launch spacecraft from the territory of a third country.

Registration Convention

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"[13]:

- 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, including:
    1. Nodal period (the time between two successive northbound crossings of the equator, usually in minutes);
    2. Inclination of the orbit (polar orbit is 90 degrees and equatorial orbit is 0 degrees);
    3. Apogee (highest altitude above the Earth's surface [in km]);
    4. Perigee (lowest altitude above the Earth's surface [in km]);
- General function of the space object.

This data is maintained in a public "Convention Register," the benefits of which include effective management of space traffic, enforcement of safety standards, and attribution of liability for damage. Furthermore, it acts as a space security confidence-building measure by promoting transparency. As of 2011, 55 states have ratified and four have signed the Registration Convention.[14] The UN also maintains a separate register with information provided by states not party to the Convention (the Resolution Register), based on UNGA Resolution 1721B of 20 December 1961.[15]

The lack of timelines for UN registration remains a shortcoming of the Registration Convention. While information is to be provided "as soon as practicable," it might not be provided for weeks or months, if at all. Moreover, the Convention does not require that a launching state provide appropriate identification markings for its spacecraft and its component parts. Various proposals have been advanced at the CD to resolve the shortcomings of the Registration Convention. In 2007, the UNGA adopted a resolution to improve state practice in registering space objects and adhering to the Registration Convention that included wider ratification of the Convention by states and international organizations, efforts to attain uniformity of information submitted to the UN registry, and efforts to address gaps caused by the ambiguity of the term "launching state" based on recommendations by the Legal Subcommittee of COPUOS.[16]

Moon Agreement

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.[17] However, it is not widely ratified due to contentious issues surrounding lunar exploration.[18] States continue to object to its provisions for an international regime to govern the exploitation of the Moon's natural resources and differences exist over the interpretation of the Moon's natural resources as the "common heritage of mankind" and the right to inspect all space vehicles, equipment, facilities, stations, and installations belonging to any other party.

Astronaut Rescue Agreement

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 are to be returned promptly to the responsible launching authority, should they land within the jurisdiction of another state party.

Table 3.1: Status of major space treaties as of June 2011[19]

Treaty	Date	Total R*	Total S**
Outer Space Treaty	1967	100	28
Rescue Agreement	1968	92	24
Liability Convention	1972	90	23
Registration Convention	1975	55	4
Moon Agreement	1979	13	4

* R: Ratification, Acceptance, Approval, Accession, or Succession
** S: Signature

UN space principles

In addition to treaties, various UN resolutions, known as UN 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 reflecting the conviction of the international community on these issues.

Table 3.2: 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.
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.
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.

PAROS resolution

Since 1981 the UNGA has passed an annual resolution asking all states to refrain from actions contrary to the peaceful use of outer space and calling for negotiations in the CD on a multilateral agreement to support PAROS.[20] PAROS resolutions have had overwhelming support in the UNGA, demonstrating a widespread desire of the international community to prohibit the deployment and use of weapons in space.[21] Starting in 1995, however, the U.S. and Israel consistently abstained from voting on the resolution, and they cast the first negative votes in 2005.[22] Israel has since reverted to abstaining.

Multilateral and bilateral arms control and outer space agreements

Since space issues have long been a topic of concern, there are a range of other legal agreements that have attempted to provide predictability and transparency in the peacetime deployment or testing of weapons that either travel through space or can be used in space. For example, one of the key provisions of some arms control treaties, beginning with the 1972 Strategic Arms Limitation Treaty I, has been recognition of the legitimacy of space-based reconnaissance, or National Technical Means (NTMs), as a mechanism of treaty verification, and agreement not to interfere with it.[23] A claim can be made, therefore, that a norm of noninterference with NTMs, early warning satellites, and certain military communications satellites has been accepted as conforming to the OST's spirit of populating space with systems "in the interest of maintaining peace and international security."[24] A summary of the key space provisions of these agreements is provided in Table 3.3.

Table 3.3: Multilateral and bilateral arms control and outer space agreements

Agreement	Space Security Provisions
Limited Test Ban Treaty (1963)	Prohibition of nuclear weapons tests or any other nuclear explosion in outer space[25]
Strategic Arms Limitation Treaty I (1972)*	Acceptance of, and prohibition of interference with, national technical means of verification Freezes the number of intercontinental ballistic missile launchers[26]
Hotline Modernization Agreement (1973)*	Sets up direct satellite communication between the U.S./USSR[27]
Anti-Ballistic Missile Treaty (1972)*†	Prohibition of space-based anti-ballistic missile systems and interference with national technical means of verification[28]
Environmental Modification Convention (1977)	Bans using as weapons modification techniques that have widespread, long-lasting, or severe effects on space[29]
Strategic Arms Limitation Treaty II (1979)*	Acceptance of, and prohibition of interference with, national technical means of verification Prohibits fractional orbital bombardment systems (FOBS)[30]
Launch Notification Agreement (1988)*	Notification and sharing of parameters in advance of any launch of a strategic ballistic missile[31]
Conventional Armed Forces in Europe Treaty (1990)	Acceptance of, and prohibition of interference with, national and multinational technical means of verification[32]
Strategic Arms Reduction Treaty I (1991)*	Acceptance of, and prohibition of interference with, national technical means of verification[33]
Intermediate-Range Nuclear Forces Treaty (1997)	Acceptance of, and prohibition of interference with, national technical means of verification[34]
Memorandum of Understanding establishing a Joint Data Exchange Center (2000)*	Exchange of information obtained from respective early warning systems[35]

Memorandum of Understanding establishing a Pre- and Post-Missile Launch Notification System (2000)*	Exchange of information on missile launches
Strategic Arms Reduction Treaty – New START (2011)*	Acceptance of and prohibition of interference with, national technical means of verification[36]

* Indicates a bilateral treaty between U.S. and USSR/Russia
† U.S. withdrew according to the terms of the treaty in 2002

Other laws and regimes

among participating states in the Missile Technology Control Regime (MTCR) adds another layer to the international regulatory framework for space-related activities.[37] The MTCR is a voluntary partnership among 34 states to apply common export control policy on an agreed list of technologies, such as launch vehicles that could also be used for missile deployment.[38] Specifically, the MTCR seeks to prevent the proliferation of missile and unmanned aerial vehicle technology that would be used to carry payloads weighing 500 kg for 300 km or more, as well as systems that could be used to deliver weapons of mass destruction.[39]

Another related effort is the International Code of Conduct against Ballistic Missile Proliferation (Hague Code of Conduct), which calls for greater restraint in developing, testing, using, and proliferating ballistic missiles.[40] To increase transparency and reduce mistrust among subscribing states, it introduces confidence-building measures such as the obligation to announce missile launches in advance.

Treaties that have an impact on space during times of armed conflict include the body of international humanitarian law composed primarily of the Hague and Geneva Conventions — also known as the Laws of Armed Conflict. Through the concepts of proportionality and distinction, they restrict the application of military force to legitimate military targets and establish that the harm to civilian populations and objects resulting from specific weapons and means of warfare should not be greater than that required to achieve legitimate military objectives.[41] However, it is not clear how these laws apply to spacecraft and other space objects.

The emergence of space commerce and the potential for space tourism has led at least 20 states to develop national laws to regulate these space activities in accordance with the OST, which establishes state responsibility for the activities of national and nongovernmental entities.[42] While the proliferation of national legislation may increase compliance with international obligations and reinforce responsible use of space, in practice it has occasionally led to divergent interpretations of treaties.[43]

The Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III), held in 1999, adopted the Vienna Declaration on Space and Human Development. It established an action plan calling for the use of space applications for environmental protection, resource management, human security, and development and welfare. The Vienna Declaration also called for increasing space access for developing countries and the promotion of international space cooperation.[44] A concrete outcome of UNISPACE III is the United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER), adopted by the UNGA under Resolution 61/110 on 14 December 2006. It is the first program aimed specifically at ensuring access to and use of space-based information for all countries and organizations during all phases of a disaster.

Space Security Proposals

A number of proposals to address gaps in the existing space security regime have been put forth in the past three decades. At the 1981 UN General Assembly, the USSR first proposed a "Draft Treaty on the Prohibition of the Stationing of Weapons of Any Kind in Outer Space" to ban the orbiting of objects carrying weapons of any kind and the installation of such weapons on celestial bodies or in outer space and to prevent actions to destroy, damage, or disturb the normal functioning of unarmed space objects of other states. A revised version of the draft treaty was introduced to the CD in 1983 with a broader mandate that included a ban on anti-satellite testing or deployment as well as verification measures.[45]

During the 1980s, several states tabled working papers in the CD proposing arms control frameworks for outer space, including the 1985 Chinese proposal to ban all military uses of space. India, Pakistan, and Sri Lanka made proposals to restrict the testing and deployment of anti-satellite weapons. Canada, France, and Germany explored definitional issues and verification measures.[46] Since the late 1990s, Canada, China, and Russia have contributed several working papers on options to prohibit space weapons. In 2002, in conjunction with Vietnam, Indonesia, Belarus, Zimbabwe, and Syria, Russia and China submitted to the CD a joint working paper called *Possible Elements for a Future International Legal Agreement on the Prevention of Deployment of Weapons in Outer Space*.[47] The paper proposed that states parties to such an agreement undertake not to place in orbit any object carrying any kind of weapon and not to resort to the threat or use of force against outer space objects.

A treaty proposal containing elements from this paper was jointly introduced by Russia and China to the CD in 2008 as the Draft Treaty on the Prevention of the Placement of Weapons in Outer Space and of the Threat or Use of Force against Outer Space Objects (PPWT). Still under consideration, the PPWT has failed to galvanize sufficient support and has, notably, encountered resistance from the U.S. Since renewed use of weapons against space objects by China in 2007 and the U.S. in 2008, efforts to clarify or strengthen international law on the use of weapons or force in outer space have been informed by a greater sense of urgency.

In 2005, the UNGA first adopted what has become an annual resolution sponsored by Russia, entitled "Transparency and confidence-building in outer space activities," which invites states to inform the UN Secretary-General of transparency and confidence-building measures, and reaffirms that "the prevention of an arms race in outer space would avert a grave danger to international peace and security."[48] The U.S. consistently registers the only vote against the resolution and Israel the only abstention, because the text links such measures with negotiation of a treaty on arms control.

Nongovernmental organizations have also contributed to this dialogue on gaps in the international legal framework. For example, the Union of Concerned Scientists drafted a model treaty banning ASATs (1983).[49] Since 2002, the UN Institute for Disarmament Research (UNIDIR) has periodically convened expert meetings to examine space security issues and options to address them.[50] The most recent such meeting, "Space Security 2011: Building on the past, stepping toward the future," was held in Geneva on 4-5 April 2011.

In 2003 and 2007, the Henry L. Stimson Center proposed a code of conduct on dangerous military practices in space.[51] The concept of a Code of Conduct or rules of the road for space operations has since been supported by multiple stakeholders, including government and military officials, commercial representatives, and nongovernmental organizations.[52] The European Union's Code of Conduct for Outer Space Activities, which mainly addresses issues related to harmful interference with space objects and skirts controversial issues related to the placement of weapons in outer space, has undergone international consultations and is expected to be open for signatures in 2011 or 2012.

2010 Development

Shift in U.S. National Space Policy toward increased international cooperation and responsible use of space, but domestic objectives face implementation problems

Following Presidential Study Directive-3 (PSD-3) issued by President Obama in May 2009, calling for a broad review of President George Bush's October 2006 space policy,[53] the new National Space Policy of the United States was released on 28 June 2010. The Bush-era policy was criticized for its unilateral and U.S.-centric tone[54] and, as anticipated,[55] the Obama administration changed the focus of U.S. space policy to increased international cooperation, when it is in the interests of the U.S. Although the policy review did not detail the specific steps that the government would take to achieve such cooperation,[56] the 2010 Space Policy outlined potential areas for cooperation.[57] The administration's current focus for arms control is on pursuing bilateral and multilateral transparency and confidence-building measures (TCBMs) to encourage responsible actions in space, as well as shared space situational awareness, improved information sharing for collision avoidance, and orbital debris mitigation.[58]

In an apparent departure from the 2006 Space Policy, which stated that "the United States will oppose the development of new legal regimes or restrictions that seek to prohibit or limit U.S. access to or use of space,"[59] the 2010 Space Policy states that the U.S. will pursue TCBMs and "consider proposals and concepts for arms control measures if they are equitable, effectively verifiable, and enhance the national security of the United States and its allies."[60] Because it emphasizes the desire to enhance the country's ability to identify and characterize threats and, if necessary, deter and defeat efforts to interfere with or attack U.S. or allied space systems, some commentators are not certain that U.S. space policy has substantially changed regarding warfare in space.[61] On the other hand, the 2010 policy states that the U.S. considers the security and sustainability of space vital to its interests, that "space systems of ALL nations…have the rights of passage through, and conduct of operations in space without interference," and that the U.S. will help "assure the use of space for all responsible parties."[62]

In October 2010, NASA Administrator Charles Bolden undertook a "very comprehensive visit"[63] of facilities linked to China's manned space flight program and held talks with senior officials. He concluded that the visit "had helped the two sides 'reach a common understanding of the importance of transparency, reciprocity and mutual benefit as the underlying principles of any future interaction' in the area of space flight."[64] A less optimistic assessment was made by the Union of Concerned Scientists (UCS), which found the administration's attempts to engage China unproductive. According to Gregory Kulacki, China Program manager at UCS, "Obama administration officials responsible for engaging China on space issues have privately confessed frustration and disappointment with China's response to their efforts, which they perceive as a lack of interest."[65]

2010 Development

Despite initial delay, the U.S. Space Posture Review concludes with the release of the National Space Security Strategy

The Space Posture Review (SPR) was mandated by the FY09 National Defense Authorization Act to analyze the relationship between military and national security space strategy and assess space acquisition programs, future space systems, and technology development. The review, initially slated to be unveiled on 1 February 2010, was delayed;[66] instead an interim report was sent to Congress in March 2010.[67] The report highlighted, among other issues, the threat posed to the access to, and use of, space because the domain is increasingly congested and contested. On 14 April, the U.S. Deputy Defense Secretary William Lynn stated at the U.S Strategic Command National Space Symposium that the Pentagon's new national space security strategy, initially set to be released in the fall,[68] would propose international rules of the road for orbital space, to provide predictability in the changing outer space environment.[69] The National Security Space Strategy was released in January 2011, which "culminates the Space Posture Review."[70]

2010 Development

The United Nations General Assembly establishes Group of Governmental Experts (GGE) to study transparency and confidence building measures in space

At the UN Institute for Disarmament Research (UNIDIR) Space Security Conference 2010 – From Foundations to Negotiations held 29-30 March in Geneva, Victor Vasiliev, deputy permanent representative at the Permanent Mission of the Russian Federation to the United Nations in Geneva, proposed the establishment of a UN Group of Governmental Experts with an "appropriate mandate" to conduct a more in-depth study of issues relating to TCBMs and prepare recommendations for further work in this area, as a step toward an outer space free of weapons.[71]

Along with more than 60 cosponsoring states, Russia introduced a draft resolution at the 65th session of the UN General Assembly that noted that the work of previous GGEs on TCBMs (which worked from 1991-93) was not orientated toward the introduction of TCBMs into international practice, and that a future group should begin work in 2012 to prepare practical recommendations regarding TCBM implementation[72] and to report its recommendations at the 68th Session of the UN General Assembly.[73]

The resolution was supported at the First Committee nearly by consensus, with the U.S. abstaining.[74] However, the U.S. made clear its position that, while it supports the core idea of establishing a GGE and advancing further work on TCBMs, it "could not support attempts to establish artificial linkages between pragmatic and voluntary transparency and confidence-building measures and fundamentally flawed proposals for arms control,"[75] such as the PPWT.

On 8 December 2010, the UN General Assembly adopted resolution 65/68, on "Transparency and confidence-building measures in outer space activities" following the report of the First Committee.[76] The resolution, which was adopted by near unanimity -with no votes against, and only the U.S. abstaining- requests the Secretary-General to submit to the Assembly at its sixty-eighth session a report with an annex containing the study of governmental experts."[77]

2010 Development

EU's proposed International Code of Conduct for Outer Space Activities revised and ready for further international consultation

In a move that may help ward off further criticism that the initial consultations for the EU's draft international code of conduct for space activities were not wide or open enough,[78] in 2010 the EU conducted extensive consultations on the draft code with several spacefaring states. On the basis of the views expressed during these consultations, a revised version of the draft Code of Conduct was adopted by the Council of the European Union in October

2010.[79] The new draft is a basis for further consultations with as many countries as possible, active or not yet active on space issues,[80] and it is reported that the EU "might (still) consider refining some provisions in order to get other countries involved."[81] It is anticipated that, at the end of the next phase of the consultation process, the EU will propose a final version of the Code of Conduct that would be open to endorsement by all states on a voluntary basis at an ad hoc conference.

While the U.S. has been working with the EU on the code for the past two years and "is completing an extensive and lengthy review of the European Union's initiative,"[82] as of the December 2010, the State Department and an interagency group had yet to fully determine its implications for U.S. national security and foreign policy interests. Speaking at a forum at the Stimson Center in Washington, Frank Rose, Deputy Assistant Secretary of State for Space and Defense Policy, said that while the U.S. hasn't made a decision on whether to support the document, such a code "is very consistent with the key policies outlined in the president's new space policy and a decision will be made in the near future.[83]

Reservations still exist and this code is only one of the proposals that continue to be discussed in international space security forums. It has been suggested that there is a latent risk of polarization, with proponents of each initiative focusing on the merits of their proposal to the neglect of others.[84]

Space Security Impact

The new U.S. National Space Policy (NSP) signals that the U.S. is more open to dialogue and is committed to the responsible use of space. Because the actions and policies of the dominant space actor have a profound impact on the whole space environment, this development is welcome. However, some of the NSP declarations are vague and open to interpretation. The new policy could lead to real changes in the normative framework for outer space activities. However, the international dimension of the policy may have been overemphasized, if the lack of progress at the Conference on Disarmament (CD) and the First Committee is any evidence. Unlike Russia, China, and the EU, which have put forth specific proposals as the basis for further consultation on a multilateral regulatory regime for space activities, the U.S. has not assumed an active role by submitting a proposal of its own for the consideration of the international community.

Trend 3.2: UN COPUOS remains active as a forum for space governance, while CD deadlock persists

An overview of the relationships among key institutions mandated with addressing issues related to outer space activities is provided in Figure 3.4. Issues of space security are often debated at the First Committee (Disarmament and International Security) of UNGA, the main deliberative organ of the United Nations. While the decisions of the Assembly are not legally binding, they are considered to carry the weight of world opinion. The UNGA has long held that the prevention of an arms race in outer space would make a significant contribution to international peace and security.

The UNGA 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 the GA and Member States. There are currently 69 Member States of COPUOS, which works by consensus. As well, 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. The U.S., in particular, has maintained that COPUOS should exclusively address issues related to peaceful uses of outer space.[85]

The CD 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 plus observers, works by consensus under the chair of a rotating Presidency. The CD 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.[86] 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."[87] From 1985 to 1994, the PAROS committee met, despite wide disparity among the views of key states, and in that time made several recommendations for space-related confidence-building measures.[88]

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, a period during which 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. Similarly, in 2004, several states called for the establishment of a CD expert group to discuss the broader technical questions surrounding space weapons, but there was still no consensus on a program of work. Finally, in May 2009, the CD adopted its first program of work in over a decade, as discussed below. However, this development was short-lived as the CD reverted to a deadlock following objections from Pakistan over FMCT discussions. To date, there is still no consensus on negotiation of a PAROS treaty.

2010 Development

The CD could not agree on a Program of Work, reverting to its pre-2009 deadlock

The CD, which operates through consensus, agreed on a Program of Work in May 2009. Despite initial optimism that this agreement would end the longstanding deadlock, the CD failed to adopt a framework to implement the Program of Work by the end of 2009; this was mainly a result of Pakistani opposition to negotiations on a Fissile Material Cut-off Treaty (FMCT).[89] In 2010, the CD reverted to its pre-2009 position and once again was unable to adopt a program of work for its session. At its first session on 19 January 2010, Pakistan again opposed the proposed agenda, calling for it to cover more issues.[90] By March 2010, a draft program was tabled and debated. Consultations during the second part of the CD produced a draft agenda, which Pakistan again rejected, seeing it as undermining Pakistan's security interests.[91]

According to an inventory complied by the Nuclear Threat Initiative, "the principal problems [of the CD] included difficulties in the current relations between key players, disagreements amongst them on the prioritization of main issues on the CD agenda and attempts of some countries to link progress in one area to parallel progress in other areas,"[92] thus preventing any progress on the issue of the Prevention of an Arms Race in Outer Space (PAROS). While the validity of some of Pakistan's concerns is conceded — many other countries, including Egypt, Indonesia, Iran, North Korea, Sri Lanka, and Syria have joined Pakistan in seeking a more "balanced program of work"[93] — commentators say that the country has in fact backtracked on its commitments to these consensus-based processes, despite its apparent firm stance that consensus should prevail.[94]

Despite continued gridlock over an official program of work, the CD did organize four informal meetings on the PAROS issue in June and July under the coordination of Ambassador Soares of Brazil. Ambassador Soares provided the Conference with a written report on these discussions which conveyed the perspectives of members on the possible negotiation of an international instrument on PAROS.[95] The 2010 session ended in deadlock, with some countries proposing that FMCT negotiations be moved elsewhere or that the CD consensus principle be dropped. As long as states cannot agree on how best to deal with these issues, progress will be stalled, despite proposals to set deadlines for the CD's resumption of work.[96]

2010 Development

Progress in COPUOS as a working group emerges to take on the long-term sustainability of outer space activities

While no notable new initiative emerged from the Legal Subcommittee to the Committee on the Peaceful Uses of Outer Space, on 18 and 19 February 2010, the Scientific and Technical Subcommittee (STSC)) established a Working Group on the Long-term Sustainability of Outer Space Activities and elected Peter Martinez (South Africa) Chair of the Working Group.[97] The Subcommittee agreed that the Working Group should avail itself of the progress made within existing entities, including, but not limited to, commercial entities operating within the space industry, the other working groups of the Subcommittee, the Conference on Disarmament, the International Telecommunication Union, the Inter-Agency Space Debris Coordination Committee, the International Organization for Standardization, the World Meteorological Organization, and the International Space Environment Service and identify areas of concern that were not covered by them.[98]

Figure 3.4: Institutions relevant to international space security

Space Security Impact

Renewed deadlock at the CD heightens recognition that the premier disarmament body in the UN system is not the appropriate forum to determine the issue of PAROS. But it also illustrates the larger problem of a near-universal lack of political will to resolve such an impasse. Despite the difficulties, the acknowledgment by COPUOS of the need to liaise more closely with the CD and ITU on issues related to space safety is welcome.

Trend 3.3: Formalized African cooperation in space increases

Various African states have gradually emerged as dynamic actors in the space sector, with a focus on national and regional socioeconomic development. In 2009, the South African National Space Agency was announced, following the signing of the South African National Space Agency Act by President Kgalema Motlanthe in January.[99] The space agency, which was officially launched on 9 December 2010, will "coordinate the country's major space projects, promote space science research, develop related engineering and technological capacity, and devise and implement a national space program."[100] Specifically, the agency will focus on earth observation, space operations, space science, space engineering, space advancement and public engagement, and human capital development.[101]

The first South African satellite, built by post-graduate students at the University of Stellenbosch, was launched in 1999 aboard a Delta II rocket. On 17 September 2009, a second South African satellite was launched on a Russian Soyuz rocket from the Baikonur Cosmodrome in Kazakhstan.[102] The remote sensing satellite, called SumbandilaSat, will collect images for use by government in agriculture, water management, and urban planning.[103]

The Algerian Space Agency was created on 16 January 2002 and is responsible for the space program. The agency is governed by a board of directors and a scientific advisory council, headed by an executive director appointed by the President of Algeria. On 28 November 2002, the country's first satellite, Alsat-1, was launched by a Russian Cosmos 3 rocket.[104] The $15-million satellite, intended for multispectral image transmission, was designed in partnership with the U.K. Surrey Space Centre.[105] Alsat-2, an Earth observation satellite, was launched on 12 July 2010 by an Indian PSLV rocket from the Sriharikota launch base.[106]

Other African countries are in the process of developing their space sectors. In 1998, Nigeria established the National Space Research and Development Agency, with a focus on space science and technology, remote sensing, satellite meteorology, communications and information technology, and defense and security.[107] In May 2007, Nigeria launched NigComSat-1, its first communications satellite, which had been built in China at a cost of $340-million.[108] However, the government announced a year later that the satellite would be shut down after a power supply malfunction.

Other African countries have taken steps to develop their space sector, even if most haven't developed a full-fledged space agency. Examples include the Royal Center for Remote Sensing (CRTS) in Morocco, the National Mapping and Remote Sensing Center in Tunisia, and the National Authority for Remote Sensing and Space Sciences in Egypt.

Recent cooperation agreements on space activities have allowed emerging spacefaring nations from Africa to reap social and economic benefits from space applications. In 2009, after years of discussion, Nigeria, Algeria, South Africa, and Kenya signed a regional cooperation agreement for an African Resources Management Satellite (ARMS) Constellation.

Following the launch of the South African National Space Agency in 2010, an interagency agreement with the Algerian Space Agency to cooperate in space science and technology was signed. The same year, African nations requested that the African Union commission a feasibility study for the establishment of an African Space Agency and the development of an African Space Policy, in cooperation with the Regional Economic Communities, the UN Economic Commission for Africa, and the ITU, as described below.

2010 Development

African regional cooperation in space on the rise

During the 3rd African Leadership Conference on Space Science and Technology for Sustainable Development held in Algeria on 7-9 December 2009, Nigeria, Algeria, South Africa, and Kenya signed a regional cooperation agreement for an African Resources Management Satellite (ARMS) Constellation.[109] Coming after years of discussions,[110] it signaled increased cooperation between African countries. In a presentation to the Bengaluru Space Expo-2010 on 25 August 2010, the Director General of the Nigerian Space Agency stated that the program was open to other African countries and that Egypt had also shown interest in ARMS.[111]

At the launch of the South African National Space Agency in Pretoria on 9 December 2010, South African Minister Naledi Pandor revealed that the National Space Strategy seeks to promote research; foster international cooperation in space-related activities; and advance scientific, engineering, and technological competencies through human capital development and outreach programs.[112] The cooperation began with the signing of an interagency agreement with the Algerian Space Agency to cooperate in space science and technology, as well as with Memorandums of Understanding with Brazilian and Chinese space centres.[113]

Along with those mentioned above, the core objectives of the strategy are:

1. To capture a share in the global market for small to medium-sized space systems;
2. To improve decision-making by integrating space-based and ground-based data-providing systems; and
3. To develop applications for the provision of geospatial, telecommunications, timing, and positioning products and services

2010 Development

A group of African states seeks to protect the "common heritage" of orbital assets through the International Telecommunications Satellite Organization (ITSO) and the ITU

A conference of African Ministers in charge of communication and information technologies was held in Abuja, Nigeria, on 3-7 August 2010, under the aegis of the African Union (AU). The ministers committed themselves to securing the orbital/spectrum resources required to accommodate continental satellites, making application as a block to secure allocation of unused ITSO orbital resources to Africa a priority.[114] As a first step, a group of African states submitted a proposal to the ITU Plenipotentiary Conference in Guadalajara in October 2010, calling for assistance in addressing concerns about how to uniquely identify and protect the satellite orbital slots and associated frequency spectrum (referred to as "common heritage"[115]) used for global satellite coverage by satellite services provider Intelsat to deliver international public telecommunication services. According to reports, the member states agreed to take no action beyond discussing the proposal further.[116]

2010 Development

Africa considers the establishment of an African Space Agency

In addition, the African states requested that the AU commission a feasibility study for the establishment of the African Space Agency, taking into account existing initiatives, and to develop an African Space Policy in cooperation with the Regional Economic Communities, the UN Economic Commission for Africa, and the ITU.[117]

The objectives of the Feasibility Study for the Creation of an African Space Agency include:[118]

1. To highlight the current use of space applications in Africa and their impact on socio-economic development of the continent, including how they will contribute significantly to achieving the Millennium Development Goals;
2. To provide African policymakers with recommendations and a roadmap for the creation of the African Space Agency, including the drafting of legal and institutional instruments.

During a high-level dialogue on Africa-EU partnership in space held at the headquarters of the European Union Commission in Brussels on 17 September 2010, Jean-Pierre Ezin, AU Commissioner for Human Resources, Science and Technologies stated that the AU Commission is proposing to establish an African Space Agency "as a coordinated and integrated singular pan-African platform" to champion a well-defined African strategic space program."[119]

While it has been argued that a common space policy for Africa is long overdue,[120] some Africans have reservations. Peter Martinez, coordinator of South Africa's National Working Group on Space Science and Technology, argued that the idea was premature, saying that "a number of African countries should first develop their own capabilities and these [countries] could then take the lead in perhaps forming a continental space agency."[121]

Space Security Impact

The implementation of the South African space strategy can serve to spearhead the continent's space initiatives as it will entail the development of private sector space science and technology companies, the development of an export market for South African satellites and space services, and the development of products and services that can respond to the needs of users. On the one hand, this objective will encourage more collaboration with regional international partners. On the other, there may be a risk of unhealthy regional competition in the space domain. This threat may be reduced with the establishment of the African Space Agency, though it may be several years before it is created.

Trend 3.4: National space policies continue to focus on the security uses of outer space, with increased concentration on developing national space industries

Fueled in part by technological advances in military affairs, the national policies and military doctrines of a number of states increasingly 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.

Ensuring the security of vulnerable space assets remains a top priority of the U.S. military. The 2003 U.S. Air Force *Transformation Flight Plan* called for onboard protection capabilities for space assets, coupled with offensive counterspace systems to ensure space control for U.S. forces.[122] The 2004 Air Force document *Counterspace Operations* explicitly mentioned military operations "to deceive, disrupt, deny, degrade, or destroy adversary space capabilities."[123] The authoritative DOD *Joint Publication 3-14* on Space Operations states that "space systems have increased the importance of space power to joint force commanders (JFCs) and U.S. national interests"[124] and adds: "Military, civil, and commercial sectors of the U.S. are increasingly dependent on space capabilities, and this dependence can be viewed by adversaries as a potential vulnerability."[125] Furthermore, the importance of space applications for military operations is highlighted and space force application operations are defined as "combat operations in, through, and from space to influence the course and outcome of conflict by holding terrestrial targets at risk."[126]

Russia has repeatedly expressed concern that attacks on its early warning and space surveillance systems would represent a direct threat to its security.[127] Hence, a basic Russian national security objective is the protection of Russian space systems, including ground stations on its territory.[128] These concerns are rooted in Russia's assessment that modern warfare is becoming increasingly dependent on space-based force enhancement capabilities.[129]

In practical terms, Russian military space policy in the last decade appears to have had two main priorities. The first was transitioning to a new generation of space equipment capabilities, including cheaper and more efficient information technology systems.[130] The second was upgrading its nuclear missile attack warning system. Russia has expressed concern about the potential weaponization of space and the extension of the arms race to outer space, especially in light of the development of U.S. missile defense systems.[131] Russia has actively argued for a treaty prohibiting the deployment of weapons in space and, as discussed elsewhere in this chapter, it jointly introduced the PPWT with China to the CD in 2008. As well, its National Security Strategy, signed by President Medvedev in 2009, cites the potential dangers posed by the increased militarization of space activities.

China's military space doctrine is not made public. The country's 2006 *White Paper on Space Activities* identifies national security as a principle of China's space program.[132] The 2004 *National Defense White Paper* describes China's plans to develop technologies as part of the modernization of its armed forces, including "dual purpose technology" in space, for civil and military use.[133] A subsequent White Paper in 2006 describes "informationization" as a key strategy of its military modernization — although there is no express mention of the use of outer space for national defense — and asserts an international security strategy based on developing cooperative, non-confrontational, and nonaligned military relations with other states.[134] Nonetheless, in contemporary Chinese military science, the military use of space is inextricably linked to attaining comprehensive national military power.[135] China demonstrated significant space negation capabilities in the destruction of one of its orbiting satellites with a missile in 2007, but maintains that the test was "not targeted at any country and will not threaten any country," remaining publicly committed to the non-weaponization of space.[136] A 2009 statement by a high-ranking official of the People's Liberation Army (PLA) about the inevitability of an arms race in outer space[137] proved highly controversial.

The space policies of EU member states recognize that efforts to assume a larger role in international affairs will require the development of space assets such as global communications, positioning, and observation systems;[138] this understanding is reflected in the European Security and Defence Policy (ESDP). The paper "European Space Policy: ESDP and Space" adopted by the European Council in 2004 was the first council strategy paper on the use of space for ESDP purposes, and was followed by a roadmap for implementation in 2005.[139] While most European space capabilities have focused on civil applications, there is an increasing awareness of the need to strengthen dual-use and dedicated military capabilities.[140]

The EU/ESA European Space Policy adopted in 2007 highlights implementation of the space dimension of the ESDP and seeks to develop synergies between defense and civil space programs and also to guarantee EU independent access to space.[141] While military space capabilities remain within the exclusive purview of member states, the new policy urges them to increase coordination to achieve the highest levels of interoperability between military and civilian space systems. The policy envisages that "sharing and pooling of the resources of European civilian and military space programmes, drawing on multiple-use technology and common standards, would allow more cost-effective solutions."[142]

Emerging spacefaring powers have also begun to emphasize the security dimension of outer space. Israel's space program is based on national security needs and tightly linked to its military. In 2006, the Israeli Air Force was renamed the Air and Space Force and was given sole responsibility for all military activities in space, as well as for designing and operating the nation's future satellites. Its mission is to operate in the air and space arena for purposes of defense and deterrence.[143] Similarly, India has been working to bridge the gap between its military and ISRO through the development of the Integrated Space Cell to enhance the effectiveness of its military operations by using its space assets.[144] Indian Army Commanders also adopted *Space Vision 2020* — "its philosophy for using space in future warfare" — that reportedly emphasizes aspects of force modernization,[145] and intends to join the ranks of the U.S. and Russia with plans to launch a dedicated military satellite in the near future.[146]

In addition to focusing on the security implication of outer space capabilities, 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. Recent efforts in this respect are described below.

2010 Development

Mixed signals regarding India's plans to develop an ASAT capability

During 2010, India gave various indications that it may be considering the development of ASATs in the near future, in apparent contradiction to previous statements by political leaders. For a full description of this development, see Trend 8.2.

2010 Development

National space strategies focus on developing the space industrial sector alongside security objectives

United Kingdom

At an event on space innovation and growth strategy in the U.K. in February 2010, the team behind the joint government, industry, and academia initiative Space IGS unveiled a 20-year strategy for the future of the British space industry.[147] The strategy calls for a carefully orchestrated and executed series of steps to ensure the necessary structural, regulatory, investment, and commercial decisions are made at the right time and for the right reasons.[148] It identifies key market opportunities to position the U.K. for future success.[149] Among its 16 recommendations are that a national space policy be adopted and administered by the newly created U.K. Space Agency and that a high-level panel be established to make a strategic assessment of emerging space capabilities and contribute directly to a U.K. strategic security review.

The U.K. Cabinet Office reviewed British strategic interests in space in the development of the National Security Strategy and Strategic Defence and Security Review. The first-phase analysis concluded that there were significant risks for key parts of critical national infrastructure and defense capabilities; the second sought to develop a coordinated cross-government space security policy to address these risks.[150] The U.K. National Security Strategy, published 18 October 2010, highlights national security priorities, including severe disruption to information received, transmitted, or collected by satellites, possibly as the result of a deliberate attack by another state.[151]

The Strategic Defence and Security Review, published the following day, called for a National Space Security Policy that would "coherently address all aspects, both military and civil, of the UK's dependence on space; assure access to space; help mitigate risks to critical national infrastructure; focus future investment and research on national priorities, opportunities, and sovereign capability requirements; and encourage co-operation with UK industry and with international partners."[152] The Review goes on to say that "examples of these risks include the potential effects of interference, cyber-attack, physical damage, and electromagnetic pulse (whether natural or deliberate) on satellites or their ground stations critical to our security and the economy."[153]

Germany

Germany also adopted a new space strategy aimed at safeguarding the future of the German space industry. The strategy sets specific policy priorities, which include a focus on benefits and needs and the principle of sustainability; creating a uniform legal framework; expanding space research; promoting stronger links between various stakeholders in European space operations; and fostering international cooperation.[154] A further focus on finding uses for space expertise in the contexts of civilian and military security will require that Germany maintain its technological independence and have unrestricted access to space transportation systems.[155]

Australia

Australia launched a web presence for its newly established space policy unit under the Department of Innovation, Industry, Science and Research, in an effort to publicize opportunities and achievements in the Australian space sector. As well as promoting industry, the unit has been tasked with developing a National Space Policy encompassing civil and defence matters, including climate change, weather forecasting, navigation, and timing applications.[156]

United States

Despite attention focused on the international dimension of the 2010 Space Policy, the policy also seeks to maintain a robust and competitive industrial base in the U.S., and specifically seeks partnerships with the private sector to enable commercial spaceflight capabilities for the transport of crew and cargo to and from the International Space Station. To advance U.S. exploration objectives, the policy's "bold new approach to space exploration" argues for the development of a new heavy lift vehicle[157] and proposes human missions to asteroids and Mars. Since this new goal effectively does away with plans of going to the Moon,[158] critics have declared that the U.S. will fall behind the Chinese and Indians,[159] who have expressed a desire to pursue lunar exploration.

Concerns have also been raised about the lack of a backup government-managed rocket system[160] in the event that the private sector is not able to meet expectations of safe and reliable taxi servicing,[161] despite the successful test launch of the Space X Falcon 9 craft in December 2010. This marked the first time a private company had launched and reentered a spacecraft from LEO.[162] At the end of 2010, the human spaceflight program seemed fraught with challenges, while NASA faced fiscal uncertainties in the absence of a 2011 appropriations bill.[163]

2010 Development

U.S. export reforms welcomed, but Senate must still consider removal of commercial satellites from Munitions List

On 31 August 2010, during a Department of Commerce annual conference, President Obama announced key elements of the administration's export control reform effort,[164] elaborating on the plan announced by Secretary of Defense Robert Gates on 20 April.[165] The plan relies on four key reforms: a single (but tiered) export control list, a single licensing agency, a single enforcement coordination agency, and a single information technology system. In the first phase of a three-phased approach, the executive branch will begin the transition toward the single export control list[166] with a focus on the amendment of Category VII of the munitions list, which deals with tanks and military vehicles. The aim is to define more precisely the defense articles described.[167] Satellites and related components fall under Category XV of the munitions list. Because experts believe that a review of other munitions list categories will be more difficult than the work on Category VII, the timetable for completing the reform remains unclear.[168]

Under the Foreign Relations Authorization Act for 2010 and 2011, passed by the House of Representatives in 2009, the administration of President Obama was authorized to remove commercial satellites from the State Department Munitions List,[169] thus circumventing application of stringent International Traffic in Arms Regulations (ITAR). The bill was referred to the Senate Foreign Relations Committee and, while this authority has not yet been exercised and no changes have been made to the current regulations, it has been suggested that the Senate is delaying any action until the release of a U.S. Department of Defense report outlining which space items it recommends be eliminated from the Munitions List.[170]

Despite calls from Chinese Commerce Minister Chen Deming that the U.S. relax its control on high-tech exports to China,[171] India was the first international beneficiary of the export reforms. In November 2010, Indian Prime Minister Singh and President Obama signed a bilateral export control cooperation agreement, whereby India's defense and space-related entities are to be removed from the Department of Commerce "Entity List," which is subject to the jurisdiction of the Export Administration Regulations. Removal from the list means that export licenses are not required, thereby facilitating trade and cooperation in civil space and defense, and enabling the two governments to focus on other outstanding barriers to expanded bilateral high technology trade.[172] Restrictions on launching commercial satellites from India remain.[173]

Space Security Impact

It is inevitable that major spacefaring states will continue to use space for national security. But they and other states are also increasingly interested in developing a healthy commercial and industrial sector based on space. Tensions could build with the increased use of space for security, the growing competitiveness in the space industry, and heightened awareness of the vulnerabilities and fragility of many space capabilities. So, while linking national space strategies to the industrial sector could bode well for space security by encouraging clear rules, greater transparency, and cooperation, an overreliance on space for national security could lead to a climate of mutual suspicion and mistrust that will ultimately be detrimental to space security.

CHAPTER FOUR

Civil Space Programs

This chapter assesses trends and developments associated with civil space programs and global space-based utilities. The civil space sector comprises those organizations engaged in the exploration of space, or in scientific research in or related to space, for non-commercial and non-military purposes. This sector includes national space agencies such as the U.S. National Aeronautics and Space Administration (NASA), the Russian Federal Space Agency (Roscosmos), and the European Space Agency (ESA), and missions such as Soyuz, Apollo, the Hubble Space Telescope, and the International Space Station. Developments related to the launch vehicles that enable space access are also covered in this chapter, as well as the international collaborative efforts that facilitate space access for countries without the necessary means to independently engage in space activities.

The chapter examines the links between civil space programs of different nations and reviews recent developments related to actors with access to space, either independently or as a result of partnerships. Also covered here are the scope and priorities of civil space programs, including the number of human and civil satellite launches made by each actor and the funding levels of national space agencies.

Furthermore, this chapter examines trends and developments with regard to space-based global utilities. These applications, provided by civil, military, and commercial actors, can be freely used by anyone equipped to receive their data, either directly or indirectly. Global utilities include remote sensing satellites that monitor the Earth's changing environment, such as weather satellites. Satellite navigation systems that provide geographic position (latitude, longitude, altitude) and velocity information to users on the ground, at sea, and in the air, such as the U.S. Global Positioning System (GPS), are perhaps the best-known global utilities.

Space Security Impact

Civil space programs can have a positive impact on the security of outer space as 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 the need to ensure the sustainability of space activities and preserve this domain 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.

International cooperation remains a key aspect of both civil space programs and global utilities, affecting space security positively by enhancing transparency of the nature and purpose of certain civil programs that could potentially have military purposes. Furthermore, international cooperation in civil space programs can assist in the transfer of expertise and technology for the access to, and use of space, by emerging space actors. International cooperation can also help nations undertake vast collaborative projects in space, such as the International Space Station, whose complex technical challenges and prohibitive costs are difficult for any one actor to take on.

Conversely, civil space programs could have a negative impact on space security by diverting technological advances for peaceful space exploration to military applications, thereby facilitating the development of dual-use technologies for space systems negation or space-based strike capabilities. In addition, the growing number of spacefaring nations and the increasing diversity of sub-national space actors contribute to the overcrowding of space orbits and place great strain on scarce space resources, such as orbital slots and radio frequencies. Competition for access to and use of space resources in the longer term could generate tensions insofar as emerging spacefaring states and commercial providers of space-related services find limited opportunities to secure access to space resources.

Many civil space programs are dual-use and can support military functions. Civil-military cooperation can have a mixed impact on space security. On the one hand, it helps to advance the capabilities of civil space programs to access and use space. On the other hand, it could encourage adversaries to target dual-use civil-military satellites during conflict.

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. Consequently, global utilities are important for space security because they broaden the community of actors with access to space data, who have a direct interest in maintaining space for peaceful uses. Still, global utilities, like navigation systems, are space applications that can also support military operations; dual-use satellites, which blur the distinction between civil and military space assets, could be open to attack in the event of a conflict.

Trend 4.1: Growth in the number of actors accessing space

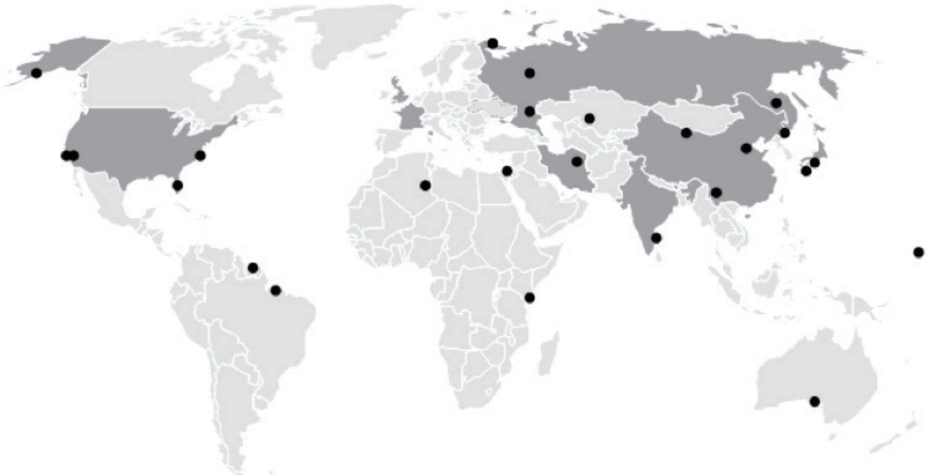
Civil space programs, along with military space programs and the commercial sector, add to the number of actors with access to space. By the end of 2010, nine states (of which Iran was the latest in February 2009) plus the ESA had demonstrated an independent orbital launch capability (see Figure 4.1 and Table 4.2). This total does not include private actors such as Sea Launch and International Launch Services — two consortia that provide commercial orbital launch services using rockets developed by state actors. Ukraine has not yet conducted an independent launch, but builds the Zenit launch vehicle used by Sea Launch. Brazil, Kazakhstan, North Korea, and South Korea are also developing launch vehicles, some of which are based on ballistic missile designs.

Another 17 actors have suborbital capability, sufficient for a rocket to enter space in its trajectory, but not to achieve an orbit around the Earth. These actors are Argentina, Australia, Brazil, Canada, Germany, Iraq, Italy, Libya, North Korea, Pakistan, Saudi Arabia, South Africa, South Korea, Spain, Sweden, Switzerland, and Syria.[1]

The rate at which new states gain access to space has increased dramatically in the past decade. By the end of 2010, more than 50 states had placed satellites in space, either independently or through cooperative agreements, with Switzerland's SwissCube the latest successfully launched first satellite. More states are gaining the socioeconomic benefits that space provides, with the aid of the commercial sector and countries such as China, which are helping states to develop affordable small satellites. Algeria, Egypt, Malaysia, Nigeria, Portugal, South Korea, Thailand, Turkey, and South Africa have launched satellites thanks to partnerships with other nations or companies such as Surrey Satellite Technology.[2]

Many civilian spacecraft are also used for military purposes. This trend is increasing as more states with fewer resources seek to maximize the use of data derived from civilian space programs. Many civilian communications satellites and global utilities such as navigation systems are prime examples of multiuse civilian applications that may serve military purposes.

Figure 4.1: Countries with independent orbital launch capability*[3]



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

Table 4.2: Countries' first orbital launches

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

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

The trend toward miniaturization in electronics has helped to reduce the size and weight of satellites, which can now perform the same functions as their bulkier predecessors, but are produced and launched more cheaply. One of the first microsatellites to implement this technology was the U.S. Clementine lunar mission in 1994. In 2007, the Indian Space Research Organisation announced plans to launch satellites weighing less than 100 kg to meet the needs of developing countries and the domestic scientific community.[4] Although such satellites are generally less capable than larger spacecraft, microsatellites such as the multinational Disaster Monitoring Constellation are increasingly used for functions traditionally performed by larger, heavier satellites, including communications and remote sensing.

2010 Development

Various countries prepare or declare launching of their first satellites, mainly with partners

In September 2010, Euroconsult, a leading research firm specializing in the satellite sector, released a report forecasting that more than 1,200 satellites are expected to be launched over the next 10 years,[5] a number of which will be the first for some nations. It is estimated that 122 satellites will be launched annually: this figure constitutes a significant increase over 77, the average for the previous decade. According to the report "Satellites to be built and launched by 2019, World Market Survey," national governments will be the main drivers of the projected growth and will account for more than two-thirds of all satellite launches.[6]

In November 2010, it was announced that Azerbaijan had selected Arianespace to launch its first communications satellite.[7] The satellite, to be built by Orbital Sciences Corporation of the U.S. using a STAR-2 platform, will provide various communications services, not only for Azerbaijan, but also for parts of Central Asia, Europe, the Middle East, and Africa.[8] It is slated to be launched to geostationary transfer orbit by the end of 2012 aboard an Ariane 5 rocket from the Guiana Space Centre in French Guiana.

In 2010, Bolivia also announced that it was planning to launch its first communications satellite by 2013, with significant financial and technical assistance from China.[9] The construction and launch of the Bolivian satellite, which is expected to cost $300-million, were made possible by China's offer to fund the project for the impoverished South American country "on easy loan terms."[10] In April, the executive director of the Bolivian Space Agency, Willy Herbas, signed a memorandum of understanding with Great Wall Industries Corporation to manufacture and launch the satellite.[11]

The launch of the first Latvian nano-satellite, Venta 1, was postponed — for the second time — until the first quarter of 2011.[12] The small communications satellite was first scheduled to be launched in December 2009 by ISRO aboard an Indian Polar Satellite Launch Vehicle (PSLV). That launch date was initially postponed to March 2010 when a lack of funds caused the project to fall behind schedule.[13] Venta-1 will have automatic identification system transmitters to supervise ship traffic in Europe.[14]

The launch of the first Singaporean satellite, also to be flown into orbit aboard an Indian PSLV, was also postponed to an undetermined date in 2011.[15] The refrigerator-sized satellite, called X-Sat, was first scheduled to be launched in 2007.[16] In March 2010, it was originally reported that the satellite would be ready to be launched in June or July 2010,[17] before the launch was first postponed to December[18] and then to 2011.

China is also helping other countries to acquire their first satellites. The Chinese government agreed to assist with the construction of Laos' first satellite and its respective ground control stations.[19] The joint venture, funded with Chinese loans, is expected to cost $250-million. A launch date of the third quarter of 2013 was set.[20] China also pledged to help launch Bangladesh's first satellite,[21] although no timeline was announced.

Belarus signed a framework of space cooperation with Ukraine[22] and cooperated with Russia on two space programs: development of nanotechnologies for the space sector and spin-off applications, and development of new space technologies for economic development.[23] Russia was expected to launch the first (remote sensing) Belarus satellite in early 2011.[24]

2010 Development

New launch capabilities are advanced, with mixed results

On 3 February, Iran reportedly launched into orbit a Kavoshgar-3 rocket carrying a rodent, two turtles, and some worms, later claiming that the event was a successful advance in its space program.[25] Although this success has been questioned,[26] international concerns have been raised about the peaceful nature of Iran's space program, with White House spokesman Bill Burton calling the display "obviously a provocative act."[27] On 30 January 2011, Iranian president Mahmoud Ahmadinejad predicted that Iran would send humans to space by 2021.[28] In 2009, Iran became the ninth nation in the world to independently send a satellite to space when it launched the Omid on the eve of the thirtieth anniversary of the Islamic revolution.[29]

On 10 June, South Korea attempted the launch of Korea Space Launch Vehicle 1 (KSLV-1), but ground controllers lost contact with the rocket 137 seconds after lift-off and the launch failed.[30] Lee Joo-jin, president of the state-run Korea Aerospace Research Institute (KARI), said that the rocket had reached an altitude of 70 km and was about 87 km from the launch site when all communications were lost.[31] The rocket appears to have exploded moments after takeoff,[32] but Russia, South Korea's partner in this venture, could not identify the precise reasons for the malfunction.[33]

Figure 4.3: Worldwide orbital launch events in 2010[34]

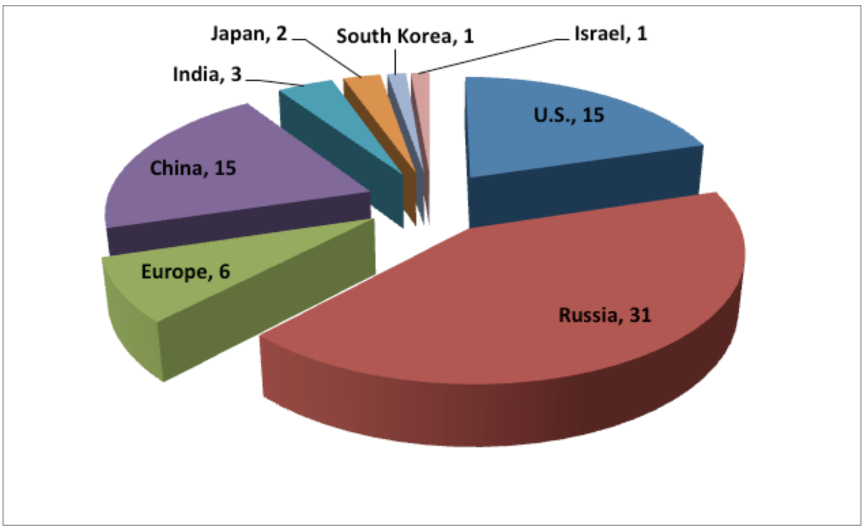


Table 4.4: The 2010 space launch scorecard[35]

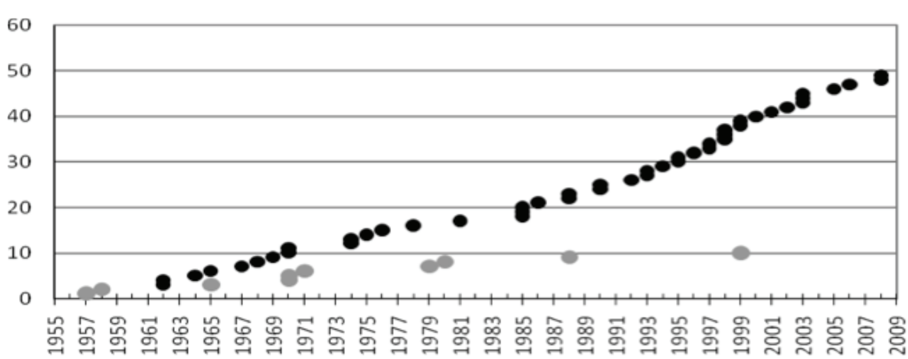
Country	Launch vehicle	Launch vehicle	Launch vehicle	Launch vehicle	Launch vehicle	Launch vehicle	Launch vehicle	Total	Failed
1 **Russia**	Proton: 12 (1)*	Soyuz-U/ FG: 10	Dnepr: 3	Kosmos-3M: 1	Rockot: 2	Molniya-M: 1	Soyuz-2: 2	31	1
2 **U.S.**	Space Shuttle: 3	Atlas 5: 4	Delta IV: 2	Falcon-9: 2	Minotaur 4: 2	Delta 2: 1	Delta IV Heavy: 1	15	0
3 **China**	Long March 3C: 4	Long March 4C: 2	Long March 2D: 3	Long March 3A: 3	Long March 3B: 1	Long March 4B: 2		15	0
4 **Europe**	Ariane-5 ECA: 6							6	0
5 **India**	GSLV: 2 (2)*	PSLV: 1						3	2
6 **Japan**	H-IIA: 2							2	0
7 **S. Korea**	KSLV 1: 1*							1	1
8 **Israel**	Shavit: 1							1	0
Total								**74**	**4**

* failed missions

On 22 February, South African Science and Technology Minister Naledi Pandor announced the plan to look into the possibility of reestablishing its own space rocket launching capabilities.[36] Pandor acknowledged that launch facilities had been deactivated as part of the country's nuclear nonproliferation policy, but indicated that such capabilities need not be used for weapons purposes, adding that South Africa took "space and technological development very seriously."[37]

On 12 December, Brazil reported a successful suborbital launch of its VSB-30 VO4 rocket from Alcantara space center with cargo and microgravity experiments payload.[38] The rocket flew for about 18 minutes, reaching an altitude of approximately 242 km before descending 233 km off Brazil's Atlantic coast.[39] The South American country reportedly is aiming to become a top emerging economy with an indigenous space program.[40]

Figure 4.5: Growth in the number of civil actors accessing space[41]



● Independent launch
● First satellite

2010 Development

National and international space bodies continue to expand and grow in numbers

ESA signed cooperation agreements with Slovenia[42] and Slovakia[43] on 22 January and 28 April, respectively. The agreements laid down the principles and plans for a more consolidated relationship with ESA, and included the development of a Plan for European Cooperating State Charter that describes activities, projects, and budgets. On 15 December, ESA renewed its partnership in space science and technology with Canada, effectively extending this relationship until 2020.[44] ESA and Canada will continue to pursue joint projects focusing primarily on space applications such as Earth observation, GMES, and satellite-based navigation, including Galileo.[45]

During 2010, several countries officially established national space agencies. On 23 March, the U.K. launched the U.K. Space Agency.[46] It fits into the broader Space Innovation and Growth Strategy that is expected to lead Britain from a position where it currently claims 6 per cent of the global market in space products and services to a position in 2030 when it hopes to claim 10 per cent.[47] On 9 December, the South African National Space Agency (SANSA) was officially unveiled by the country's minister of science and technology.[48] However, it was also announced that the agency, which will cost South Africa approximately $68.7-million a year, will not be fully operational until 2012.[49]

In April, Mexico's Congress approved the creation of a national space agency, Agencia Espacial Mexicana, with an initial budget of $800,000; the projected annual budget is $8-million.[50] Bolivia announced plans to launch, with Chinese assistance, its first communications satellite and the creation of the Bolivian Space Agency, which will operate out of La Paz and have an initial budget of $1-million.[51]

Space Security Impact

The increasing globalization of space technology has led not only to the diversification of suppliers and customers for space applications, but also to a sharp reduction in entry barriers to the space domain for many nations. As the number of space actors able to access space increases, more parties have a direct stake in the need to ensure the sustainability of space activities and preserve this domain for peaceful purposes. However, more space actors means greater overcrowding of space orbits and greater strain on such scarce space resources as orbital slots and radio frequencies. In a more crowded environment, the risk of accidental interference with space assets goes up. Even though the development of civilian space applications is driven mostly by economic development aspirations and public safety considerations, the spread of launch capabilities could exacerbate regional tensions.

Trend 4.2: Civil space programs continue to prioritize scientific missions and exploration

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:[52] *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 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.[53] 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. Such decentralization of civil activities makes obtaining accurate, comprehensive budget figures for Russian civil space programs difficult.[54]

In 1961, France established its national space agency, the Centre National d'Études Spatiales, which remains the largest of the EU national-level agencies. Italy established a national space agency (ASI) in 1989, followed by Germany in 1990 (DLR). 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. As of June 2011, ESA had 18 Member States; the last to join was the Czech Republic on 12 November 2008. 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, these efforts were all assumed by the Japanese Aerospace Exploration Agency.[55] India's civil space agency ISRO was founded in 1969. Israel's space agency was formed in 1982, Canada's in 1989, and Agência Espacial Brasileira in 1994.

Expenditures

Although still dwarfing the civil space budgets of all other actors put together, the NASA budget dropped 25 per cent in real terms between 1992 and 2001.[56] The ESA budget dropped nine per cent in the same period. This follows a long period of growth (1970-1991) for both NASA and ESA, during which the NASA budget grew 60 per cent and the ESA budget 165 per cent in real terms.[57] NASA's budget is now close to $19-billion per fiscal year.

The USSR/Russia was the most active civil space actor from 1970 until the early 1990s, when sharp funding decreases led to a reduction in the number of civil missions. By 2001, the number of Russian military, civil, and commercial satellites in space had decreased from over 180 during the Soviet era to approximately 90. The budget had been reduced to $309-million — about 20 per cent of the 1989 expenditure and less than the cost of a single launch of the U.S. space shuttle.[58] This steady decline was reversed in 2005, however, when Russia approved a 10-year program with a budget of approximately $11-billion.[59] The annual budget for 2010 was 67-billion rubles (approximately $2.5-billion), not including funds for the Global Navigation Satellite System (GLONASS), which had a separate budget allocation.[60]

The ESA budget is approximately $3.6-billion per year. All member states make financial contributions to the Agency's General Budget on a scale based on their GDP.[61]

Civil expenditures on space continue to increase considerably in India and China, due in large part to the growth of civil programs, including large satellites and human spaceflight programs. Since 2005, India's space budget has dramatically increased and is now approximately $1-billion.[62] The Chinese space budget is complex. Officials have been quoted as saying that the Chinese civil space budget is as low as $500-million, while media sources place the figure closer to $2-billion. It is safe to speculate that it falls somewhere between these two figures.[63] However, expenditures are not the sole indicator of capabilities, because of differences in production cost among countries, as well as local standards of living and purchasing power.[64]

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 space flight. 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.[65]

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 U.S. 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. In the 1970s, the U.S. initiated the Space Shuttle, which was capable of launching as many as seven people to LEO. The first Space Shuttle, Columbia, was launched in 1981. By the end of 2008 the program had completed 124 launches and at the end of 2010 was the only human spaceflight capability for the U.S.[66] For a time after the 2003 Space Shuttle Columbia disaster, Russia was the only actor performing regular human missions and its Soyuz spacecraft provided the only lifeline to the ISS. This situation may recur following the Space Shuttle's last scheduled flight in 2011 and consideration being given to future reliance on commercial providers of transport services, though the extent to which they will become a viable alternative is still unclear.

In 2004, the U.S. announced a new NASA plan that includes returning humans to the Moon by 2020 and a human mission to Mars thereafter. A new strategy for lunar exploration was announced in 2006.[67] Future plans include a permanent human presence on the lunar surface.[68] These plans were examined in 2009 by the Review of United States Human Space Flight Plans Committee, whose major finding was that the U.S. human spaceflight program is 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 suggests two possible solutions to the problem of limited resources:

1. Transporting astronauts to LEO could be turned over to the commercial sector. If this option is chosen, the government should create a competitive bidding process.
2. Levels of international cooperation between the U.S. and other national space programs could increase.

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.

Other civil programs are also turning to human spaceflight and the Moon. In 2005, JAXA released its 20-year vision statement, which includes expanding its knowledge of human space activities aboard the ISS as well as developing a human space shuttle by 2025.[70] The ESA also has a long-term plan to send humans to the Moon and Mars through the Aurora program. India approved a human spaceflight program in 2006.[71] In 2007, both Japan and China launched robotic lunar missions: Kaguya and Chang'e-1, respectively.[72] Germany, India, and South Korea have also considered lunar missions going forward.[73]

Direction of civil space programs

More civil space projects are now explicitly focused on social and economic development objectives. ISRO was established on this basis in 1969 and has since developed a series of communications satellites that provide tele-education and telehealth applications and remote sensing satellites to enhance agriculture, land, and water resource management and disaster monitoring.[74] In 2000, Malaysia launched Tiungsat-1, a microsatellite that included several remote sensing instruments for environmental monitoring. In 1998, Thailand and Chile together launched TMSat, the world's first 50-kg microsatellite to produce high-resolution, full-color, multispectral images for monitoring the Earth, and FASat-Bravo, a microsatellite to study depletion of the ozone layer.[75] Algeria, Egypt, Nigeria, and South Africa have built or are in the process of building satellites to support socioeconomic development. A part of the 2007 EU/ESA Space Policy's mission was to serve the public in the area of "environment, development, and global climate change."[76]

Efforts have also been made to expand the reach of such programs. China and Brazil have agreed to provide free land images to African and Asian countries from their joint optical remote sensing satellite CBERS-2B (China-Brazil Earth Resource Satellite-2B), launched in September 2007.[77] They will also provide the software needed to read the data, which is intended to help countries respond to threats such as deforestation, desertification, and drought.[78] India has also committed to sharing remote sensing data for disaster management in the Asia-Pacific region and provides data analysis and training to countries without independent access.[79]

Civil space programs, particularly meteorology and Earth observation science, are increasingly used for national security missions. For example, the objective of the EU/ESA Global Monitoring for Environment and Security program is to "support Europe's goals regarding sustainable development and global governance, in support of environmental and security policies, by facilitating and fostering the timely provision of quality data, information, and knowledge."[80]

2010 Development

Spacefaring states continue to pursue Moon exploration

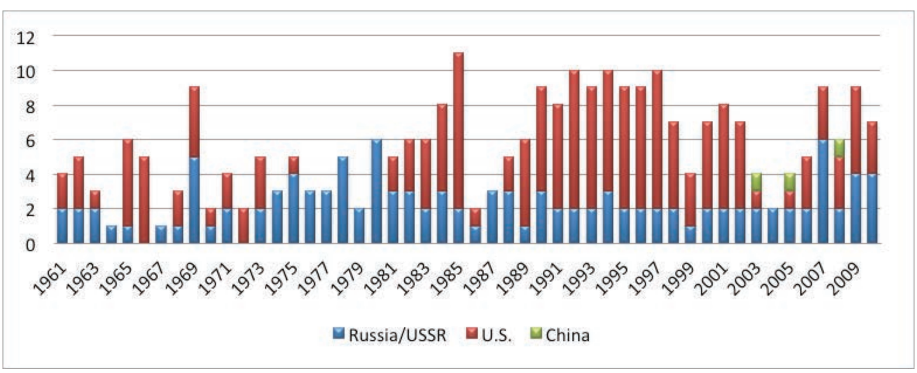
In 2010, Chinese sources indicated that the country intends to continue pursuing the launch of its own space station as a step to reaching the Moon.[81] The first module of a three-stage process to assemble an orbital lab is Tiangong 1, an 8.5-ton structure, whose construction, as well as electronic, mechanical, and thermal testing, have reportedly already been completed. It was scheduled to be launched into orbit in 2011.[82] The completed Chinese space station will be a collection of modules that some sources say will be comparable to the Mir station, which Russia took out of orbit in 1996.[83] On 1 October, China launched Chang'e-2 – a mission to map potential landing sites on the Moon;[84] the mission's success was announced in early November.[85]

The Russia-India Luna-Resource project includes sending a research lunar probe (Chandrayaan-2) to the Moon's surface to study polar areas and extract and return to Earth samples of water and soil.[86] The launch from an Indian facility is scheduled for 2013. India also announced plans to send humans into space by 2017.[87] The initial phase will cost approximately US$2.8-billion[88] and start with a pre-project study, followed by testing of the unmanned crew module and the launch of astronauts by a geostationary satellite launch vehicle (GSLV).[89]

Japan confirmed its interest in exploring the Moon and plans to develop a follow-on mission to Hayabusa, an unmanned spacecraft that successfully collected samples from a near-Earth asteroid and returned them to Earth on 13 June 2010.[90] It also intends to build on the success of the Selenological and Engineering Explorer (SELENE, also known as Kaguya), a lunar orbiter spacecraft, with SELENE2, a robotic landing and exploration mission to the Moon by 2015.[91] Japan also plans to build a robot space-base on the Moon by 2020[92] and intends to do more research and development in relation to BepiColombo, a mission of the Japan Aerospace Exploration Agency (JAXA) and ESA to study the structure, exosphere, and magnetosphere of Mercury.[93]

Despite the cancellation of NASA's Constellation program, the U.S. has not fully dismissed the Moon as a space exploration goal.[94] On 30 September, NASA Deputy Administrator Lori Garver stated that the Moon has a role to play in President Obama's space exploration plan, and that "lunar science and lunar exploration is alive and well in NASA,"[95] as evidenced by the success of the Lunar Reconnaissance Orbiter (LRO), which completed the mission exploration phase on 16 September.[96]

Figure 4.6: Human spaceflight missions 1961–2010



2010 Development

Mix of successes and failures in the development of new launch vehicles

In 2010, Russia remained focused on the development of the new Angara family of space launchers, which are to replace some of the aging Molniya-M launch vehicles currently in service.[97] The development of the Angara space launcher is the largest Russian space project included in the Federal space program for 2006-2015.[98] Once completed, the light-, medium-, and heavy-duty Angara rocket will be mostly used at the new Vostochnyj spaceport.[99] Building the infrastructure of Russia's new spaceport was expected to start in 2011. However, launches using the new Angara rocket are not expected to start before 2013.[100] Roscosmos, the Russian federal space agency, has estimated that by 2020 the new spaceport will host half of Russia's yearly launches, leaving Baikonur with about 11 per cent.[101]

Another new Russian launcher under development, "Rus" (Russia), will be used to launch the future manned spaceships currently being designed.[102] The first launch of a manned spacecraft from Vostochnyj is expected in 2018. The Energiya company planned to start developing a nuclear-engine launcher in 2011.[103]

The China Academy of Launch Vehicle Technology (CALT) continued work on the Long March-5, the next generation of launch vehicles, which officials say will be significantly more powerful than previous launch systems.[104] The Long March 5 is expected to have engines that generate 120 tons of thrust; test launches are planned for 2014.[105] CALT general manager Li Tongyu has stated that engineers are studying a rocket engine with a thrust of 600 tons, adding that such rockets "would only be justified for things like sending humans to the Moon, if those projects are approved."[106] The Long March 5 rockets are expected to be able to carry 25 tons to near-earth orbits and 14 tons to geosynchronous orbits, compared to nine and five tons, respectively, of current-generation models.[107]

Following the cancellation of the Constellation program,[108] the U.S. focused on the development of new launchers by private industry rather than NASA.[109] The new U.S. National Space Policy released in June emphasized maintaining a robust and competitive industrial base in the U.S., specifically seeking partnerships with the private sector to enable commercial spaceflight capabilities for the transport of crew and cargo to and from the International Space Station.[110]

2010 Development

Scientific space missions continue to be developed worldwide

Several successful scientific missions were launched or executed in 2010. The Planck space telescope, designed to map and measure the anisotropies of the Cosmic Microwave Background (CMB),[111] continued to transmit high-quality data to the Earth.[112] On 5 July, the ESA released the first full-sky image of microwave radiation taken by the Planck telescope between August 2009 and May 2010. Although definitive results about the observation will likely not be available until at least 2012, Nazzareno Mandolesi, director of the Institute of Space Astrophysics and Cosmic Physics in Italy, said that the telescope is "very healthy and all the instruments are working, sometimes better than expected."[113]

On 15 June, French space agency CNES successfully launched the solar science satellite Picard aboard a Russian Dnepr-1 launcher from Dombarovskiy Cosmodrome.[114] Picard, which is equipped with a 4.3-inch imaging telescope that can obtain precise measurements of the Sun's diameter, shape, and rotation, started a two-year mission to research the Sun's variability.[115] The $85-million project is managed by CNES in collaboration with Belgian, Swiss, and French research institutions.[116] The UN was also preparing for the 2011[117] launch of its first satellite, UNESCOSat, which will undertake a scientific mission[118] to study alternative fuel sources

On 11 February, NASA launched the Solar Dynamics Observatory, a mission to study the Sun's influence on Earth.[119] The WISE (Wide-field Infrared Survey Explorer) mission completed its infrared survey in 2010.[120] On 21 May, the Japanese IKAROS mission to test the possibility of transforming sunlight into propulsion was launched.[121] On 8 December, the IKAROS mission was successfully completed after the spacecraft passed Venus at a distance of 80,800 km. Another planned Japanese mission will send a bigger solar-sail spacecraft to Jupiter and the Trojan asteroids.[122] A JAXA mission to Venus — the Climate Orbiter "AKATSUKI" — failed in December. The next chance for the spacecraft to approach and study Venus is not for six years.[123]

None of the four Russian science satellites planned for launch in 2010-2011[124] were sent into space in 2010. These include Spektr-R spacecraft that will produce high-energy astrophysics data using German and Russian instruments, as well as the sensing complex MKA-FKI that will, inter alia, study ways to improve remote sensing techniques.[125] In 2011, Russia will again try to launch the Phobos-Grunt spacecraft to one of the moons of Mars. It will study the lunar surface and a special lander (provided by Chinese partners) is intended to grab samples of soil and send them back to the Earth in a special capsule.[126]

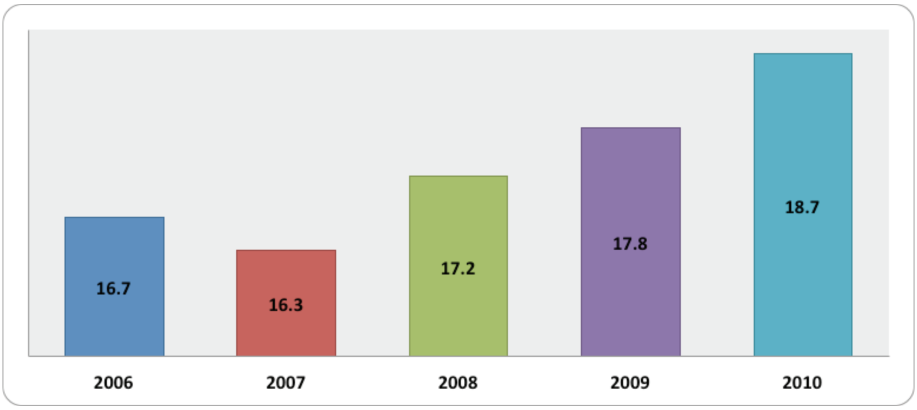
2010 Development

National space budgets increase slightly

The slight increase in the NASA budget from $18.7-billion in 2010 to $19-billion proposed for 2011 does not include funding for a manned mission to the Moon.[128] Obama signed the NASA Authorization Act in October, allocating $58.4-billion to NASA for the next three years.[129] One-fifth of the Russian space budget, the fourth largest in the world, is spent on modernizing the space industry to increase product quality and reliability.[130] In 2010, it planned to spend 180 million rubles to develop GLONASS.[131] Vitaly Davydov, deputy chief of the Russian Space Agency, declared that the budget for the implementation of the federal space program in 2011 was 75 billion rubles, an increase of almost 15 per cent over the budget for 2010, which stood at 67 billion rubles.[132]

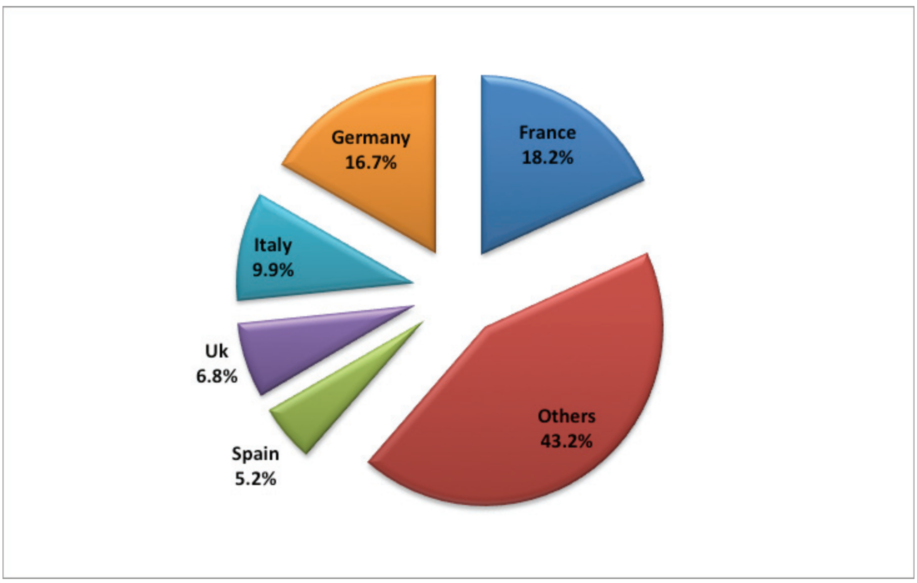
ESA's budget for 2011 will likely remain at the 2010 level of approximately US$4-billion.[133] The 25-26 November meeting of the European Space Council unanimously endorsed a resolution calling for a space strategy that prioritizes the Galileo navigation system, the European Geostationary Navigation Overlay Service (EGNOS), and the GMES projects. Nevertheless, the meeting did not adopt a concrete funding strategy for these programs and it provided "little tangible guidance for overcoming the funding shortfall that Galileo faces in the near future,"[134] despite an early draft of the 2011 budget that allocated approximately $720-million for Galileo and EGNOS. France will increase its contribution to ESA's budget by 10 per cent to $1.06-billion.[135] French agency CNES will receive a little over $1-billion for 2011.[136]

Figure 4.7: NASA 2006-2010 budget (in $USB)[137]



The budget of the German Aerospace Center (DLR) grew by 5 per cent for 2010 to $370-million, despite some cuts within the overall federal budget of Germany. Germany's contributions to ESA totaled $830-million in 2010, $23-million more than for the previous year.[138] The new U.K. space agency will have an annual budget of approximately 220 million pounds.[139] In 2010, the Canadian Space Agency was allocated a budget of CND$397-million for five years, with a focus on the development of the RADARSAT Constellation Mission.[140]

Figure 4.8: Top contributors to ESA's 2010 General Budget*[141]



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

India is reported to have significantly increased ISRO's budgets for 2011 from $700-million to $1-billion.[142] JAXA's budget for 2011 remained at the 2010 level of 180-billion Yen, despite a request for an increase of 10-billion Yen.[143] The Chinese budget, for which reliable information is hard to get, was estimated at $1.3-billion in 2009.[144]

Space Security Impact

Recent events highlight issues that will have longer-term impact. Global space industries face increasing economic and competitive pressures from limited government discretionary spending, existing overcapacity, and new entrants. These pressures on addressable markets, combined with uncertain future plans for space exploration, are leading to increasing costs for major spacefaring countries, which in turn may limit future flight opportunities. At the same time, continued scientific missions and international cooperation increase the level of transparency and contribute to security among spacefaring nations.

Trend 4.3: Steady growth in international cooperation in civil space programs

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 driven cooperation.[145] 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 on programs that culminated in a joint docking in space of U.S./USSR human modules in July 1975. However, "collaboration has worked most smoothly when the science or technology concerned is not of direct strategic (used here to mean commercial or military) importance," and when projects have "no practical application in at least the short to medium term."[146] If government support for space science decreases, such cooperative efforts may also decline.

The 1980s saw a plethora of international collaborative projects involving the USSR and countries including the U.S., Afghanistan, Austria, Bulgaria, Canada, France, Germany, Japan, Slovenia, Syria, and the U.K. to enable astronauts to conduct experiments onboard the Mir space station.[147] Many barriers to global partnership have been overcome since the end of the Cold War. Examples include the EU-Russia collaboration on launcher development and utilization, and EU-China cooperation on the Galileo navigation system. From 1995 to 1998, there were nine dockings of the U.S. Space Shuttle to the Mir space station, with various crew exchanges.[148] The ESA and NASA have collaborated on many scientific missions, including the Hubble Space Telescope, the Galileo Jupiter probe, and the Cassini-Huygens Saturn probe.

The most prominent example of international civil space cooperation is the ISS, the largest, most expensive international engineering project ever undertaken. The project partners are NASA, Roscosmos, ESA, JAXA, and the Canadian Space Agency. Brazil participates through a separate agreement with NASA. The first module was launched in 1998. As of 9 March 2011, 109 flights had carried components, equipment, and astronauts to the station, which remains unfinished.[149] The ISS is projected to cost approximately $129-billion over 30 years of operations.[150]

Table 4.9: Flights to the International Space Station[151]

	ISS Flights (by March 2011)
U.S.	35 Space Shuttle flights
Russian:	2 Proton flights
	25 Soyuz crew flights
	2 Soyuz assembly flights
	41 Progress resupply flights
European:	2 Automated Transfer Vehicle flights
Japanese:	2 H-II Transfer Vehicle flights

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.[152] Significant bilateral cooperation on Moon and Mars missions is also taking place. For example, ESA provided technical support and knowledge-sharing for both China's Chang'e-1 lunar orbiter and India's Chandrayaan-1 lunar orbiter.

2010 Development

International Space Station marks 10 years of operations and uninterrupted inhabitancy

In 2010, the ISS marked 10 years in operation and uninterrupted inhabitancy, a record in the history of human space exploration and use.[153] The number of scientific experiments conducted aboard the ISS increased.[154] According to officials from space agencies, upon completion of the station, the ISS crews were able devote 25 per cent more time to scientific experiments.[155] All new Russian crew vehicles will be docked to the new Poisk (Search, *aka* Mini-Research Module 2) module[156] that was docked to the station in November 2009 and became usable in 2010. Russian module "Rassvet" (Dawn) was attached to the ISS and became operational in May.[157] Two more modules — the US "Tranquility" (Node 3)[158] and the European "Cupola"[159] — were added to the ISS in February. Tranquility was built by Thales Alenia Space, but ownership was transferred to NASA in November 2009.[160]

Plans for the ISS include its potential use in the assembly of spaceships bound for the Moon and Mars.[161] The possibility was raised that NASA might fly an extra shuttle in 2011 if the relevant commercial capabilities were not yet available.[162] Roscosmos and NASA signed an agreement for the Russian space agency to provide transportation of American astronauts to the ISS in 2013 and 2014 at a cost of $335-million.[163]

2010 Development

More cooperation agreements on exploration and launchers

Russian Soyuz launches from ESA's spaceport in Kourou were postponed to spring 2011.[164] The Russians cited difficulties in developing the movable service tower,[165] but the launch pad was reportedly complete and ready.[166] As part of this project Arianespace ordered 10 Soyuz launchers from Russia in June.[167] In April, the Kazakh parliament ratified the 2004 agreement to extend the lease of the Baikonur Cosmodrome to Russia until 2050[168] at a yearly rate of $115-million.[169] In November, the two countries agreed to facilitate the construction of an environment-friendly Baiterek Space Launch Complex at Baikonur.[170] Brazil-Ukraine cooperation on launching Tsyklon-4 rockets from the Alcantara spaceport continued, but the launches were postponed until 2012.[171]

After the meeting of the Russian-American working group on cooperation in November, the head of Roscosmos said that Russia and the U.S. were collaborating on a joint lunar exploration mission, which at the current stage is carried out through the use of the Russian-built LEND instrument on the NASA LRO.[172] He declared that Russia, the U.S., Europe, China, Japan, and India will be the key players in exploration.[173]

India and Russia have determined the Moon locations for the Chandraayan-2 and Luna-Glob stations.[174] Five spots near the lunar south pole were identified as suitable for the landing on the Moon's surface, and the Russian Astronomical Institute is in charge of choosing the most favourable location, particularly taking into account visibility of the stations from Earth. The Luna-Resources /Chandraayan-2 mission that is scheduled to fly to the Moon by 2013 will explore them more closely.[175] Roscosmos also revealed plans to fly to Mars in 20 years.[176]

The U.S. maintains exploration plans with the focus on asteroids and Mars, as mandated by the NASA Authorization Act 2010.[177] ESA and the European Commission agreed that the European Union should "coordinate the efforts needed for the exploration and exploitation of space"[178] and stressed that space exploration is crucial for innovation and technological progress.[179]

Space Security Impact

International civil space cooperation is a positive factor in improving space security, because it helps to build formal and informal ties across the global space community. It can also help groups of nations undertake vast projects in space, such as the International Space Station, which would be too complex and expensive for any one state. Working on challenging bi- and multinational space projects builds confidence for countries at all levels of space development. The relationships and interdependence created through cooperative space projects help foster transparency and allow for a more accurate assessment of the space capabilities of cooperating states.

Trend 4.4: Continued growth in global utilities as states seek to expand applications and accessibility

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 are almost indispensable to the civil and commercial sectors as well.

Satellite navigation systems

There are currently two global satellite navigation systems: the U.S. GPS and the Russian GLONASS system. 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. A GPS receiver must receive signals from four satellites to determine its location, with an accuracy of 20 m, depending on the precision of available signals. 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 two per cent of its total market. The commercial air transportation industry, with more than two billion passengers a year, relies heavily on GPS.[180] U.S. companies receive about half of GPS product revenues, but U.S. customers account for only about one-third of the revenue base. Demonstrating the growing importance of satellite navigation for civilian uses, former U.S. President George W. Bush announced in 2007 that next-generation GPS Block III satellites will not have the capability to degrade the civilian signal. The "decision reflects the United States strong commitment to users of GPS that this free global utility can be counted on to support peaceful civil activities around the world."[181]

GLONASS uses principles similar to those used in the 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.[182] The first GLONASS satellite was orbited in 1982 and the system became operational in 1996. Satellites soon malfunctioned, however, and the system remains below operational levels, retaining only some capability, although efforts are again under way to complete the system.[183] 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.[184] Russia has extended cooperation on GLONASS to China and India[185] and continues to allocate significant funding for system upgrades, independent of the 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, to provide Europe with independent 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.[186] After a five-year delay, European governments agreed in 2007 to provide the necessary $5-billion to continue work on what is now a public system not set to be deployed until 2013.[187] 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.[188]

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.[189] In 2006, China announced that it will extend Beidou into a global system called Compass or Beidou-2 for military, civilian, and commercial use.[190] 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 eventually evolve into a global navigation system.

India has also proposed an independent, regional system — the Indian Regional Navigation Satellite System (IRNSS) — intended to consist of a seven-satellite constellation.[191] Japan is developing the Quazi-Zenith Satellite System (QZSS), which is to consist of a few satellites interoperable with GPS in HEO to enhance regional navigation over Japan, but operating separately from GPS, providing guaranteed service.[192] The system is expected to be operational by 2013.[193]

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 require cooperation 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 inter-system 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 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. Access to EO data is spreading worldwide, although not without difficulties.[194] To ensure truly broad access to data, agencies across the globe are working to enhance the efficiency of data sharing with international partners.[195]

The European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) provides meteorological data for Europeans. The National Oceanic and Atmospheric Administration (NOAA), founded in 1970, provides the U.S. with meteorological services.[196] Satellite operators from China, Europe, India, Japan, Russia, and the U.S., 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.[197]

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."[198] As of March 2011, the Group on Earth Observation has members from 86 state governments and the European Commission. In addition, 61 intergovernmental, international, and regional organizations are recognized as Participating Organizations.[199] 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.[200] The European GMES initiative is another example of a centralized database of Earth observation data made available to users around the world.[201]

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."[202] 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.[203] DMC International Imaging operates satellites for the Disaster Monitoring Constellation, a collaboration of Algeria, China, Nigeria, Spain, Thailand, Turkey, the U.K., and Vietnam. Initiated by China, the project uses dedicated microsatellites to provide emergency Earth imaging for disaster relief, as well as daily imaging capabilities to partner states.[204]

In 1979, COSPAS-SARSAT, the International Satellite System for Search and Rescue, was founded by Canada, France, the USSR, and the U.S. 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.[205] Similarly, states including Canada and Norway have begun to develop satellite systems to better collect and track Automated Identification System signals for collision avoidance. Satellite receivers for such signals could improve search-and-rescue efforts, as well as ship surveillance for security purposes.[206]

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 statement 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." The 2010–2011 work plan for UN-SPIDER was adopted in April 2009.

2010 Development

Satellite navigation systems around the globe continue to evolve

The development of the Russian navigation system GLONASS marked its fifteenth anniversary in 2010.[207] Three GLONASS satellites were successfully launched on 1 March and their frequencies activated within a couple of weeks.[208] Three more were launched on 2 September, with two slated for operational use and one serving as backup.[209] The GLONASS constellation of satellites was to have been complete by the end of the year — which would have allowed the system's coverage to be global[210] — but failure to put three more satellites of the new generation (GLONASS-K[211]) in orbit made it impossible to meet the target.

The three-satellite launch was attempted on 5 December, but suddenly failed when the Proton-M rocket deviated eight degrees from course and fell into the Pacific Ocean.[212] Following the failure, Anatoli Perminov, head of Roscosmos, said that despite the "heavy loss," which analysts have estimated at $160-million, GLONASS would be fully operational after only a three-month delay.[213] In 2011, the program is scheduled to receive an additional 60 billion rubles.[214] Russia also maintains the position that GLONASS should complement rather than replace (or serve as an alternative to) the U.S. Global Positioning System (GPS).[215]

China's first satellite for the Compass (or Beidou 2) navigation system was launched on 17 January,[216] and was followed by launches in June,[217] July,[218] October,[219] and December.[220] The constellation now has a total of seven satellites in orbit, with 10 expected by 2012.[221] Japan also launched the first navigation satellite of a planned Quasi-Zenith Satellite System (QZSS) that augments GPS over East Asia.[222] India launched the first satellite of a planned 24-satellite navigation system in August.[223] ESA signed major contracts with the European industry[224] to build Galileo operational infrastructure. Europe continues to be opposed to the overlay of portions of the Galileo signal by signals from China's Compass system. International consultations in recent years have not shown a willingness of either party to move or modify their respective signals.[225]

2010 Development

Development continues on disaster relief and remote sensing capabilities

An increasing number of Earth Observation (EO) missions are planned for the coming years. South Korea plans to launch a radar satellite, the primary mission of which is generation of high resolution (1 meter) data to facilitate development of Korean geographic information systems, as well as monitoring climate, ocean, land, and disaster management.[226] Its launch is scheduled for summer 2011 by the Russian company Cosmotras.[227] A domestically built Turkish EO satellite, initially scheduled for launch by Russia in December 2010,[228] was postponed until April 2011.[229] On 21 November, Iranian defense minister Ahmad Vahimi claimed that the country was working on various satellites, some of which would be launched "in the near future."[230] Possibly among them is the country's first EO satellite, the Rasad (Observation), slated for launch in 2011.[231] Russia and South Africa signed a memorandum of understanding regarding cooperation in EO activities.[232] Within the framework of cooperation with African countries, Russia will launch South Africa's ZA-002 SumbandillaSat,[233] as well as two Nigerian EO satellites.[234]

The EO data systems also continued to evolve during 2010. In November, a conference of the Group on Earth Observations brought the Global Earth Observation System of Systems to the implementation phase. The European Commission and the Council adopted a joint declaration setting the goal of adopting GMES regulation and initial operations.[235] During 2011, the Commission will consider ways to complete the overall GMES governance structure and present a new legislative proposal on this program beyond its initial operations. The Russia-driven EO monitoring and rescue system (MAKSM) received the support of Roscosmos; development and implementation are estimated to cost $10-billion.[236] In September, the first Chinese EO micro-satellite was successfully launched,[237] and the Indian Cartosat[238] was launched in July. ESA's CryoSat was also successfully launched from Baikonur in April[239] and will be used to monitor Earth's ice fields.[240]

Space Security Impacts

The development of and reliance on space systems for global utilities support their reliability and give countries a strong incentive to ensure safe and responsible space operations. Progress made on the compatibility and interoperability of space-based communications, Earth Observation, and navigation systems will likely have a positive impact on space security. However, increasing competition for radio frequencies represents a potential source of international friction and should be watched closely. Maintaining space for global utilities will likely require greater international cooperation to reduce the risks of orbital debris, protect the spectrum required by space systems, and promote safe and responsible space operations.

CHAPTER FIVE

Commercial Space

This chapter assesses trends and developments in the commercial space sector, which includes manufacturers of space hardware such as rockets and satellite components, providers of space-based information such as telecommunications and remote sensing, and service operators for space launches. Also covered in this chapter are the developments related to the nascent space tourism industry, as well as the relationship between commercial operators and the public sector.

The commercial space sector has experienced dramatic growth over the past decade, largely as a result of rapidly increasing revenues associated with satellite services provided by companies that own and operate satellites, as well as the ground support centers that control them. This growth has been driven by the fact that space-based services that were once the exclusive purview of governments, such as satellite-based navigation, are now widely available for private customers. In 2010 alone, the world satellite industry had revenues in excess of $168-billion.[1] As well, companies that manufacture satellites and ground equipment have contributed significantly to the growth of the commercial space sector. This includes both direct contractors that design and build large systems and vehicles, smaller subcontractors responsible for system components, and software providers.

This chapter also assesses trends and developments associated with access to space via commercial launch services. In the early 2000s, overcapacity in the launch market and a reduction in commercial demand combined to depress the cost of commercial space launches. More recently, an energized satellite communication market and launch industry consolidation have resulted in stabilization and an increase in launch pricing. Revenues from 23 commercial launch events in 2010 were close to $2.45-billion,[2] an increase of $43-million over 2009.[3]

This chapter also examines the relationships between governments and the commercial space sector, including the government as partner and the government as regulator, and the growing reliance of the military 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. Indeed, the space launch and manufacturing sectors rely heavily on government contracts. The retirement of the space shuttle in the U.S., for instance, will likely open up new opportunities for the commercial sector to provide launch services for human spaceflight. Conversely, because space technology is often dual-use, governments have sometimes taken actions such as the imposition of export controls, which impact the growth of the commercial market. There is also evidence that commercial actors are engaging governments on space governance issues, in particular space traffic management and best practices, and space situational awareness.

Space Security Impact

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. This has a positive impact on space security by increasing the number of actors that can access and use space or space-based applications, thereby creating a wider pool of stakeholders with a vested interest in the maintenance of space security. 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.

Commercial space efforts have the potential to increase the level of transnational cooperation and interdependence in the space sector, thereby enhancing transparency and confidence among international partners. Additionally, the development of the space industry could influence, and be influenced by, international space governance. To thrive, sustainable commercial markets must have the freedom to innovate, but they also require a framework of laws and regulations on issues of property, standards, and liabilities.

Issues of ownership and property may also pose a challenge to the growth of the industry. For example, while the non-appropriation clause of the Outer Space Treaty is generally understood to prohibit ownership claims in space, this clause also raises questions about the allocation and use of space resources, which are utilized by a variety of space actors, but are technically owned by no one.

Growth in space commerce has already led to greater competition for scarce space resources such as orbital slots and radio frequencies. To date, the ITU and national regulators have been able to manage inter- and intra-industry tensions. However, strong demand for additional frequency allocations and demands of emerging nations for new orbital slots will provide new challenges for domestic and international regulators. The growing dependence of certain segments of the commercial space industry on military clients could also have an adverse impact on space security, by making commercial space assets the potential target of military attacks.

Trend 5.1: The global commercial space industry continues to experience overall growth, but seeks creative solutions to offset probably future downturn

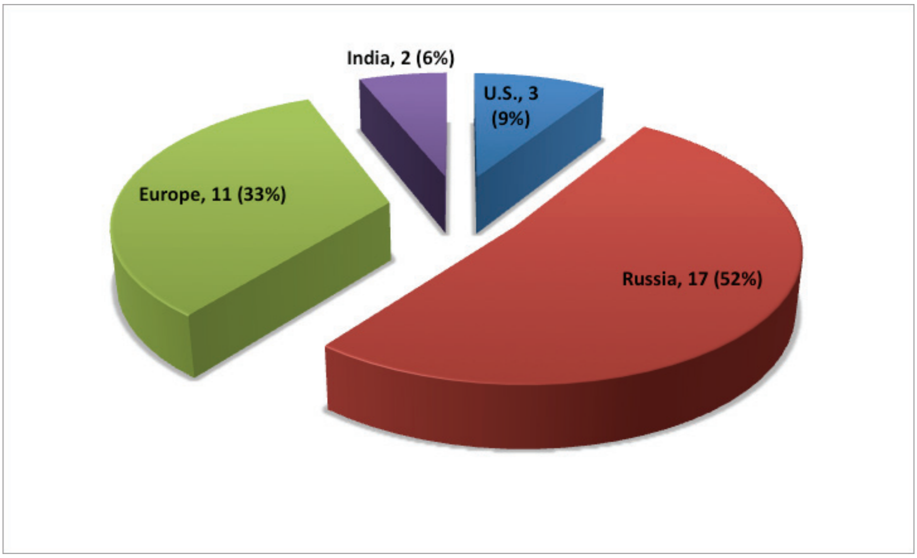
Commercial space revenues have steadily increased since the mid-1990s, when the industry first started to grow significantly. The satellite industry is made up of four major segments: ground equipment, satellite services, launch industry, and satellite manufacturing, with satellite services accounting for approximately 60 per cent of total worldwide revenues.[4] Between 2009 and 2010, the ground equipment and launch industry segments remained steady with, respectively, 31 per cent and 3 per cent of total revenues. Satellite manufacturing decreased slightly in 2010 to 6 per cent from 8 per cent in the previous year; satellite services grew from 58 per cent to 60 per cent.[5] Growth in services such as telecommunications has been largely driven by commercial rather than government demand; this trend is mirrored in other sectors.

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.[6] Satellite industry revenues were first reported in 1978, when Communication Satellite Corporation claimed 1976 operating revenues of almost $154-million.[7] By 1980, it is estimated that the worldwide commercial space sector already accounted for revenues of $2.1-billion.[8] 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.[9] 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.

More satellite launches and a growing satellite services sector have a direct impact on the commercial manufacturing industry. 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.[10] Of the 110 payloads carried into orbit in 2010, 33 provide commercial services and the remaining 77 perform civil government, nonprofit, or military missions.[11]

Figure 5.1: Commercial payloads launched by country in 2010[12]



The shape of the commercial space industry is beginning to shift as it becomes more global. Although it is still dominated by Europe, Russia, and the U.S., countries including India and China are starting to become involved. Developing countries are the prime focus of these efforts.[13] India has been positioning itself to compete for a portion of the commercial launch service market by offering lower-cost launches,[14] and it also intends to compete in the satellite manufacturing industry.[15] For the first time in 2007, China both manufactured and launched a satellite for another country, Nigeria's Nigcomsat-1.[16] Moreover, because it uses no U.S. components, China has marketed manufactured satellites as free of International Traffic in Arms Regulations (ITAR) restrictions, reportedly at prices below industry standard.[17]

The 2000 downturn in the technology and communications sectors affected the commercial space sector, reducing market take-up of satellite telephony and creating overcapacity in the launch sector. The number of commercial satellite launches dropped from a peak of 38 in 1999 to 16 in 2001. The sector has since recovered, with 33 global launches in 2010.[18] The commercial launch market continues to be dominated by Russia and Europe, followed by the U.S. Currently, satellite operators are tapping into the strong demand for new services to compensate for a possible decrease in new satellite orders, as described below.

2010 Development

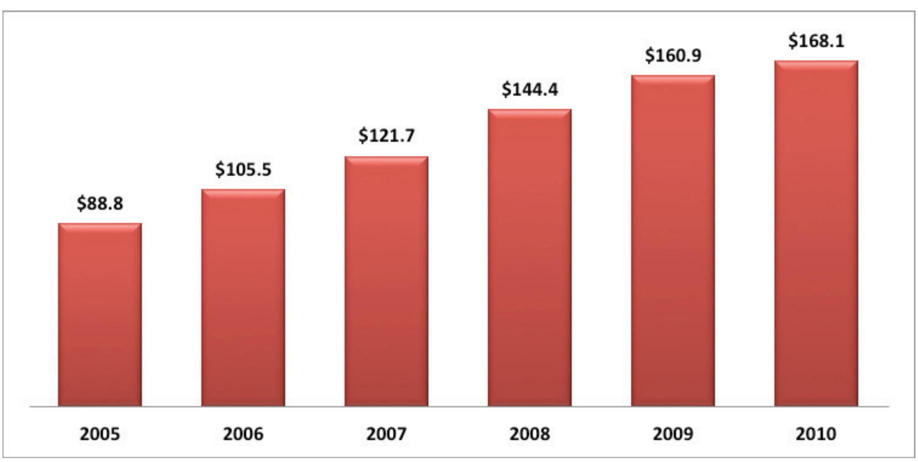
New applications in response to Federal Communications Commission (FCC) Ancillary Terrestrial Component regulations could help compensate for downturn

In the face of decreased orders for satellite fleet replenishment, manufacturers and launch providers are looking to the robust demand for new services to facilitate new satellite orders.[19] One such sector is Mobile Satellite Services (MSS). Despite an antenna malfunction, MSS operator LightSquared launched its first satellite in November 2010.[20] The company intends to roll out the first coast-to-coast hybrid wireless network, positioning itself to compete with AT&T Inc. and Verizon Wireless in the provision of mobile services.[21] The company's satellite operations will be integrated with a ground-based network utilizing Long-Term Evolution (LTE) technology.[22]

LightSquared will provide nationwide services from its commercial launch date through satellite coverage and roaming partnerships, as it continues to extend its footprint while expecting partners will begin launching LightSquared-enabled products during the second half of 2011. The company's enabled devices include data cards, embedded modules, personal hotspots, and routers — scheduled to become available during the second half of 2011. By 2012, LightSquared's service hopes to expand to incorporate smart phones and other innovative next-generation devices.

Per its commitment to supporting the National FCC Broadband Plan, it expects to cover at least 100 million Americans by 31 December 2012, 145 million by the end of 2013, and 260 million by the end of 2015. In November 2010, LightSquared filed its ATC (Ancillary Terrestrial Component) Modification Request with the FCC, asserting that its business plan had evolved and explaining how it remained in compliance with the FCC's Integrated Service Rule.[23] That rule ensures that MSS operators seeking to provide terrestrial service achieve the purposes for which the ATC regime was enacted by establishing gating criteria that guarantee that the added terrestrial component will remain ancillary to the principal MSS offering.[24] Rather than granting the requested modification, the FCC instead granted a conditional waiver to LightSquared, allowing it to go forward with its plans while meeting certain delineated criteria.[25]

Figure 5.2: World satellite industry revenues by year (in $B)[26]



It remains unknown whether and how the FCC's possible MSS rule change will affect LightSquared's plan.[27] In July, the FCC adopted a Notice of Proposed Rulemaking and Notice of Inquiry to promote investment and deployment of terrestrial wireless facilities in two ways: 1) by amending spectrum allocation tables to create co-primary fixed and mobile wireless allocations next to current satellite allocations for 40 MHz in the 2.1 and 2.2 GHz bands; and 2) by employing the FCC's spectrum leasing rules to all MSS spectrum.[28] Ultimately, the FCC granted the company a conditional waiver of its Integrated Service Rule.[29]

In December 2010, AT&T reported that it had experienced a 5,000 per cent increase in its data traffic, mainly due to the growing customer desire for smart phones;[30] the requirement for cellular telephone backhaul is another factor driving new growth.[31] Analyst firm Creative Strategies estimates that by 2012 smart phones will account for 65 per cent of all phones sold in the U.S. To compensate for the voracious appetite these devices have for data and the increase in wireless data traffic, operators are reconfiguring infrastructure and including backhaul in business planning.[32]

2010 Development

Significant growth in commercial remote-sensing business

The commercial remote-sensing industry continues to expand substantially, but is changing its business model. It lessened its dependence upon sales to the military and government, instead expanding into urban planning, natural resource exploitation, agriculture, mapping and navigation, transportation, and scientific study of the Earth's climate.[33] Euroconsult estimates a growth spurt of 27 per cent per annum since 2007 for sales of commercial data.[34] This shift in market dynamics prompted German satellite-imagery provider RapidEye to announce in September that it is seeking a new investor to sustain it during its transition, to invest in new market development, to upgrade and improve current systems, to initiate development of new geo-information products and services, and to prepare for the second generation of satellites.[35]

At the Symposium on Earth Observation Business held in Paris in September, Surrey Satellite Technology Ltd. (SSTL) announced that the construction of a one-meter third-generation Disaster Monitoring Constellation (DMC) to operate on a lease basis for the provision of commercial imagery was being considered.[36] SSTL and Blue Planet have reportedly been courting Microsoft and Google as possible investors for this type of high-accuracy satellite constellation, which the companies believe could drive down the cost of commercial satellite imagery by a factor of 10 or more.[37]

2010 Development

Top satellite supplier Space Systems/Loral evaluates ways to offset imminent sales decrease

On 5 November, Loral Space and Communications, owner of Space Systems/Loral (SS/L), announced that a sale or spinoff of its satellite manufacturing subsidiary is likely.[38] SS/L had become the top commercial satellite supplier worldwide after emerging from its 2005 Chapter 11 bankruptcy.[39] Now it is considering a change in ownership or an initial public offering[40] to offset the imminent decrease in sales,[41] as new orders for satellites drop. To that end, SS/L began a dialogue with the U.S. Securities and Exchange Commission in November.[42] The decision is largely contingent upon the actions of satellite operator Telesat — in which Loral has a 64 per cent stake — which could decide to pursue a stock offering, eventually triggering the transaction.[43]

Space Security Impact

The diversification of space applications has an overall positive impact on space security. The development of new products and services lessens dependence upon one facet of commercial activity, thus helping to insulate against fluctuations in specific markets. A great positive impact can be found in the remote-sensing sector, which has developed new markets. Increased access to space assets and applications has both positive and negative impact. On the one hand, the pool of stakeholders with a direct interest in preserving space as a peaceful domain is steadily growing. On the other, issues of congestion, competition, and spectrum management become more pressing as commercial space activity increases and could potentially result in friction among providers of commercial services.

Trend 5.2: Commercial sector supports increased access to space products and services

Space Launches

For a launch to be considered commercial, at least one of the payload's launch contracts must be subject to international competition; thus, in principle, a launch opportunity is available to any capable launch services provider. Russian, European, and U.S. companies remain world leaders in the commercial launch sector, with Russia launching the most satellites annually, both commercial and in total. Generally, launch revenues are attributed to the country in which the primary vehicle manufacturer is based. However, Sea Launch is designated "multinational" and so a clear division of revenues among participating countries is harder to establish.

Commercial space access grew significantly in the 1980s. At that time, NASA viewed the provision of commercial launches more as a means to offset operating expenses than as a viable commercial venture. European and Russian companies chose to pursue commercial launches via standard rocket technology, which allowed them to undercut U.S. competitors during the period when the U.S. was only offering launches through its Space Shuttle.

Increasing demand for launch services and the ban of commercial payloads on the Space Shuttle following the 1986 Challenger Shuttle disaster encouraged further commercial launch competition. The Ariane launcher, developed by the French in the 1980s, captured over 50 per cent of the commercial launch market during the period 1988-1997.[44] The Chinese Long March and the Russian Proton rocket entered the market in the early and mid-1990s. Although the Long March was pushed out of the commercial market because of "reliability and export control issues,"[45] China has opened the possibility of reentering it.[46] Today, Ariane, Proton, and Zenit rockets dominate the commercial launch market.

Japanese commercial efforts have suffered from technical difficulties and its H-2 launch vehicle was shelved in 1999 after flight failures.[47] Although the H-2 was revived in 2005, Japan lags behind Russia, Europe, the U.S., and China in global launches.[48] In May 1999, India's Augmented Polar Satellite Launch Vehicle performed the country's first LEO commercial launch, placing German and South Korean satellites in orbit.[49]

Top commercial launch providers include Boeing Launch Services and Lockheed Martin Commercial Launch Services (vehicles procured through United Launch Alliance) and Orbital Sciences Corporation in the U.S.; Arianespace in Europe; ISC Kosmotras, Polyot (with partners), and ZAO Puskovie Uslugi in Russia; Antrix in India; China Great Wall Industry Corporation in China; and international consortia Sea Launch, International Launch Services (ILS), Eurockot Launch Services GmbH, and Starsem. Sea Launch —

comprised of Boeing (U.S.), Aker Kvaerner (Norway), RSC-Energiya (Russia), and SDO Yuzhnoye/PO Yuzhmash (Ukraine) — operates from a mobile sea-based platform located on the equator in the Pacific Ocean. ILS was established as a partnership between Khrunichev State Research and Production Space Center (Russia), Lockheed Martin Commercial Launch Services (U.S.), and RSC-Energiya (Russia). In 2006, Lockheed sold its share to U.S. Space Transport Inc. Eurockot is a joint venture between EADS Space Transportation and Khrunichev, while Starsem is a joint venture between the Russian Federal Space Agency, TsSKB-Progress, EADS Space Transportation, and Arianespace. Commercial launch vehicle builders such as Space Exploration Technologies (SpaceX) have become increasingly active in research and development and are seeking to compete by providing cheaper, reusable launch vehicle systems such as the Falcon 9.

In addition to a proliferation of rocket designs, the launch sector has also seen innovations in launch techniques. For example, since the early 1990s companies such as the U.K.'s Surrey Satellite Technology Ltd. have used piggyback launches, in which a small satellite is attached to a larger one. It is now also common to use small launchers such as the Cosmos rocket and India's PSLV to deploy clusters of smaller satellites.

Commercial Earth Imagery

Until a few years ago only a government could access remote sensing imagery; today any individual or organization with access to the Internet can use these services through Google Maps, Google Earth, and Yahoo Maps programs.[50] Currently several companies in Canada, France, Germany, Israel, Russia, and the U.S. are providing commercial remote sensing imagery. The resolution of the imagery has become progressively more refined and affordable. In addition to optical photo images, synthetic aperture radar images up to one meter in resolution are coming on the market and a growing consumer base is driving up revenues. Security concerns have been raised, however, due to the potentially sensitive nature of the data.

Commercial Satellite Navigation

Initially intended for military use, satellite navigation has emerged as a key civilian and commercial service. The U.S. government first promised international civilian use of its planned Global Positioning System in 1983, following the downing of Korean Airlines Flight 007 over Soviet territory, and in 1991 pledged that it would be freely available to the international community beginning in 1993.[51] While GPS civilian signals have dominated the commercial market, new competition may emerge from the EU's Galileo system, which is specifically designed for civilian and commercial use, and Russia's GLONASS.[52] China's regional Beidou system will also be available for commercial use.[53] (For further information on satellite navigation systems see Chapters 4 and 6.)

The commercial satellite positioning industry initially focused on niche markets such as surveying and civil aviation, but has since grown to include automotive navigation, agricultural guidance, and construction.[54] Sales of ground-based equipment provide the core of revenues to the commercial satellite positioning industry. Commercial users first outpaced military buyers in the mid-1990s.[55] The commercial GPS market continues to grow with the introduction of new receivers that integrate the GPS function into other devices, such as cell phones.[56]

Commercial Space Transportation

An embryonic private spaceflight industry continues to emerge, seeking to capitalize on new concepts for advanced, reliable, reusable, and relatively affordable technologies for launch to near-space and LEO. In December 2004, the U.S. Congress passed the "Commercial Space Launch Amendments Act of 2004." Intended to "promote the development of the emerging commercial human space flight industry," the Act establishes the authority of the Federal Aviation Administration (FAA) over suborbital space tourism in the U.S., allowing it to issue permits to private spacecraft operators to send customers into space.[57] In 2006, the ESA announced the "Survey of European Privately-funded Vehicles for Commercial Human Spaceflight" to support the emergence of a European commercial space transportation industry.[58]

The market for commercial space transportation remains small, but has attracted a great deal of interest. In September-October 2009, Canadian Guy Laliberté became the seventh and latest private citizen to fly in space through Space Adventures, which sells seats on the Russian Soyuz.[59] Prices for this opportunity are increasing, with Charles Simonyi paying $25-million for his trip in 2007 and $35-million for a second trip in March 2009.[60]

In June 2004, SpaceShipOne, developed by The Spaceship Company, a joint venture between Scaled Composites and the Virgin Group, became the first private manned spacecraft, but only conducted suborbital flights.[61] It was followed by SpaceShipTwo, unveiled in December 2009 and expected to carry passengers on suborbital flights. Although a specific date for the first private flights on SpaceShipTwo has not yet been confirmed, Virgin Galactic, a subsidiary of the Virgin Group, has already started taking booking for sub-orbital flights at a cost of $200,000.[62] While the industry continues to face challenges — including a lack of international legal safety standards, high launch costs, and export regulations[63] — important liability standards are beginning to emerge. In 2006, the FAA released a set of rules governing private human spaceflight requirements for crew and participants.[64] Final rules were also issued for FAA launch vehicle safety approvals.[65]

Insurance

Insurance affects both the cost and risk of access to space. Insurance rates also influence the ease with which start-up companies and new technologies can enter the market.[66] Although governments play an important role in the insurance sector insofar as they generally maintain a certain level of indemnification for commercial launchers, the commercial sector assumes most of the insurance burden. There are two types of coverage: launch insurance, which typically includes the first year in orbit, and on-orbit insurance for subsequent years. Most risk is associated with launch and the first year in orbit. When covering launches, insurance underwriters and brokers discriminate among launch vehicles and satellite design so that the most reliable designs subsidize the insurance costs of the less reliable hardware.[67]

Following a decade of tumultuous rates due to tight supply of insurance and a series of industry losses, many companies abandoned insurance altogether, but recently there has been a softening of the launch insurance market.[68] The approximate premium for launch vehicles (as a percentage of launch costs) has recently been in the following range: Ariane-5, 6.5 per cent; Atlas-5, 6.6 per cent; Sea Launch, 7.5 per cent; Chinese Long March, 7.9 per cent; and Proton, 10.3 per cent.[69] Terms have also become more restricted. Insurers do not generally quote premiums earlier than 12 months prior to a scheduled launch and in-orbit rates are usually limited to one-year terms. It is possible that insurance costs may go higher in the future, owing to the risk caused by the significant increase in space debris in recent years.[70]

With the advent of space tourism, the space insurance industry may expand to cover human spaceflight. In the U.S., the FAA requires commercial human spacecraft operators to purchase third-party liability insurance, although additional coverage is optional. Each of the first two space tourists purchased policies for training, transportation, and time spent in space.[71]

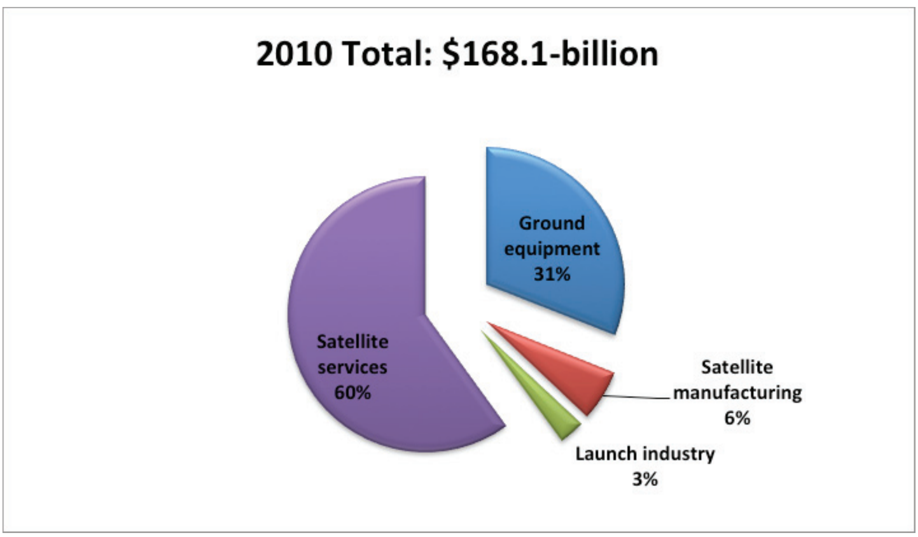
2010 Development

Two new services bring high-speed Internet to underserved markets

With pockets of Europe and the Mediterranean still lagging behind the digital age in terms of Internet connectivity, in 2010, two companies launched satellites with new technology capable of providing broadband via satellite.[72] On 26 November, Avanti Communications, a startup U.K. company, launched the first European spacecraft dedicated to providing broadband Internet access via satellite.[73] With the $159-million satellite, the company plans to serve Europe, the Middle East, and Africa and hopes for a base of up to 1.2 million customers.[74]

Between mid-November and late December, Eutelsat launched three satellites to provide broadband service to Europe, the Mediterranean, and North America.[75] The third of these, a $475-million satellite primarily targeting the European market, is larger than Avanti's and is capable of providing broadband to two million homes. Although already available in the U.S., the new services are the first outside that market to operate on a new transmission frequency providing true broadband speeds.[76] The satellite, called Ka-Sat, will provide ample coverage for Europe with 80 spot beams, which allow for frequencies to be reused in various regions without interference, resulting in increased capacity.[77] Both Avanti and Eutelsat plan to market through Internet providers rather than directly to end-users.[78]

Figure 5.3: Worldwide satellite industry revenue by sector (2010)[79]



A related new enterprise is Google's initiative to bring high-speed Internet to remote areas of the developing world by promoting effective FCC management of spectrum resources and comprehensive review of competition rules.[80] The company put out its Request for Information in February to help identify interested communities.[81] Google is planning to build and test ultra-high speed broadband networks in a small number of trial locations across the U.S. It hopes to transmit data at Internet speeds more than 100 times faster than what most Americans have access to today with 1 gigabit per second, fiber-to-the-home connections, and to offer service at a competitive price to at least 50,000 and potentially up to 500,000 people.[82]

2010 Development

Use of small satellites increases, providing a possible new market for dedicated launcher

Small satellites are proving useful in a variety of scenarios: academic, military, civil, and commercial.[83] These versatile miniatures can access space either as a secondary payload or on a dedicated, expendable launch vehicle.[84] As small satellites fill the manifests for more and more launches, Interorbital Systems (IOS), a company based at the Mojave Air and Spaceport, is developing a launch vehicle dedicated to the launch of these small satellites and the kits that rocket will lift. The launcher under construction, Neptune 45, is a modular system built of standard modules common to the design of predecessor IOS launch vehicles.[85] The company plans to carry out its first orbital launch in 2011from Tonga, hoping to decrease standard spaceport launching fees.[86]

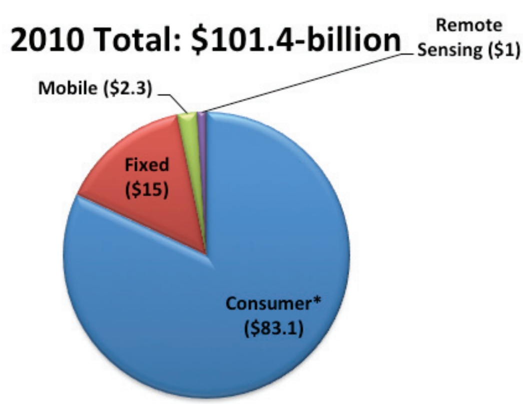
2010 Industry Updates

Recognizing the imperative for reasonable development time and lower costs, SpaceX will respond to a NASA study and offer guarantees on future heavy-lift launches (150 tons to orbit @ < $300M/launch).[87] The SpaceX Dragon capsule successfully reentered the Earth's atmosphere on 8 December, becoming the first privately owned spacecraft recovered from orbit. This achievement places SpaceX at the forefront of private space transport to the ISS.[88] In 2008, SpaceX won the right to resupply cargo to the ISS as a part of NASA's Commercial Orbital Transportation System (COTS), along with Orbital Sciences Corp (OSC).[89]

Also as a part of COTS, Thales Alenia was working on the cargo module Cygnus for OSC.[90] Thales expected to deliver the module, essentially a new spaceship,[91] in time for the February 2011 COTS qualification flight.[92] As well, Thales Alenia committed to supply three more communications payloads of Russian ISS satellites, continuing longstanding ties to the Russian space sector.[93] The satellites will expand direct-to-home services and develop new broadcasting markets such as high-definition and 3-D television, and replace aging spacecraft. The result will be increased access to the global market for Russian firms.[94]

With the Commercial Crew Development (CCDev) competition, NASA is stimulating the private sector to develop and demonstrate safe, reliable, and cost-effective transportation to deliver first cargo, and ultimately crew, to LEO and the ISS.[95] Originally funded with $50-million, CCDev is now distributing $200-million. To date, seven companies are vying for these funds: ATK, Blue Origin, Boeing, OSC, Sierra Nevada Corporation, SpaceX, and United Launch Alliance.[96]

Figure 5.4: 2010 worldwide satellite services revenue (in $B)[97]



* Includes satellite TV, satellite radio, and consumer satellite broadband.

At the Spaceport America runway dedication in Las Cruces on 22 October, Sir Richard Branson publicly declared Virgin Galactic's intentions to go orbital, despite the likely timeframe of 9-18 months before actual suborbital spaceflight participant operations.[98] In addition, Branson discussed the possibility of point-to-point transportation, an application achievable by suborbital vehicles such as SpaceShipTwo, in which the craft would launch from a spaceport in one country and land halfway around the world in another, in significantly less time than traditional aircraft.[99] Virgin Galactic completed its fourth glide test over the California desert in mid-January 2011.[100]

In April, the Space Data Association, formed by commercial operators to support data-sharing to better facilitate space situational awareness, entered into a contract with AGI, its technical advisor.[101]

Three years after launching the competition, Google Lunar X Prize (GLXP) closed its registration, reporting that 24 teams had registered for the race to the Moon.[102] GLXP hosts interactive events for competitors and observers, such as Friday Funday Q & A sessions, Photoshop contests, and submissions of YouTube videos.[103] One innovative team, the Rocket City Space Pioneers, builds its business model on the purchase of a SpaceX Falcon 9 launch for $60-million, reselling excess capability on the rocket for twice the price.[104]

2010 Development

Intelsat satellite Galaxy-15 goes adrift following malfunction, reestablishes contact nearly nine months later

As described in Chapter 1, on 4 April Galaxy 15 suffered an anomaly which left it drifting without contact across the western edge of the arc of satellites used by cable programmers.[105] In April, Intelsat sent over 200,000 commands to the satellite in an unsuccessful attempt to either turn off its communications payload or maneuver it to stop the drift.[106] Service was not affected as Intelsat successfully transitioned service from Galaxy 15 to Galaxy 12.[107] On 29 December, Intelsat announced that it had regained full control of Galaxy 15.[108] On 13 January 2011, Intelsat announced that it would be moving Galaxy 15 to an orbital slot at 93W for a full systems checkout.[109] Afterwards, the satellite could be put back into service in its original slot. In an effort to avert similar events in the future, the company uploaded new software. After testing and relocating the satellite in safe mode while still in-orbit, the company will determine its functionality.[110]

Space Security Impact

Developing underserved markets also creates more stakeholders with a vested interest in space security. The malfunction of the Galaxy-15 satellite showed how to responsibly manage an unexpected event that might otherwise have had a detrimental effect on space security. That the satellite corrected according to design has a positive impact upon security. The event also provides the industry with a working model of how to respond to similar problems transparently and collaboratively. The commercial sector's continued development has a positive impact upon access to space, but also comes at the price of congestion. Furthermore, developing regulations for private international corporations, including those venturing into the uncharted realm of space tourism, might be as challenging as regulating state activities in space.

Trend 5.3: Continued government dependency on the commercial space sector develops interactions between public and private sectors

Government Support

Governments have played an integral 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.

A report commissioned by the FAA indicates that a successful U.S. commercial launch industry is viewed as "beneficial to national interests."[111] The U.S. Space Launch Cost Reduction Act of 1998 established a low-interest loan program to support the development of reusable vehicles.[112] In 2002, the U.S. Air Force 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.[113] 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.[114] The U.S. Commercial Remote Sensing Space Policy directs the U.S. government to "rely to the maximum practical extent on U.S. commercial remote sensing space capabilities for filling imagery and geospatial needs for military, intelligence, foreign policy, homeland security, and civil users" to "advance and protect U.S. national security and foreign policy interests by maintaining the nation's leadership in remote sensing space activities, and by sustaining and enhancing the U.S. remote sensing industry."[115]

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.[116] 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.[117] 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."[118]

Russia's commercial space sector maintains a close relationship with its government, receiving contracts and subsidies for the development of the Angara launcher and launch site maintenance.[119] China's space industry is indistinguishable from its government, with public and private institutions closely intertwined.[120] The industries responsible for supporting China's space program fall under the auspices of the China Aerospace Science and Technology Corporation (CASC), which is directly linked to the government.

In many instances, governments are partnering with the private sector to subsidize the commercial development of systems also intended to meet national needs. For example, the U.S. National Geospatial-Intelligence Agency's (NGA) NextView program included subsidies for commercial remote sensing to meet military needs for high-resolution images, which are then for sale commercially at a lower resolution.[121] The commercial Radarsat-2 satellite was largely paid for by the Canadian Space Agency, which spent $445-million to pre-purchase data that is also sold commercially.[122] This arrangement is similar to that for Germany's TerrSar-X remote sensing satellite.[123]

Remote sensing is not the only instance of such partnering. The U.K.'s Skynet-5 secure military communications satellite is operated by a private company, which sells its excess capacity.[124] 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.[125]

Export controls

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.

The Missile Technology Control Regime, formed in 1987, is composed of 34 member states seeking to prevent the further proliferation of capabilities to deliver weapons of mass destruction by collaborating on a voluntary basis to coordinate the development and implementation of common export policy guidelines.[126] However, export practices differ among members. For example, although the U.S. "Iran Nonproliferation Act" of 2000 limited the transfer of ballistic missile technology to Iran, Russia's Federal Law on Export Control still allowed it.[127] Most states control the export of space-related goods through military and weapons-of-mass-destruction export control laws, such as the Export Control List in Canada, the Council Regulations (EC) 2432/2001 in the EU, Regulations of the People's Republic of China on Export Control of Missiles and Missile-related Items and Technologies, and the WMD Act in India.[128]

From the late 1980s to the late 1990s, the U.S. had agreements with China, Russia, and Ukraine to enable the launch from foreign sites of U.S. satellites and satellites carrying U.S. components. In 1998, a U.S. investigation into several successive Chinese launch failures led to allegations of the transfer of sensitive U.S. technology to China by aerospace companies Hughes Electronics and Loral Space & Communications Ltd. Concerns sparked the transfer of jurisdiction over satellite export licensing from the Commerce Department's Commerce Control List to the State Department's U.S. Munitions List (USML) in 1999.[129] In effect this placed satellite sales in the same category as weapons sales, making international collaborations more heavily regulated, expensive, and time consuming.

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. As a result of such stringent requirements, the case has been made that "the unintended impact of the regulation change has been that countries such as China, Pakistan, India, Russia, Canada, Australia, Brazil, France, the United Kingdom, Italy, Israel, the Republic of Korea, Ukraine, and Japan have grown their commercial space industries, while U.S. companies have seen dramatic losses in customers and market share."[130] Industries are maneuvering around ITAR restrictions by purchasing ITAR-free satellites and launch services. For instance, China was able to launch the Chinasat 6B telecommunications satellite, built by Thales Alenia Space, on its Long March launcher because the satellite was built without U.S. components. Thales Alenia Space is the only western company that has deliberately designed a product line to avoid U.S. trade restrictions on its satellite components.[131]

Finally, because certain commercial satellite imagery can serve military purposes, a number of states have implemented regulations on the sector. The 2003 U.S. Commercial Remote Sensing Policy set up a two-tiered licensing regime, limiting the sale of sensitive imagery.[132] In 2001, the French Ministry of Defense prohibited open sales of commercial Spot Image satellite imagery of Afghanistan.[133] Indian laws require the 'scrubbing' of commercial satellite images of sensitive Indian sites.[134] 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.[135]

Commercial space systems as critical infrastructure

Space systems, including commercial systems, are increasingly considered to be critical national infrastructure and strategic assets. During the 1990s, the U.S. military began employing commercial satellite systems for non-sensitive communications and imagery applications.

The U.S. DOD is the single largest customer for the satellite industry, although it accounts for less than 10 per cent of the revenue of most large satellite operators.[136] By November 2003, it was estimated that the U.S. military was spending more than $400-million each year on commercial satellite services.[137] By 2006, this figure had jumped to more than $1-billion a year for commercial broadband satellite services alone.[138] For instance, three years after Operation Iraqi Freedom began, it was reported that more than 80 per cent of satellite bandwidth utilized by DOD was provided by commercial broadband satellite operators.[139] A 2003 U.S. General Accounting Office report recommended that the U.S. military be more strategic in planning for and acquiring bandwidth by, inter alia, consolidating bandwidth needs among military actors to capitalize on bulk purchases.[140]

European states also view the space sector as a strategic asset "contributing to the independence, security, and prosperity of Europe."[141] And China's 2006 White Paper on Space Activities identified the development of an independent space industry as a key component of its goals for outer space.[142]

Governance

While governments and industry have long worked together to develop and control the commercial space sector, there is evidence that they may also start working together to provide better governance in outer space. As noted in chapter 3, it has been hard to reach international consensus on a broad regulatory framework for outer space activities. Following the Chinese interception of one of its own satellites in 2007, Dave McGlade, CEO of Intelsat, added his voice to those of several governments in calling for a code of conduct or rules of the road to provide norms and guidelines on space activities.[143] The importance of the private sector in space safety and governance issues has also been highlighted by the U.S. government. Under the SSA Sharing Program, previously called the Commercial and Foreign Entities program, the DOD is attempting to align government and industry resources to address growing space security challenges and increase space situational awareness (see chapter 2 for further information). The draft EU Code of Conduct for Outer Space Activities[144] specifically addresses harmful interference with space assets, but is not legally binding; the level of international support it will receive when it opens for signatures is unclear.

2010 Development

Changes to U.S. Space Policy affect U.S. space companies and create uncertainty at NASA

On 28 June, the U.S. released its new National Space Policy, which focuses on maintaining a robust and competitive industrial base in the U.S. and specifically seeks partnerships with the private sector to enable commercial spaceflight capabilities for the transport of crew and cargo to and from the ISS. In furtherance of U.S. exploration objectives, the policy's "bold new approach to space exploration," which in effect cancels the NASA Constellation lunar program, argues for the development of a new heavy lift vehicle.[145] However, the net effect may be uncertainty for U.S. companies and the space industry worldwide.[146] One change is that private companies servicing the ISS will not be required to launch from Kennedy Space Center, but will have the discretion to determine the site that works best.[147] Generally, the shift in NASA's mandate should provide stimulation for private launch companies and those involved in commercial human spaceflight.[148]

SpaceX has gained credibility as a viable means of transport for NASA. By successfully reentering Earth's atmosphere, SpaceX joined a club that previously included only five nations: the U.S., Russia, China, Japan, and India. SpaceX is now a credible option for ISS transport.[149] Not only was this SpaceX flight the FAA's first-ever commercial license to reenter a spacecraft from Earth orbit, it was also the first under NASA's COTS program and the first flight of an operational Dragon spacecraft. SpaceX CEO Elon Musk said he could be launching station crews within three years of NASA approval. SpaceX has a $1.6-billion contract with NASA for 12 supply runs, while OSC has a $1.9-billion contract for eight.[150]

2010 Development

Export credit agency financing makes projects viable

Export credit agency financing, or financing supported by governmental departments and/or agencies,[151] has become a viable source of funding for new satellite projects.[152] Faced with bleak prospects in the aftermath of three large bankruptcy reorganizations (Iridium, Globalstar, and ICO Global Communications), manufacturers turned to another source of money to back second-generation constellations: export credit agencies.[153] While the availability of financing has revitalized the industry during difficult economic times, it is not without its critics. Some see the loans as government subsidies used to support nationals and direct business.[154]

2010 Development

The European launch sector scrutinizes Arianespace, considers changes in governance and shareholding structure

Although Arianespace benefitted from a successful 6-for-6 launch year in 2010, the consortium faces the challenge of decreased revenues[155] and increased expenses related to two new launch vehicles, the Soyuz 2 medium lifter and the Vega light booster. It has requested governmental aid[156] and the European launch community is examining both Arianespace's governance and shareholding structure.[157] Germany leads a group of ESA countries in a renewed call for private ownership of Arianespace. France, whose CNES owns 32.5 per cent of the company's stock at present, leads a group supporting control by public entities.[158] Still others would remain with the status quo — a mixed public-private shareholding setup — but with a different governance mechanism.[159]

2010 Development

ISS partners agree to publish interface standards for interoperable spacecraft docking

In an initiative that will allow engineers anywhere in the world access to information to build docking systems for the current ISS and future missions, the ISS Multilateral Coordination Board has approved a standards for a common docking interface[160] and ISS partners published the new set of standards.[161] All that is needed to download the information is an Internet connection.[162] The standards provide what is necessary to dock both crewed and uncrewed vehicles to the ISS. The standards do not provide specific data regarding actual technology, but measurements and force loads describing physical interfaces.[163] Technology transfer is not an issue, with standards available to China and India as well as commercial companies.[164]

Space Security Impact

Increased interaction between the public and private sectors in collaborative space projects has an overall positive impact upon space security. However, this impact is somewhat offset by the uncertainties caused by changes in U.S. Space Policy. Still, these interactions, often more intricate than simple partnerships, better spread the risks among actors and can supply a more cost-effective distribution of public services/public goods. Furthermore, the publication of ISS docking standards provides sustainable access to states and companies beyond the ISS partners, without sacrificing national security. And it potentially increases the number of stakeholders with a vested interest. A negative impact could result if hosted payloads make commercial assets a target, but no such developments in this area are noted for 2010.

Trend 5.4: Commercial space operators gradually embrace cyberspace capabilities

The link between cyberspace and outer space is becoming increasingly important for commercial operators as they seek to capitalize on emerging technologies that enable space-based Internet Protocol-enabled services. Although still in the early stages of development, these services are expected to deliver cost-effective connectivity for military and commercial users.

A key driver for the development of such technologies has been a partnership between the U.S. military and the commercial sector. The Internet Router in Space (IRIS) Joint Capability Technology Demonstration is a DOD demonstration program managed by a Cisco-led team that also includes Intelsat General.[165] The nature of the government-commercial partnership is innovative as, "rather than Department of Defense dictating requirements to industry, the consortium would design, develop and launch the capability at its own expense to meet their market forecast."[166]

IRIS, launched on board Intelsat-14 in 2009,[167] was designed to support network services for voice, video, and data communications.[168] The most significant advantage over conventional satellite technology is that the system eliminates the need to send data to and from an extra ground station, which can be expensive and time-consuming.

2010 Development

Aerospace e-business platform Exostar providing cloud services to the space industry

Exostar, long a provider of software applications to the aerospace and defense industries, transitioned from traditional log-in formats to its cloud-based Managed Access Gateway in July.[169] In addition, in October the company announced a new version of its supply chain management application, SCP2, raising the bar for aerospace and defense supply chain collaboration.[170]

However, by making cloud services available to the industry, Exostar is feeling the brunt of concerns voiced by the U.S. Aerospace Industries Association (AIA).[171] Although cloud computing makes possible increased collaboration and communication between small or mid-sized companies and much larger ones, the AIA has identified concerns related to security, availability, and interoperability, such as "controlling who can access data in the cloud, assuring the services are uninterrupted, and ensuring applications are portable between cloud providers."[172] Despite these concerns, the U.S. government is transitioning into the cloud to reduce costs and boost efficiency.[173]

2010 Development

Cisco's Internet Router in Space is an immediate hit

In an effort to transform the satellite industry, Cisco developed IRIS, an Internet Router in Space.[174] By eliminating the need to downlink and uplink data to/from an extra ground station, IRIS should prove more cost effective and less time consuming.[175] In addition, it should extend IP access to areas not covered by traditional methods – either ground or 3G.

Cisco first launched a satellite providing IRIS to the U.S. DOD in November 2009.[176] Demand for IRIS during its evaluation period exceeded company projections and Cisco offered commercial capability by the middle of 2011, sooner than originally anticipated.[177] IRIS manages traffic and processes signals aboard the spacecraft Intelsat 14, rather than using traditional satellite networks that rely on ground-based equipment. Government users, including the military, comprise the bulk of IRIS users.[178]

Space Security Impact

The commercial space community is made more efficient by the increased availability of internet services in terrestrial contexts such as cloud services. As the American Institute of Aeronautics and Astronautics notes, the security, availability, and interoperability of such services are an ongoing concern for end-users. Internet routers in space, such as Cisco's IRIS space router, eliminate the need to downlink and uplink data to/from a ground station; thus threats can be minimized and financial and time costs better managed.

CHAPTER SIX

Space Support for Terrestrial Military Operations

This chapter assesses trends and developments in the research, development, testing, and deployment of space systems that are used to support terrestrial military operations. This includes early warning; communications; intelligence, surveillance, and reconnaissance; meteorology; as well as navigation and weapons guidance applications. Although the U.S. alone 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 U.S. 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, leading U.S. President John F. Kennedy to realize that fears of a missile gap between the U.S. and the Soviet Union were greatly overstated. 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 U.S. and Russia had begun to develop satellite navigation systems that provided increasingly accurate geographical positioning information. Building upon the capabilities of its Global Positioning System, the U.S. 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 at all times.

The U.S. currently leads in deployment of dedicated space systems to support military operations, accounting for roughly half of all dedicated military satellites.[1] Russia maintains the second largest number, with roughly a quarter of the total. Together, these two nations dwarf the military space capabilities of all other actors, although several countries are pursuing space-based military capabilities. The U.S. and USSR/Russia have launched more than 3,000 military satellites, while the rest of the world have launched fewer than 100. By the end of 2010 there were over 165 dedicated military satellites worldwide.[2]

Given the overwhelming superiority of U.S. and Russian space-based military capabilities, this chapter identifies developments related to these countries as a distinct space security trend. Also assessed separately are developments related to the increasing role afforded to space-based military support in China and India. In addition, this chapter examines the efforts of a growing number of other states that have begun to develop national space systems to support military operations, primarily imagery intelligence and communications. Many of these systems are dual-use, so they also support civilian applications. This section does not examine military programs pertaining to space systems resiliency or negation, which are described in chapters 7 and 8, respectively.

Space Security Impact

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, and 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 arms escalation dynamic. 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 (OST), but state practice over the past 40 years has generally accepted these applications as peaceful insofar as they are not aggressive in space (see Trend 3.1). Space has been militarized since the first satellite, Sputnik, was placed into orbit. Of concern here is not whether militaries should use space, but rather how the use of space by militaries improves or degrades the security of space.

Trend 6.1: The U.S. and Russia continue to lead in deploying military space systems

During the Cold War, the U.S. and USSR developed military space systems at a relatively equal pace. The collapse of the USSR, however, saw a massive drop in Russian military space spending, while the U.S. expanded its military space capabilities. There has been a general decrease in the number of military launches by both states in recent years; this is, in part, explained by the longer average lifespan of modern space systems. However, U.S. and Russian dependence on military space systems appears to be increasing. While new systems are being orbited at a slower rate, they have greater capabilities and longevity and are more closely integrated with the military. Commercial systems are also playing a rapidly growing military support role. Figures 6.3 and 6.4 provide an overview of U.S. and Russian military satellite launches since 1957.

United States

The U.S. has dominated the military space arena since the end of the Cold War, and continues to give priority to its military and intelligence programs. The U.S. currently outspends all other states combined on military space applications. The Department of Defense Budget for FY2010 stood at approximately $10.6-billion for the Space-based and Related Systems funding category. This amount included, inter alia, $1.13-billion for the Evolved Expendable Launch Vehicle, $2.29-billion for the Advanced Extremely High Frequency satellite constellation, $987-million for the Space Based Infrared System, $398-million for the Defense Weather Satellite System, and $279-million for the Wideband Global SATCOM System.[3] U.S. military and intelligence space-based capabilities continue to outpace those of the rest of the world. By all indications, the U.S. is the nation most dependent on its space systems. While the U.S. is currently upgrading almost all of its major military space systems, they remain robust[4] and technically advanced.

Satellite Communications

Satellite communications have been described by one expert as "the single most important military space capability."[5] The Military Satellite Communications System (Milstar) is currently one of the most important of these systems, providing protected communications for the U.S. Army, Navy, and Air Force through five satellites in geostationary orbit. Replacement of Milstar satellites with AEHF satellites is under way in cooperation with Canada, the U.K., and the Netherlands. The DOD budget for the AEHF program in 2010 constitutes an increase of more than 300 per cent over the 2009 figure of $552-million.[6]

Development of the next-generation Transformational Satellite Communications System (TSAT), which would provide protected, high-speed, Internet-like information availability to the military, was cancelled in 2009 The program, with a projected cost of between $14-billion and $25-billion by 2016,[7] was disrupted by repeated delays; the first launch had been postponed several times.[8] More recently, DOD has partnered with a commercial sector team led by Cisco in the IRIS Joint Capability Technology Demonstration program, which is expected to support military communications. (See chapter 5 for further details.)

Table 6.1: U.S. dedicated military satellites launched in 2010[9]

Satellite	Operator	Function	Orbit	Launch Date	Contractor
AEHF-1, USA 214	U.S. Air Force	Communications	GEO	8/14/2010	Lockheed Martin Space Systems
FIA Radar 1, NROL-41, USA 215	NRO	Reconnaissance	LEO	9/21/2010	NRO
SBSS-1, SBSS Block 10 SV1, USA 216	Strategic Space Command/Space Surveillance Network	Reconnaissance	LEO	9/26/2010	Boeing/Ball Aerospace
STPSAT 2, USA 217	USAF Space Test Program	Technology Development	LEO	11/20/2010	Ball Aerospace
Orion/Mentor 5, NRO L-32, USA 223	NRO	Surveillance	GEO	11/21/2010	National Reconnaissance Laboratory

The Defense Satellite Communications System (DSCS) — the workhorse of the U.S. military's super-high frequency communications — is a hardened and jam-resistant constellation that transmits high-priority command-and-control messages to battlefield commanders using nine satellites in GEO. The planned follow-on to this system, the Wideband Global Satellite System or Wideband Global SATCOM (WGS), is expected to significantly increase available bandwidth. The $279-million 2010 DOD budget for WGS, intended to transmit data at gigabit speeds, was to be used mainly for on-orbit testing of the second and third satellites of the constellation.[10]

In addition to dedicated systems, space-based military communications use commercial operators such as Globalstar, Iridium, Intelsat, Inmarsat, and Telstar. The U.S. DOD will likely continue to use some commercial services in the future, even with the deployment of new systems.

Early Warning

Space-based early warning systems provide the U.S. with critical missile warning and tracking capabilities. The U.S. Missile Defense Alarm System was first deployed in a polar orbit in 1960. U.S. DSP early warning satellites were first launched in the early 1970s, with the final one in 2007, providing enhanced coverage of Russia while reducing the number of necessary satellites to four.[11] The U.S. plans to replace the DSP system with SBIRS to provide advanced surveillance capabilities for missile warning and missile defense. However, the completion of SBIRS is more than eight years behind schedule and significantly over budget, with an estimated final cost of more than $10-billion.[12] Details on the current status of SBIRS are discussed below. The Alternative Infrared Space System, intended to act as insurance in case of further difficulties with the SBIRS program, was redesigned in 2007 as a follow-on program, 3GIRS.[13] The U.S. STSS, discussed below, will work with SBIRS to support missile defense responses.

Intelligence

The first U.S. optical Corona satellites for imagery intelligence were launched as early as 1959, with the Soviets following suit by 1962. These early remote sensing satellites, equipped with film cameras, had lifetimes of only days. At the end of their operational lifetimes, capsules with the exposed film were ejected from the satellite and collected, usually from the ocean. Gradually, resolution of these cameras improved from about 10 m to less than one meter. As early as 1976, the U.S. began to fit its remote sensing satellites with charge-coupled devices that took digital images, which could be transmitted back to Earth via radio signal, providing near-real-time satellite imagery.[14] Open source information suggests that the U.S. currently operates between eight and 10 imagery intelligence satellites through two optical systems known as Crystal and Misty, and one synthetic aperture radar system known as Lacrosse. While the exact resolution of recent remote sensing satellites remains classified, the Improved Crystal satellites are believed to have a resolution of up to 6 inches.[15] The U.S. operates between 18 and 27 signals intelligence satellites in four separate systems — the Naval Ocean Surveillance System, Trumpet, Mentor, and Vortex.[16] The U.S. military also uses commercial imagery services from DigitalGlobe and GeoEye.

The Future Imagery Architecture, intended to provide next-generation reconnaisance capabilities through electro-optical and radar remote sensing, was cancelled in 2005 at a loss of at least $4-billion, in what has been called "the most spectacular and expensive failure in the 50-year history of American spy satellite projects."[17] The Misty Stealth Reconnaissance Imaging program was also cancelled due to costs, schedule delays, and poor performance.[18] An additional setback occurred when USA-193 failed in orbit in 2006.

Navigation

In 1964, the first navigation system was deployed for military applications by the U.S. Navy and 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 (for further information, see chapters 4 and 5). Although commercially available, the GPS system provides greater accuracy for its military users. Recent GPS updates are discussed below.

Launch
In 2007, the U.S. DOD Operationally Responsive Space (ORS) Office was opened at the Kirtland Air Force Base in New Mexico to coordinate the development of hardware and doctrine in support of ORS across the various agencies.[19] New launch capabilities such as SpaceX Falcon launch vehicles form the cornerstone of this program. ORS allows deployments of space systems designed to meet the needs of specific military operations. For instance, the U.S. TacSat microsatellite series falls under ORS jurisdiction and combines existing military and commercial technologies such as remote sensing and communications with new commercial launch systems to provide "more rapid and less expensive access to space."[20] The satellites are controlled directly by deployed U.S. commanders.[21] The latest TacSat satellite, TacSat-3, was successfully launched on 19 May 2009.[22]

The Evolved Expendable Launch Vehicle (EELV) program is a $31.8-billion USAF effort that began in 1994, with the objective to reduce launch costs by at least 25 per cent by partnering with industry to develop capabilities that could be used for both commercial and government purposes.[23] To meet future government requirements, both Lockheed Martin and Boeing are pursuing a Heavy Lift launch capability in a joint venture, the United Launch Alliance, which markets both the Delta-4 and the Atlas-5 launch vehicles.

Russia
Russia maintains the second largest fleet of military satellites. Its early warning, imaging intelligence, communications, and navigation systems were developed during the Cold War, and between 70 and 80 per cent of spacecraft have exceeded their designed lifespan, making the current operational status of these programs uncertain.[24] Forced to prioritize upgrades, Russia focused first on its early warning systems, and continues to move to complete the GLONASS navigation system, which was allocated 3.7-billion rubles for 2010-2011.[25] Since 2004, Russia has focused on "maintaining and protecting" its fleet of satellites and developing satellites with post-Soviet technology.[26] 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.[27] Despite the recent growth in Russia's spending, capabilities will only gradually increase, because there are significant investments required to upgrade virtually all parts of its military space systems.

Satellite Communications
Russia maintains several communications systems, most of which are dual-use. Between 1975 and 1994 Russia conducted an average of 16 communications missions each year; more than 600 spacecraft were placed in orbit during this period.[28] The Raduga constellation, described as a general purpose system, is reported to have secure military communications channels. The latest satellite of this constellation was successfully launched on 28 January 2010 (see Table 6.2 below). The Geizer system was designed to deploy four GEO satellites as a communications relay system for Russian remote sensing and communications satellites in low earth orbit (LEO).[29] Satellites in the civilian Gonets LEO system reportedly relay information to the Russian military, in addition to other government agencies and private

organizations.[30] The latest Gonets satellite to be launched, Gonets M-5, was placed in orbit on 8 September 2010.[31] The Molniya-1 and -3 communications satellites in Highly Elliptical Orbit (HEO) serve as data relay satellites for both military and civilian use and are to be replaced by the Meridian series of communications satellites.[32]

Table 6.2: Russian dedicated military satellites launched in 2010[33]

Satellite	Operator	Function	Orbit	Launch Date	Contractor
Raduga 1-M2 (Raduga 1-9)	Ministry of Defense	Communications	GEO	1/28/2010	Applied Mechanics (NPO)
Parus-99 (Cosmos 2463)	Ministry of Defense	Navigation	LEO	4/27/2010	Information Satellite Systems
Strela 3 (Cosmos 2467)	Ministry of Defense	Communications	LEO	9/8/2010	OAO ISS
Strela 3 (Cosmos 2468)	Ministry of Defense	Communications	LEO	9/8/2010	OAO ISS
US-KS Oko 90 (Cosmos 2469)	Ministry of Defense	Early Warning	Elliptical	9/30/2010	NPO Lovochkin

Early Warning

The USSR launched its first early warning Oko satellite in 1972 and by 1982 had deployed a full system of four satellites in HEO to warn of the launch of U.S. land-based ballistic missiles. Over 80 Oko satellite launches allowed the USSR/Russia to maintain this capability until the mid-1990s. By the end of 1999, the Oko system was operating with four HEO satellites — the minimum number needed to maintain a continuous capability to detect the launch of U.S. land-based ballistic missiles. The Oko system provides coverage of U.S. intercontinental ballistic missile fields about 18 hours a day, but with reduced reliability; it is capable of detecting massive attacks but not individual missile launches.[34] The Oko system is complemented by an additional early-warning satellite in GEO, which is believed to be a next-generation US-KMO or Prognoz satellite capable of detecting missiles against the background of the Earth.[35] On 30 September 2010, the latest satellite in the system, US-KS Oko 90, was placed in orbit by the Molinya-M launch vehicle.

The importance of adequate early warning capabilities was highlighted in 1995 when Russian early warning radars mistakenly warned of a potential incoming Trident nuclear missile. Russian President Boris Yeltsin made a decision not to retaliate with a nuclear launch, averting disaster.[36]

Intelligence

The USSR began using film-based optical imagery satellites in 1962 and by the 1980s could electronically transmit images while still maintaining a film-based system.[37] Russia's optical imaging capabilities have declined since the Cold War. The three Russian film-based and opto-electronic reconnaissance systems used today are the Kobalt, Arkon, and Orlets/Don systems, which in 2008, 2002, and 2006 respectively received new satellites, but with lifespans of only 60-120 days. In 2005, Russia announced plans for a constellation of high-resolution space radars in the next few years, using Arkon-2 and Kondor-E satellites. The Arkon-2 satellite can provide photos with a resolution of up to one meter, while the Kondor-E satellite has multirole radar that provides high-resolution images along two 500-km sectors to the left and right of its orbit.[38] Russia maintains two signals intelligence satellite systems, neither of which is fully operational; US-PU/EORSAT is dedicated to detecting electronic signals from surface ships, while Tselina is used for more general signals intelligence purposes.

Navigation
The first Soviet navigational system, Tsyklon, was deployed in 1968. It was followed by the Parus military navigation system, deployed in 1974 and still operating, with an accuracy of about 100 m.[39] Currently this constellation provides more services to the civilian than the military sector. In 1982, the USSR began development of its second major navigation system, GLONASS, which became operational in 1996. Unlike Tsyklon and Parus, GLONASS can provide altitude as well as longitude and latitude information by using a minimum constellation of 24 satellites at a 19,100-km orbit.[40] The system is reportedly inaccurate, providing at best positional accuracy of 10-17 m, and has also experienced instability, sometimes providing no reading at all.[41] Despite setbacks, funding for GLONASS continues, as discussed below.

2010 Development

Despite persistent delays, the U.S. continues to update its systems

Intelligence, Surveillance, and Reconnaissance
Two classified payload launches began "the most aggressive launch campaign that the National Reconnaissance Office (NRO) has had in 20 years," according to NRO director Bruce Carlson.[42] NROL-41 was launched aboard an Atlas V on 20 September.[43] NROL-32, launched aboard a Delta 4 heavy rocket on 21 November after a series of delays, was described by Carlson as "the largest satellite in the world."[44]

In July, prime contractor Lockheed Martin selected Goodrich ISR Systems to build the main telescopes for the NRO's Next Generation Optical System, which is currently in the design phase. The contract for the multi-billion-dollar program is expected to be awarded in 2012.[45]

Consistent with a policy shift away from monolithic capabilities in some missions, the U.S. military is moving toward distributed constellations of smaller satellites. The NRO issued a contract in February to Boeing Phantom Works for as many as 50 triple-unit CubeSats for technology demonstrations as part of its Colony-2 program.[46] The Colony 1 satellites were flown aboard the Falcon 9 in August and the rest will be launched aboard the Falcon 1e in 2011.[47]

The U.S. Army has also been interested in small satellites for imaging purposes. Its Space and Missile Defense Command awarded Microcosm Inc. a $120,000 contract in 2009 for initial design of a satellite called NanoEye Inc.,[48] followed by a $730,000 contract in February 2010 for preliminary design review.[49]

Looking to bolster the sources of imaging data for use by U.S. military forces, in August the National Geospatial-Intelligence Agency (NGA) awarded contracts worth up to $7.3-billion over 10 years to DigitalGlobe and GeoEye, under the Enhanced View Program.[50] The initial contract runs from 1 September 2010 to 31 August 2011, and includes nine one-year options, which are subject to annual congressional budget approval.[51]

In April, the U.S. Air Force launched the X-37B robotic space plane or Orbital Test Vehicle (OTV-1) aboard an Atlas V expendable launch system.[52] After more than seven months in orbit, the X37-B landed itself in December,[53] completing the second autonomous reentry and landing in the history of spaceflight. A second vehicle, OTV-2, was scheduled for launch in March 2011. The U.S. military has stated that the non-operational X-37B is a test platform for reusable spacecraft technology.[54] David Hamilton, Director of the Air Force Rapid Capabilities Office in charge of the program, said that "once declared operational, the X-37B could have applications to support missions such as space situational awareness;

intelligence, surveillance, and reconnaissance; on-orbit servicing and repair; and satellite deployment and/or retrieval."[55] However, analysts have argued that a system like the X-37B is expensive and not well suited to these tasks, leading to speculation about other possible intended purposes.[56]

Satellite Communications

A DOD report released in June 2010 found that between 2004 and 2008 overall demand for commercial satellite communications increased by about 90 per cent.[57] Even as the military moves forward to upgrade its own systems, its reliance on supplemental commercial bandwidth — already an estimated 80 per cent of Satellite Communications (SATCOM) demand[58] — is expected to grow. However, according to General James Cartwright, vice chairman of the Joint Chiefs of Staff, this dependence is "a great thing," because commercial providers are pushed to continually update and refresh their systems.[59]

The long process to replace the Air Force's Milstar communications satellite constellation finally saw the launch of the first of six Advanced Extremely High Frequency satellites, AEHF-1 or USA-124 on 14 August. Nevertheless, the already delayed $2-billion satellite will become operational between seven and eight months later than planned after its liquid apogee engine (LAE), developed by the IHI Aerospace Company of Japan, failed to raise the satellite to its appropriate testing orbit.[60] Preliminary findings indicated that the malfunction was caused by an anomaly and not from design failure.[61] The cause was later identified as a blockage in the satellite's fuel lines produced by improperly vacated cleaning material.[62]

In early 2011, manufacturer Lockheed Martin was performing testing to ensure the problem did not occur in the other satellites.[63] In the meantime, the Air Force was implementing a three-month orbit-raising strategy with its smaller hall current thrusters (HCTs).[64] The initial step was completed in September. Getting the satellite to the intended geosynchronous orbit was expected to take a half-year; if successful the AEFH-1 was to reach its orbit in June or July 2011.[65] Consequently, the launch of the AEHF-2 has been delayed until at least March 2012.[66] AEHF-3 is undergoing environmental testing.[67] A $1.4-billion contract was awarded to Lockheed Martin in December for a fourth AEFH, to be launched in 2017.[68] Once operational, these powerful satellites — each more capable than the entire legacy constellation — will provide faster and more secure communication, enabling a five-fold increase in coverage opportunities.[69]

In January, the Navy awarded Intelsat General Corporation a five-year contract worth up to $542.7-million to provide global satellite communication services in the Ku- and K-band, as well as ground terminals and network management services, as part of the Navy's Commercial Broadband Satellite Program.[70] The first satellite in the Lockheed Martin-built Navy Mobile User Objective System (MUOS) will enter acoustic testing and thermal vacuum trials, and be delivered in 2011. MUOS will provide narrowband UHF communications, voice, data, and video for military users.[71]

For the first time in 50 years, in December 2010 the U.S. Army saw the launch of its own communications satellite, the SMDC ONE-1 aboard SpaceX's Falcon 9 rocket.[72] The Army is planning the launch of several small satellites to demonstrate communications capabilities, as part of the Operational Nanosatellite Effect (ONE) program, which began in 2008 within the Army Space and Missile Defense Command (SMDC).[73] After a month of demonstrating the performance of low-data-rate communication, of up to 10 megabits per second, the satellite reentered the atmosphere on 12 January 2011.[74] Two additional ONE satellites will be launched in 2011.[75]

The Defense Advanced Research Projects Agency (DARPA) is exploring the development of broadband data communication links to orbiting constellations. On 13 August, DARPA awarded an $18-million research contract to Inmarsat for the Persistent Broadband Ground Connectivity for Spacecraft in Low Earth Orbit program. This could enable persistent SATCOM capability and real-time control of the satellites from military theaters of operation.[76]

Early Warning

Two STSS demonstrator satellites launched in 2009 provide data for development of an operational space-based missile warning constellation. The STSS ATRR satellite, launched as a classified payload on 5 May 2009, demonstrated performance of prototype sensor technology and will be transferred to the Air Force Space Command for continued situational space awareness support.[77] In its 2011 budget request, the MDA introduced a new program element, the Precision Tracking Space System (PTSS), a follow-on effort to STSS for which $67-million was requested. If approved, MDA will conduct initial reviews in 2011, aiming to demonstrate functionality of the prototype PTSS system by 2014.[78]

Efforts to replace the legacy Defense Support Program (DSP) with the struggling Space Based Infrared System (SBIRS) program have begun moving forward. The system, which Lockheed Martin is contracted to deliver, includes four dedicated SBIRS satellites that will operate in GEO, four infrared payloads hosted on classified satellites in highly elliptical orbits (HEO), in addition to ground control and data processing systems.[79] After several delays, the Air Force announced in October that the first SBIRS (GEO-1) satellite was scheduled for launch in April 2011.[80] If further delayed, the scheduled launch of two NASA science missions could push the launch of SBIRS-1 into 2012.[81] The second GEO SBIRS satellite is slated for a 2012 launch.[82] In May 2010, the National System for Geospatial Intelligence announced that the second of two classified HEO SBIRS payloads had been operationally accepted for the Technical Intelligence mission.[83] A $3-billion follow-on contract for the third and fourth satellites, third and fourth payloads, and associated ground stations, was signed in June with Lockheed Martin.[84] Two more satellites may be purchased, increasing SBIRS program costs to $15.12-billion.[85] Progress with the program led to the proposed cancellation of the Third Generation Infrared Surveillance program (3GIRS or TGIRS, previously the Alternative Infrared Satellite System). TGIRS was originally seen as a cost-effective alternative that would entail only modest technical risks when compared to SBIRS and could be available for launch by 2015.[86] The Air Force's budget request for FY2011 describes TGIRS as an "unneeded program"[87] under which the Air Force purchased two sensors built by Raytheon and SAIC. The SAIC sensor will be launched as a hosted payload on a commercial communications satellite in 2011.[88]

Some officials fear that gaps in critical U.S. missile warning capabilities will remain after transitioning from DSP to SBIRS.[89] In December 2009, Air Force General Kevin Chilton, then Commander of U.S. Strategic Command, urgently requested that the Air Force's Operationally Responsive Space (ORS) Office develop alternatives to augment the mission and address this potential shortfall.[90]

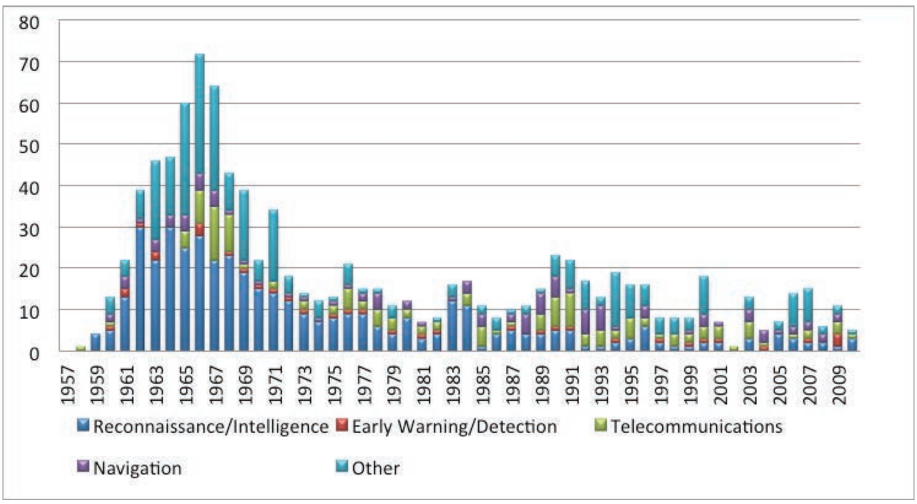
Launch

The U.S. military unveiled a new rocket, the Minotaur IV, derived from the Peacekeeper intercontinental ballistic missile.[91] After delays caused by software problems, it launched three times in 2010.[92] A Minotaur IV Lite configuration made its maiden flight on 22 April[93] for the suborbital launch of the Hypersonic Test Vehicle (Falcon HTV-2). The HTV-2 of the Conventional Prompt Global Strike mission eventually self-destructed during flight.[94]

The Minotaur IV made its first flight on 25 September from Vandenberg Air Force Base, carrying the SBSS-1 satellite into orbit. A subsequent launch on 19 November from the Kodiak Launch Complex in Alaska carried four microsatellites and two CubeSats into orbit as part of the Air Force Space Test Program S26 (STP-S26).[95]

The ORS initiative, which seeks the quick development and deployment of space capabilities in response to emerging military needs, continued to develop in 2010. TacSat3, an ORS experimental satellite launched in 2009, completed a series of objectives, including capturing images from a hyperspectral camera and transmitting processed data, and was transferred to an operational role with Air Force Space Command in June.[96] TacSat 4 was scheduled for launch aboard the Minotaur IV in May 2011. As a result of persistent challenges with the imaging payload, the launch of ORS-1, the first operational satellite to be built under the ORS initiative, was postponed from 2010 until April 2011, aboard a Minotaur 1 rocket. In February, the ORS-1 bus was built and ready for primary sensor installation.[97] By December 2010, Goodrich ISR Systems was implementing environmental testing of the final component to be installed on the satellite.[98]

Figure 6.3: U.S. dedicated military spacecraft launched by application: 1957–2010[99]



The U.S. Army has been funding development of what could be the smallest orbital launch vehicle, the Multipurpose Nanomissile system, a liquid-fueled core booster with solid-rocket strap-on motors that can launch payloads of 20 kg.[100] The Army has spent about $7-million since 2008, when it contracted with Colsa Corporation and Dynetics Corporation to develop the vehicle.[101]

Navigation / GPS

Launch delays continued to plague the first of the Boeing-built GPS IIF navigation satellites, already more than three years late and costing more than double the original $729-million.[102] The Delta IV launch of the GPS IIF-1 finally took place in May[103] and, although the launch was successful and the craft was accepted into operation in September, software fixes were later deemed necessary to reduce cross-link degradation of its nuclear-blast detection payload.[104]

Progress continued on the next-generation GPS III space segment program. In June, prime contractor Lockheed Martin announced the completion of key requirements review for the GPS IIIB satellites. The company is working under a $3-billion development and production contract for 12 GPS IIIA satellites, which are to begin launching in 2014; included in this contract is a Capability Insertion Program to mature technologies for the future IIIB and IIIC segments.[105] Under current plans, the GPS III payload will be delivered in 2011 for integration with the prototype GPS Non-flight Satellite Trailblazer.[106] Because of the health of the existing constellation, as well as GPS IIF delays, the Air Force has been considering a slower production rate.[107] A September GAO Report noted progress in the DOD's management of the program, but cautioned that persistent risks could affect the launch of the subsequent blocks of satellites. The report found that a delay in the launch of GPS IIIA satellites could reduce the size of the constellation to fewer than the 24 satellites needed to meet GPS user needs.[108]

Military officials have also expressed concerns about the increasing vulnerability of the system. On 20 January, General Norton Schwartz, Chief of Staff of the Air Force, highlighted GPS-signal vulnerability during times of war and urged the U.S. military to lessen its dependence on the system.[109] This reliance was highlighted in June when a software compatibility issue, associated with the IIF block of satellites, made between 8,000 and 10,000 military GPS receivers useless for days.[110] Officials quickly implemented fixes to address the issue, but Center for Strategic and International Studies fellow James Lewis described the event as a warning, "in the context where people are every day trying to figure out how to disrupt GPS."[111]

2010 Development

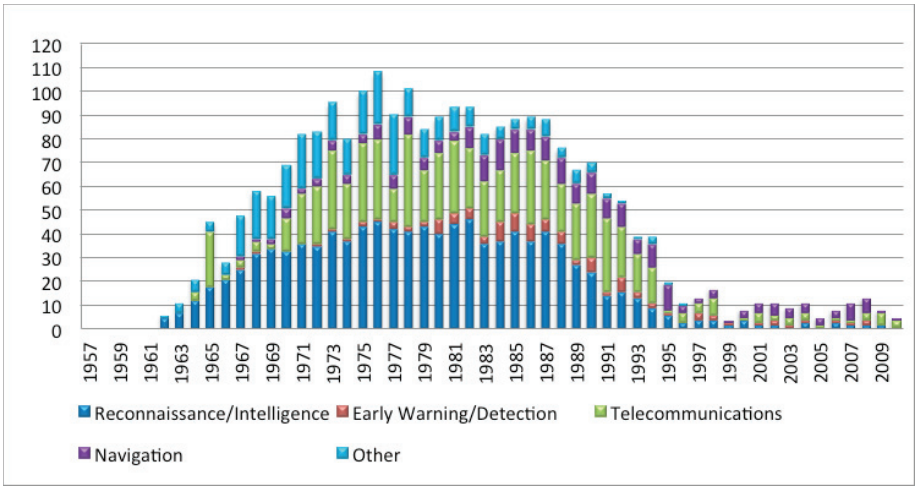
Russia continues to lead in military satellite launches; GLONASS nears full operational capacity

Navigation/GLONASS

Early in the year, Russia announced the launch of at least seven *Global'naya Navigatsionnaya Sputnikovaya Sistema* (GLONASS) satellites in order to achieve full operational capability of the satellite navigation system.[112] A total of 3.7-billion rubles were allocated for the program for 2010-2011.[113] By September 2010, the system was providing 98 per cent of global coverage; one Roscosmos official predicted that, by the end of 2011, its performance would be comparable to the U.S. GPS.[114]

Three GLONASS satellites were successfully launched on 1 March, their frequencies activated within a couple of weeks.[115] Three more were launched on 2 September, with two slated for operational use and one serving as backup.[116] Another three-satellite launch attempted on 5 December, which would have allowed the completion of the constellation, suddenly failed when the Proton-M rocket deviated eight degrees from course and fell into the Pacific Ocean.[117] Following the failure, Anatoli Perminov, head of Roscosmos, announced that all Proton launches would be suspended until an investigation on the failure was completed.[118] He also announced plans to activate two spares already in orbit, as well as to turn a next-generation demonstration model — GLONASS-K — to operational service.[119] Perminov later said that, despite the "heavy loss," which analysts have estimated to cost $160-million, GLONASS would be fully operational after only a three-month delay.[120] The investigation revealed that the failure was due to human error in calculating the formula for the amount of liquid oxygen, whose excessive weight apparently caused the launcher to deviate from its planned trajectory.[121] Two space officials were fired and others were reprimanded.[122] The GLONASS-K launch was eventually postponed until 2011 because the satellite's ground complex had not been completed.[123] By the end of 2010, the constellation had only 20 functional satellites of the 26 in orbit, with 23 operational satellites needed for full operational capability.

Figure 6.4: Russian dedicated military spacecraft launched by application: (1957–2010)[124]



Despite the aggressive launch schedule, the GLONASS failure was one of several setbacks that the Russian space program faced in 2010, including failing to build six of 11 planned satellites for the Russian space forces. Deputy Prime Minister Sergei Ivanov said in early 2011 that he expected the GLONASS constellation to be completed by the end of 2011.[125]

During his visit to India, Russian Prime Minister Vladimir Putin signed two agreements. In the first, Russia's Navigation Information System-GLONASS and Antrix Corporation, the marketing arm of ISRO, established a joint venture to access the Indian navigation and timing services market by addressing the reliability of signals of both GLONASS and GPS.[126] A second agreement related to the use of the GLONASS signal for defense.[127]

Communications and Intelligence, Surveillance, and Reconnaissance

In January, Russia launched a military communications satellite of the Raduga series.[128] A Parus relay and navigation satellite was launched on 27 April,[129] and a military reconnaissance satellite, believed to be part of the Kobalt series of optical reconnaissance satellites, was launched on 16 April.[130] On 8 September, a Rockot launch placed three military communications satellites (a Gonets-M satellite and two Kosmos satellites) in orbit.[131] On 30 September, a US-K early warning satellite was launched aboard a Molniya-M carrier.[132]

Launch

The commander of Russia's Space Forces said in January that the country will extensively use the Angara class carrier rockets, which will eventually replace the Rockot and Proton vehicles, to launch military satellites.[133] The new heavy lift rocket, which will launch mainly from upgraded launch facilities in the Plesetsk space center, will eventually be able to lift between 2 and 24.5 metric tons to LEO. Both projects have been stalled because of budgetary issues. Vladimir Nesterov, head of the Khrunichev State Research and Production Space Center, announced in July that test launches for the Angara rocket would begin in 2013, after rocket assembly is completed in 2011.[134] The first-stage engine is "99% ready," and the second-stage engine has been tested three times. He added that Khrunichev is also developing the Angara 7, a super-heavy-lift version capable of launching payloads of between 45 and 74 tons.[135]

Space Security Impact

Even as reliance on space systems increases, delays, cost overruns, and other setbacks directly impacted efforts to update systems in 2010. As well, gaps in critical capabilities increase the vulnerability of these systems to attacks by adversaries. On the other hand, the situation creates incentives for Russia and the U.S. to advance policies to reduce the likelihood of conflict in outer space. Over time, growing interest in cooperating with international allies and commercial partners, such as in satellite navigation and military communications, may also reduce such vulnerability and increase interdependence, providing a positive impact on space security.

Trend 6.2: China and India afford increasing roles to space-based military support

China

China's governmental space program does not maintain a strong separation between civil and military applications. Officially, its space program is dedicated to science and exploration,[136] but like the programs of many other actors, it is believed to provide data to the military. China's space program is led by the Space Leading Group, whose members include three senior officials of government bodies that oversee the defense industry in China.[137] Most of China's satellites are civilian or commercial, but many have capabilities that could also be used for military purposes. Although China has never published a military space doctrine, its national defense strategy is based on "active defense" that "aims at winning local wars in conditions of informationization" that include maintaining "space and electromagnetic space security."[138]

China has advanced remote sensing capabilities that could support imagery intelligence. It began working on space imagery in the mid-1960s, launching its first satellite in 1975.[139] It successfully launched 15 recoverable film-based satellites, the last of which was reportedly decommissioned in 1996.[140] Today China maintains two ZY-2 series transmitting-type optical imagery satellites in LEO that could support tactical reconnaissance and surveillance.[141] In 2005, China launched the Beijing-1 (Tsingshua-1) microsatellite, a civil Earth observation spacecraft that combines a multispectral camera with a high-resolution panchromatic imager and could also support the military.[142] More recently, China launched a series of six Yaogan satellites for "scientific experiment, survey of land resources, appraisal of crops and disaster prevention and alleviation."[143] Two of these satellites are believed to use synthetic aperture radar, which would provide the Chinese government with all-weather/night-day imagery that would be advantageous for military use.[144]

Western experts believe that Chinese military satellite communications are provided by a DFH-series satellite, ChinaSat-22. Officially a civilian communications satellite, ChinaSat-22 is thought to enable "theater commanders to communicate with and share data with all forces under joint command" through C-band and Ultra High Frequency (UHF) systems.[145]

China also 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 U.S. were to deny GPS services in times of conflict.[146] Beidou may also improve the accuracy of China's intercontinental ballistic missiles (ICBMs) and cruise missiles.[147] China has expressed its intention of upgrading 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. While Compass falls under China's defense ministry, it is intended to provide both an Open Service with position accuracy of 20 m and an Authorized Service that will be "highly reliable even in complex situations."[148] China launched the first Compass-M1 test satellite into MEO in 2007.[149] In recent years the country has continued to advance the system, with five satellites successfully launched in 2010, out of 10 planned for the 2010-2012 period.[150]

China experimented with electronic intelligence satellites, called "technical experimental satellites," in the mid-1970s, but these programs were discontinued. It relies on modern air, sea, and land platforms, not satellites, to perform signals intelligence missions. However, in 2006, China launched two Shi Jian experimental satellites (SJ-6/2A and SJ-6/2B), which some Western experts believe were intended to provide signals intelligence, although their official purpose is to measure the space environment.[151]

India

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.

At the end of 2010, India maintained eight remote sensing and one dedicated military surveillance satellites.[152] The Cartosat-series remote sensing satellites, of which the latest (Cartosat-2B) was launched in 2010, 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.[153] Referring to Cartosat-2, Secretary of the Department of Space and Chairman of ISRO G. Madhavan Nair has explained that "we don't put a restriction on anybody using it,"[154] confirming beliefs that India's civil space program is available for military use.

ISRO has also developed a Radar Imaging Satellite using synthetic aperture radar that is designed to take 3-m resolution images in all-terrain, all-weather, day/night conditions — a significant dual-use capability.[155] The satellite, built with Israeli assistance and equipped with all-weather vision capabilities, was successfully launched in April 2009.[156]

The Indian National Satellite System[157] is one of the most extensive domestic satellite communications networks in Asia. India uses its Metsat-1 satellite for meteorology. To enhance its use of U.S. GPS, the country is developing GAGAN, the Indian Satellite-Based Augmentation System. This will be followed by the Indian Regional Navigation Satellite System (IRNSS), which is expected to be made up of seven navigation satellites by 2012[158] and is to provide an independent satellite navigation capability. In 2007, India signed an agreement with Russia to jointly use its GLONASS navigation system.[159] Although these are civilian-developed and -controlled technologies, they are used by the Indian military for dual-purpose applications.[160] In 2008, the U.S.-India civilian nuclear cooperation agreement was approved. By ending longstanding sanctions it could allow for greater cooperation between ISRO and the military.[161]

2010 Development

China continues an ambitious launch schedule to complete Beidou/Compass constellation

China is rapidly advancing with its Beidou/Compass second-generation global navigation satellite system (GNSS) and successfully launched five satellites for the constellation in 2010. In January, China announced plans to launch 10 Beidou satellites between 2010 and 2012 and unveiled a new government website (www.beidou.gov.cn) with information on the system.[162] The first Beidou launch of the year took place on 17 January,[163] followed by launches in June,[164] July,[165] October,[166] and December,[167] bringing the total number of satellites in the constellation to seven. The Beidou/ Compass system, with a final constellation of 35 satellites, will provide two levels of service for civilian and military/government users, respectively. Beidou/Compass is expected to be providing regional services by 2012 and global services by 2020.[168]

2010 Development

China continues to upgrade its satellite systems and sets a new launch record

China continued launching its Yaogan-series of remote sensing satellites in 2011. On 5 March, China launched three satellites — Yaogan 9A, Yaogan 9B, and Yaogan 9C — aboard a Long March 4C rocket.[169] They were followed by Yaogan 10, launched on 10 August,[170] and Yaogan 11, launched on 22 September.[171] While Chinese sources describe the Yaogan satellites as Earth observing satellites, intended for land survey, disaster monitoring, and other uses, Western analysts believe these satellites are also used for reconnaissance and are under military control.[172] The U.S. DOD also lists them under Chinese military assets.[173] China adhered to an aggressive launch schedule with 15 launches in 2010, including the launch of five Beidou satellites, besting its record of 11 launches in 2008.[174]

2010 Development

India continues to launch dual-use systems and plans to launch dedicated military satellites

India launched Cartosat-2B, a high-resolution remote sensing satellite, aboard ISRO's Polar Satellite Launch Vehicle in July.[175] With a panchromatic resolution better than 1 meter, its capability is close to the international standard for commercial remote sensing satellites.[176] The satellite will address the military's need for mapping and modeling of sensitive areas and support anti-terrorist operations.[177] Risat-1, a radar satellite with all-weather monitoring capability, was to be launched in early 2011.[178]

In addition to dual-use systems, India is also planning to launch dedicated military satellites in the next few years. V. K. Saraswat, Scientific Adviser to the Defence Minister, reportedly said that India has already launched such military satellites.[179] ISRO was expected to launch a $212-million multiband satellite, the first dedicated military surveillance and communications satellite, for the navy in late 2010 or 2011.[180] The $25-million Communication-Centric Intelligence Satellite (CCI-Sat), which has radar, imaging, and communication capabilities, is being developed by the Defense Research and Development Organization and will be launched by 2014.[181] The payload was developed by the Defence Electronics Research Lab, while ISRO implemented the design and development of the satellite.[182] On 28 December, Dr. V. Jayaraman, Director of India's National Remote Sensing Centre (NRSC) announced that India is planning to launch at least 30 Earth Observation satellites in the next decade, including Resourcesat-2 in early 2011. To process all of this incoming data, India will set up a single ground station in Hyderabad, which will allow delivery of products within 12 hours, and which should be operational in June 2011.[183]

2010 Development

India advances development of a regional satellite navigation system

India is moving forward with its Indian Regional Navigation Satellite System (IRNSS), which will provide navigation and timing services to India and neighboring countries.[184] ISRO announced in April that the first satellite launch will take place by the end of 2011.

Periodic launches would follow every six months, leading to a functional capability by 2014.[185] ISRO recently announced that the seven-satellite constellation had been increased to 11 satellites for the IRNSS system.[186]

Space Security Impact

China's and India's increasing dual-use and military space-support activities could have mixed results for space security. On the one hand, the strategic value of space assets increases as actors engaged in competition with each other begin to rely more on space-based support. The development of competing systems, such as individual satellite navigation systems, could result from this dynamic. On the other hand, their increased participation in space also raises the value of policies that reduce the likelihood of conflict in space. The growing roles of these countries as prominent space actors make space security discussions not only beneficial but necessary.

Trend 6.3: More states are developing military and multiuse space capabilities

During the Cold War, states allied with either the U.S. or the USSR benefited from their capabilities. Today, declining costs for space access and the proliferation of space technology enable more states to develop and deploy military satellites. Until 1988, when Israel launched its first, only the U.K., NATO, and China had joined the U.S. and USSR in launching dedicated military satellites. In 1995, France and Chile both launched dedicated military satellites.[187] Historically, military satellites not owned by the U.S. or Russia were almost exclusively intended for communications and imagery intelligence. Recently, however, states such as China, France, Germany, Japan, Italy, and Spain have been developing satellites with a wider range of functions. According to a recent report, security has become a key driver of established government space programs, pushing spending higher and encouraging dual-use applications.[188] Indeed, in the absence of dedicated military satellites, many actors use their civilian satellites for military purposes or purchase data and services from satellite operators.[189] Such activities contribute to the blurring of the divide between military, civilian, and commercial space assets and applications.

Table 6.5: Minimum resolutions for remote sensing target identification (in meters)[190]

Target on the Ground	Detection	General Identification	Precise Identification	Technical Analysis	Target on the Ground
Vehicles	1.5	0.6	0.3	0.045	Vehicles
Aircraft	4.5	1.5	1.0	0.045	Aircraft
Nuclear weapons components	2.5	1.5	0.3	0.015	Nuclear weapons components
Rockets and artillery	1.0	0.6	0.15	0.045	Rockets and artillery
Command and control headquarters	3.0	1.5	1.0	0.09	Command and control headquarters

Europe

European states have developed a range of space systems to support military operations, with France having the most advanced and diversified independent military space capabilities. While individual nations have pursued independent space capabilities for military support, many of these capabilities, in particular communications and imagery intelligence, are shared among several EU states. Greater harmonization of the EU through the Lisbon Treaty, development of the European Security and Defence Policy, and budget restrictions in member states are driving this cooperation.

The Besoin Opérationnel Commun (BOC) provides the framework for space systems cooperation among the ministries of defense of France, Germany, Italy, Spain, Belgium, and Greece.[191] France's Helios-1 observation satellite in LEO was included under this agreement[192] and was subsequently replaced by the Helios-2B second-generation defense and security observation system, which was launched in 2004 by France in conjunction with Belgium and Spain.[193] Germany's first dedicated military satellite system, Sar-Lupe, which uses synthetic aperture radar for high-resolution remote sensing, and Italy's COSMO-SkyMed radar satellites are expected to be integrated with France's Pleiades dual-use optical remote sensing satellites.[194] Austria, Belgium, France, Italy, Spain, and Sweden cooperate on the dual-use ORFEO satellite network.[195] France has also been working on the optical and radar MUSIS (Multinational Space-based Imaging System) project with Belgium, Germany, Greece, Italy, the Netherlands, Spain, and Poland;[196] the new optical component of MUSIS is expected to replace the French Helios-2 optical satellite by 2015.[197] However, recent developments suggest that MUSIS has been stalled by disagreements among the partners and the project could collapse.[198]

Europe has several dedicated and dual-use satellite communications systems. In 2006, France completed the Syracuse-3 next-generation communications system, described as "the cornerstone in a European military Satcom system."[199] France also maintains the dual-use Telecomm-2 communications satellite and the military Syracuse-2 system.[200] The U.K. operates a constellation of dual-use Skynet-4 UHF and Super High Frequency (SHF) communications satellites,[201] as well as a next-generation Skynet-5 system, intended to provide British military forces with a secure, high-bandwidth capability though 2022.[202] The latest Skynet-5 satellite was launched in June 2008 and another launch is expected in 2013, making the £3.6-billion (approximately $5.6-billion) project the single biggest U.K. space project.[203] In 2006, Spain launched the dedicated military communications satellite Spainsat to provide X-band and Ka-band services to the Ministry of Defense. Spain also owns the dual-use communications satellite XTAR-EUR and the dual-use Hispasat system, which provides X-band communications to the Spanish military. In 2006, Germany signed a procurement contract with MilSat Services GmbH to provide the German armed forces with a secure information network to assist its units on deployed missions.[204] Italy's Sicral military satellite provides secure UHF, SHF, and Extremely High Frequency (EHF) communications.[205]

Other military space capabilities in Europe include France's Essaim constellation of four signals intelligence satellites, launched in 2004. France launched two Spirale early warning satellites in early 2009 for a probative research and technology demonstration[206] and, at a cost of $142.3-million each, commissioned from EADS Astrium four Elisa microsatellites, which will gather signals intelligence data and identify civil and military radars for the French intelligence community.[207] Other European states have refused to participate or invest in a pan-European missile-warning system.[208]

The EU has called for a more coherent approach to the development of space systems capable of supporting military operations and has begun to actively develop dual-use systems. The 2007 European Space Policy makes specific reference to defense and security applications, indicating a shifting focus in support of increasing synergies between military and civil space programs.[209] The joint EU/ESA GMES project will collate and disseminate data from satellite systems and is anticipated to be operational by 2012, at a cost exceeding $2.7-billion.[210] It will support activities given priority in the European Security and Defense Policy, such as natural disaster early warning, rapid damage assessment, and surveillance and support to combat forces.[211] Similarly, the Galileo satellite navigation program, initiated in 1999 and jointly funded by the EU and ESA, will provide location, navigation, and timing capabilities for both civilian and military users.[212] ESA, which has traditionally been restricted to working on projects designed exclusively for peaceful purposes, has begun to invest in dual-use, security-related research, such as Galileo.

East Asia

The commercial Superbird satellite system provides military communications for Japan, which also has four "information gathering" remote sensing satellites — two optical and two radar — that were launched in 2003 and 2007 following growing concerns over North Korean missile launches.[213] Officially called the Information Gathering Satellite (IGS) series and under the control of the Prime Minister's Cabinet Office, IGS 3A and 3B provide images of up to 1-m resolution to the Japanese military.[214] Japan is primarily interested in monitoring the Korean Peninsula, but the IGS system provides a scan of the entire planet at least once a day.[215]

In December 2003, South Korea announced its intentions to increasingly use space for military purposes.[216] South Korea operates the civilian Kompsat-1 satellite with 6.6-m resolution, which is "sufficient for [military] mapping although not for military intelligence collection."[217] It also bought 10 Hawker 800-series satellites from the U.S. and has operated them for signals intelligence since 1999.[218] On 22 August 2006, Sea Launch launched South Korea's dual military/commercial Koreasat-5 (Mugunghwa 5) communications satellite to replace Koreasat-2 by providing Ku-band, C-band, and military SHF-band communications. Jointly owned by the French Agency for Defense Development (DGA) and South Korea's KT Corp, it will provide secure communications for South Korea's defense forces.[219] South Korea also launched the Kompsat-2 high-resolution Remote Sensing Satellite for Earth mapping in 2006.[220] Although a civilian spacecraft, its 1-m resolution could allow it to serve as a reconnaissance asset.[221]

In July 2004, Thailand signed a deal with the EADS Astrium to provide its first remote sensing satellite, to be used for intelligence and defense.[222] The THEOS Earth Observation Satellite, which orbits in LEO, was launched on 1 October 2008 for the Thai government.[223] Taiwan, which has its own space program, operates the civilian Formosa-2 optical imaging satellite, which has a resolution of 1.8 m and is also used by its military forces.[224]

Middle East

Israel operates the dedicated military Ofeq optical imaging system, which provides both panchromatic and color imagery for intelligence purposes.[225] The latest satellite in the system Ofeq-9, launched in June 2010, is in a constellations with two Ofeq satellites (Ofeq-5 and Ofeq-7), and reportedly can identify objects as small as approximately 0.5-m.[226] Ofeq's capabilities are augmented by the dual-use Eros-A and -B imagery satellites, the latter able to capture black-and-white images at 70-cm resolution.[227] In January 2008, Israel launched the TecSAR reconnaissance satellite on an Indian launch vehicle rocket. Considered one of the world's most advanced space systems[228] with a resolution of up to 10 cm,[229] the TecSAR is reportedly used to spy on Iran.[230]

Iran's first satellite, the Sina-1, was launched in 2005 with the support of a Russian launcher, and has a resolution precision of approximately 50 m.[231] Although the satellite is intended to collect data on ground and water resources and meteorological conditions, the head of Iran's space program said that it is capable of spying on Israel.[232] But poor resolution means that it is not very useful for military purposes. Iran also has a space launch vehicle program, which some speculate is linked to its development of ICBMs, and the Shahab-4 and Shahab-5 missiles.[233]

Egypt's civilian Egyptsat-1 remote sensing microsatellite was launched in 2007. Weighing just 100 kg, it has an infrared imaging sensor and a high-resolution multispectral imager to transmit black-and-white, color, and infrared images intended to support construction and cultivation and fight desertification.[234] Egypt has not released public details about the resolution or clarity of the images it provides, but an Israeli source has made an unconfirmed claim that it can detect objects as small as 4 m.[235]

Turkey awarded a $250-million contract for its first military optical imaging satellite, the GOKTURK. It is intended to have an 80-cm resolution; the launch is planned for 2011.[236]

Australia

Until recently the Australian defense forces used X-band facilities on satellites owned by the U.S. and other allies.[237] In 2003, however, Australia launched the Defence C1 communications satellite. The satellite will be part of a new Australian Defence Satellite Communications Capability system, which will provide the country's defense forces with communications across Australia and throughout the Asia Pacific region in the X, Ka, and UHF radio frequency bands.[238] Australia is also participating in the U.S. Wideband Global SATCOM program.[239]

Canada

Canada's military uses commercial satellite communications and imaging services.[240] In June 2005, the Department of National Defence announced the creation of Project Polar Epsilon, a joint space-based wide area surveillance and support capability, which will provide all-weather, day/night observation of Canada's Arctic region and ocean approaches.[241] The project will build two dedicated military ground stations to receive data from the Radarsat satellites and other sources to produce high-quality imagery for military and other applications.[242] Radarsat-2, a commercial satellite developed with the Canadian Space Agency, was launched in 2007 on a Russian Soyuz rocket and orbits the Earth at approximately 800 km.[243] It uses synthetic aperture radar to produce images with a resolution of up to 3 mz[244] and has an experimental Ground Moving Target Indicator capability to detect and track the movement of vehicles and ships.[245] A relatively low-cost ($27-million) Joint Space Support Project is intended to provide surveillance information for commanders in the field via direct in-theatre download of imagery from commercial satellites such as Radarsat-2; it will also provide space situational awareness data gathered by the U.S. SSN.[246]

Canada is on track to deliver the next evolution of the Radarsat program, the Radarsat Constellation, which will upgrade current systems features and improve reliability over the next decade.[247] The purpose of the system is not to replace Radarsat-2, but to meet its core demands at a lower cost and enable future applications. Satellite launches to enable maritime surveillance, disaster management, and ecosystem monitoring are planned for 2014 and 2015.[248]

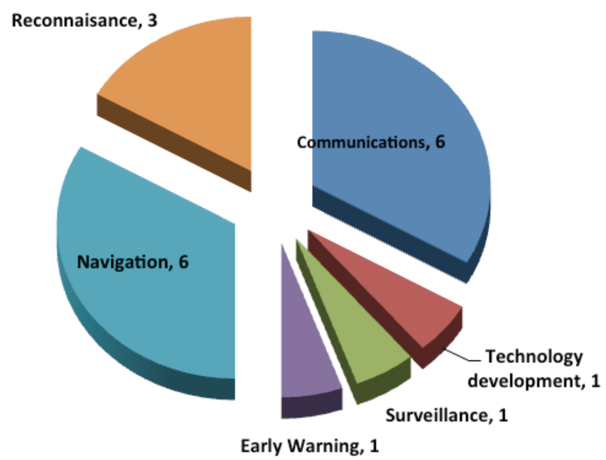
2010 Development

Japan launches "Michibiki" GPS augmentation satellite and considers an indigenous satellite navigation system

Japan launched a GPS augmentation satellite this year, but remains unsure about developing its own indigenous GNSS. The Michibiki ("to guide" or "to lead the way") satellite was successfully launched in September and should be able to improve the accuracy of GPS over Japan and East Asia.[249] The satellite began sending transmissions on 26 October.[250] On 6 January 2011, Japan announced that its signals would be free of charge for Australia and South Korea, with a formal agreement to be signed sometime in spring.[251] Michibiki is one of three satellites that Japan may potentially launch to address GPS coverage gaps. The satellite will demonstrate the system's instruments before Japan commits to launching the other two.

Japan is also considering launching its own system to reduce reliance on GPS. Some sources suggest that Japan has decided to launch six or seven satellite for an indigenous navigation system, which would be operational by 2014-2015.[252] Funding is the main limitation, both for an indigenous GNSS and for the follow-on augmentation satellites. Michibiki development costs were $878.6-million and some businesses and officials in the country have been reluctant to pledge additional funds with an existing cost-free network in place. A project team in the Space Development Strategy Office was to release a roadmap for future space programs in March 2011, and a decision related to the GNSS programs will probably be reflected in the 2012 budget.[253]

Figure 6.6: Dedicated military spacecraft launched globally in 2010, by application[254]



2010 Development

Several countries pursue remote sensing capabilities

Israel's Ofeq-9 military high-resolution imagery satellite was launched aboard a Shavit rocket on 22 June and was declared operational soon after. Although details of its payload remain classified, its sensors are similar to the previous Ofeq-5 and Ofeq-7 satellites, which had a resolution of 50 cm or less for black-and-white.[255] Israel has also been working on the technical concept for developing small satellites that could be launched from airplanes and aid intelligence-gathering efforts for the Israeli Air Force and Intelligence Corps.[256]

Turkey will soon get its own high-resolution optical observation satellite, Göktürk. On 7 September, Telespazio and Thales Alenia Space announced the official start of the program, with a scheduled launch in 2013.[257] The 2009 contract requires Thales Alenia Space to build the satellite and an integration and test center in Turkey, and charges Telespazio with the associated ground segment as well as services during launch, early orbit, and satellite testing.[258]

The scheduled August launch of Iran's second satellite, Rasad (Observation) 1, was delayed until 2011 because the device was still being developed.[259] In February, Iran unveiled three new satellites, including Toloo, a "reconnaissance satellite" designed by Iran Electronic Industries.[260] The United Arab Emirates are also looking for an expanded role in the field of imagery and remote sensing. DubaiSat-1, launched from Baikonaur in 2009, was the first satellite project of the Emirates Institute for Advanced Science and Technology (EIAST) and was built in South Korea. Over the next five years, the Emirates' own engineers will take on greater roles with the next two satellites to be added to EIAST's Earth Observation fleet.[261] Dubaisat-2 will be launched in 2012; "by the time we come to DubaiSat-3, we hope that it will be wholly made in the UAE by Emirati engineers," said Al Marri, who oversees the project.[262]

2010 Development

Europe begins awarding Galileo contracts and continues exploring expanded cooperation in military space

On 7 January, Germany's OHB-System secured a €566-million contract to build the first 14 Galileo navigation satellites.[263] Arianespace and ESA signed a €397-million launch contract for the first 10 full operational capability satellites, which will be launched from Guiana beginning in December 2012.[264] Also in January, a third contract for €85-million was awarded to Italy's Thales Alenia Space to provide system support.[265] ESA also signed a €194-million space and ground services contract with Germany's SpaceOpal GmbH to operate the fully deployed constellation.[266] On 26 November, the U.K.'s Surrey Satellite Technology Ltd. awarded a €13-million contract to Siemens Austria to supply electrical equipment for Surrey to test the 14 navigational payloads on the satellites.[267]

Galileo's four In-Orbit Validation (IOV) satellites, originally scheduled for a late 2010 launch under contract with Arianespace, will not be ready until 2011. The first two were to launch in early 2011 and the second pair three months later.[268] Most of the original €3.4-billion budget approved in 2007 has been spent on the IOV program and the launch contracts for the first 14 satellites, leaving insufficient funds to build and launch the rest of the proposed 30-satellite constellation.[269] The next budget cycle begins in 2014, but follow-on contracts are to be negotiated in 2011 to reduce the possibility of a gap between launches.[270]

With mounting costs and fears that European governments may not be able or willing to provide additional funds, critics have voiced concerns that the constellation will be limited to 18 satellites, enough to provide only limited service. Paul Verhoef, satellite navigation program manager at the European Commission, reacted to this possibility by saying that it "is an illusion to believe we can do this with 18 satellites…that would mean that for three weeks in the year you will not have satellite navigation."[271] Although no new funds were pledged, European government ministers voiced support for the system during the November Space Council.[272]

Even if Europe continues supporting the deployment of the full constellation, Galileo may provide initial services in 2014, but will likely not become fully operational until 2016-2019, officials said in March.[273] In October, the German government asked the European

Commission to propose ways to cut program costs by €500–700-million.[274] While engineers are studying how to reduce costs, an additional estimated €1.2-billion will be needed to cover the rest of launch and development costs, with at least €750-million needed each year to operate the system.[275] One suggestion has been to launch the remaining satellites using Russian Soyuz vehicles instead of Ariane 5 launchers.[276] Such a move may run counter to a policy of technology independence, which led to the removal of Chinese-built search-and-rescue payloads on the IOV satellites in March.[277] The policy also prevented Europe from purchasing equivalent equipment from Canada, an associate ESA member.[278] Furthermore, a resolution adopted in November asked all government agencies "to consider as a high priority the use of launchers developed in Europe."[279]

Efforts to increase military space cooperation among European governments have met with mixed results. In May, OHB Technology was awarded a €14-million contract to operate ground stations that would allow French and German military forces to access each other's optical and radar satellite systems — Helios 2 and SAR-Lupe, respectively — under the Europeanization of Satellite-Based Reconnaissance program.[280] Also taking shape, driven mainly by budgetary pressures, is a proposal for French and British militaries to cooperate in a next-generation satellite telecommunications program. Seeking to manage concerns over national sovereignty, as well as diverging policies and schedules, the two heads of state in November endorsed a detailed study to explore a common system in which at least two countries could participate and which could succeed their existing individual systems.[281]

France and Italy continued to move to greater cooperation. On 9 February, CNES signed a €280-million contract with Thales Alenia Space for the construction and launch of an EHF/Ka-band satellite, the Athena-Fidus, for civilian and military uses. The satellite, which will carry one payload each for the Italian and French governments, will be equally financed by both countries and will be launched in 2013-2014.[282] A 4-ton class military telecommunications satellite, Sicral 2, is to be launched aboard an Ariane 5 in 2013 under a €295-million contract with Thales Alenia Space and Telespazio signed in May.[283] It will carry two communications payloads to be used independently by French and Italian military forces and to support existing bandwidth provided to NATO.[284] The combined program, in which Italy will fund 68 per cent of the costs, allowed both countries to reduce expenditures while reinforcing their tactical satellite communication capabilities.[285]

The Multinational Space-based Imaging System (MUSIS), a multiyear effort involving France, Italy, Belgium, Germany, Greece, and Spain to develop a common ground segment for next-generation space-based reconnaissance systems, remains stalled. The countries involved have been unable to agree on a number of issues, including who will contribute existing or planned assets to the MUSIS architecture.[286] France and Italy continue to update their own national systems. France awarded Astrium Satellites a €795-million contract for two reconnaissance satellites to succeed Helios-2, the first of which, to be launched in 2016, could take part of the multinational MUSIS architecture.[287] The contract for these two satellites, part of the CSO (Optical Space Component) Constellation, includes an option for a third satellite to be built if other countries join the CSO program as part of the MUSIS effort.[288] France has not said how long it is willing to wait for the partners to decide on CSO collaboration; in the meantime, Poland and Sweden have expressed interest in joining the program.[289]

Italy's last of four COSMO-SkyMed radar satellites was successfully launched aboard a Delta 2 on 5 November.[290] The launch provided the constellation with full operating capability and may offer opportunities for expanded international cooperation. Japan, Australia, Turkey, and Germany have already expressed varying degrees of interest in using COSMO-SkyMed to complement their own planned or existing observation systems.[291] Likewise, under a contract awarded in December 2009, e-Geos — an Italian Space Agency-Telespazio venture — and Lockheed Martin Space Systems will provide the U.S. National Geospatial-Intelligence Agency with radar data from the COSMO-SkyMed constellation.[292]

In June, Astrium Satellites announced that the two French Spirale satellites launched in 2009 had completed their objectives and that their mission would be extended until the end of 2010.[293] Spirale is a demonstrator program for a future space-based infrared early warning system for detection, tracking, and identification of missiles.[294] The program is consistent with a 2008 military policy paper that stated France's interest in developing such a system for European defence.[295] While other European countries have yet to announce their support for its development, France is reportedly willing to do it on its own, and is interested in having an operational system by the end of the decade.[296]

2010 Development

Canada prepares to launch first military satellite, continues expanding multiuse capabilities

Canada will soon see the launch of its Sapphire satellite, which will orbit at 800 km to image space objects in orbit and will become a sensor within the U.S. SSN. The satellite, which one analyst describes as Canada's first "dedicated military satellite,"[297] is set to launch as early as 2011.[298]

In August, Canadian Prime Minister Stephen Harper endorsed the Radarsat Constellation Mission, Canada's next-generation radar Earth Observation system, with a commitment of CDN$397-million over five years, plus CDN$100-million already secured from the Canadian Space Agency (CSA). A contract for building the system has not been awarded, but the first of the three satellites could be launched in 2014.[299]

Canada's Polar Communications and Weather mission is progressing. In 2010, CSA officials approached Russia for advice on the two-satellite system, which will be launched in HEO.[300] The satellites will provide continuous Ka-band and X-band communications services, and will also carry a spectroradiometer and other instruments for weather monitoring. Although the Department of National Defence will be a PCW user, the system's mission is primarily civilian. It will help to address gaps in coverage in high altitudes by weather and communications satellites. Phase A, which began in July 2009, continued in 2010, with requirements and systems review in place.[301] Funding approval and contract awards for the subsequent B, C, and D phases were planned for February 2011.[302]

Space Security Impact

Increased access to space by more actors reduces the asymmetric vulnerability of those countries that already rely on space assets. However, the proliferation of individual systems increases problems of congestion and may lead to the proliferation of technology that threatens space assets and increases the possibility of conflict. This situation underscores the value of cooperating in enhanced space situational awareness as a way to protect space assets. Budgetary constraints have proven to be a positive motivator for increased cooperation and interdependence, moving some countries to look for ways to improve their access to and use of existing systems without necessarily launching their own. In the case of military systems, however, countries may choose to be less forthcoming about their capabilities or operations in space, thus increasing the risks of uncertainty or confusion.

Space Systems Resiliency

This chapter is focused on the research, development, testing, and deployment of physical and technical capabilities to better protect space systems from potential negation efforts intended to interfere with a satellite system. This includes protection capabilities designed to mitigate the vulnerabilities of the ground-based components of space systems, launch systems, and communications links to and from satellites, to ensure sustainable access to and use of outer space. Efforts to protect against environmental hazards such as space debris are examined in Chapter 1.

In addition, the ability of space systems to deny an adversary the benefits of an attack is a key concern for advanced spacefaring nations. For example, the U.S. National Security Space Strategy (NSSS) states that "resilience can be achieved in a variety of ways, to include cost-effective space system protection, cross-domain solutions, hosting payloads on a mix of platforms in various orbits, drawing on distributed international and commercial partner capabilities, and developing and maturing responsive space capabilities."[1] While countermeasures to the space negation capabilities of others are considered protection measures by some, they are addressed separately in the chapter on space systems negation.

Physical and technical capabilities can provide a certain degree of protection to spacecraft from potential negation efforts, but they cannot make space systems fully invulnerable. Consequently, different initiatives to provide non-physical protection of space assets by attempting to regulate the conduct of spacefaring nations and by defining permissible behavior in outer space are being considered at various multilateral forums, as discussed in chapter 3.

Measures to protect space systems can be broadly categorized as one of the following: capabilities to detect space negation attacks; physical and electronic means to withstand attacks on ground stations, communications links, and satellites; and reconstitution and repair mechanisms to recover from space negation attacks.[2]

The ability to detect, identify, and locate the source of space negation attacks through early warning and surveillance capabilities is critical to space protection efforts. It is important to accurately determine whether the failure of a space system is being caused by technical or environmental factors, or by the deliberate and potentially hostile actions of another space actor. Detection is often a precondition for effective protection measures such as electronic countermeasures or maneuvering a satellite out of possible harm. The ability to detect a potential negation effort is also a prerequisite for deterrence.

Due to the difficulty of distinguishing between satellite failures caused by environmental factors and deliberate attacks, greater space situational awareness can help reduce uncertainty when pinpointing the immediate cause behind the malfunction of a space asset.[3] Since Space Situational Awareness (SSA) can also be used for tracking and targeting foreign satellites, the possession of advanced SSA capabilities constitutes a strategic advantage for spacefaring nations.

Protecting satellites, ground stations, and communications links depends on the nature of the space negation threat that such systems face, but, in general terms, threats can include cyber-attacks against space system computers, electronic attacks on satellite communications links, conventional or nuclear attacks on the ground- or space-based elements of a space system, and directed energy attacks such as dazzling or blinding satellite sensors with lasers.

An advanced space systems protection capability involves the ability to recover from a space negation attack in a timely manner by reconstituting damaged or destroyed components of the space system. While capabilities to repair or replace ground stations and reestablish satellite communications links are generally available, capabilities to quickly rebuild systems in space are more difficult to develop and implement.

Space Security Impact

Most space systems remain unprotected from a range of threats, assessed by experts to include (in order of decreasing likelihood): 1) electronic warfare such as jamming communications links, 2) physical attacks on satellite ground stations, 3) dazzling or blinding of satellite sensors, 4) hit-to-kill anti-satellite (ASAT) weapons, 5) pellet cloud attacks on low-orbit satellites, 6) attacks in space by microsatellites, and 7) high altitude nuclear detonations (HAND).[4] Other potential threats include radio frequency weapons, high-powered microwaves, and "heat-to-kill" ground-based lasers. Growing awareness of the vulnerabilities of space systems has led actors to develop space system protection capabilities to better detect, withstand, and/or recover from an attack. Nonetheless, there are no effective physical protections against the most direct and destructive types of negation such as the use of kinetic or high-powered energy forces against satellites.

The development of effective protection capabilities can have a positive impact on space security by increasing the ability of a space system to survive negation efforts, thus helping to assure secure access to and use of space, and potentially to deter negation attempts. Space actors may refrain from interfering with well protected space systems if such attacks would seem both futile and costly. Moreover, the use of protective measures to address system vulnerabilities could offer a viable alternative to offensive means to defend space assets.

The security dynamics of protection and negation are closely related and, under some conditions, protection systems can have a negative impact on space security. Like many defensive systems, they can stimulate an arms escalation dynamic by motivating adversaries to develop weapons to overcome them. Conceivably, robust protection capabilities could also reduce the fear of retaliation in a space actor that possesses said capabilities, thus lowering the threshold for attempting the negation of spacecraft. In addition, effective protective measures can have significant cost implications, and can thereby reduce the number of actors with secure use of space.

Trend 7.1: Efforts to protect satellite communications links increase, but ground stations remain vulnerable

Protection of satellite 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 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 from computer hacking or possibly, but less likely, jamming.[5] 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. Many commercial space systems have a single operations center and ground station,[6] leaving them potentially vulnerable to some of the most basic attacks.

Responding to such concerns, the U.S. General Accounting Office recommended that "commercial satellites be identified as critical infrastructure."[7] 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.

Electronic protection

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. These 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.[8]

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. Advanced protection capabilities include: 1) narrow band excision techniques that mitigate jamming by using smaller bandwidth; 2) burst transmissions and frequency-hopping (spread-spectrum modulation) methods that communicate data in a short series of signals or across a range of radio frequencies to keep adversaries from "locking-on" to signals to jam or intercept them; 3) antenna side-lobe reduction designs that mitigate jamming or interception vulnerabilities by providing more focused main communication beams and reducing interference from jamming in the side-lobe regions; and 4) nulling antenna systems (adaptive interference cancellation), which monitor interference and combine antenna elements designed to nullify or cancel the interference.[9]

During the Cold War, the U.S. and the USSR led in the development of systems to protect satellite communications links. The U.S. currently appears to be leading in the development of more advanced capabilities. For example, U.S./NATO Milstar communications satellites use multiple anti-jamming technologies, employing both spread-spectrum modulation and antenna side-lobe reduction. Adaptive interference cancellation is being developed for next-generation satellites.[10] Through its Global Positioning Experiments project, the U.S. has also demonstrated the ability of GPS airborne pseudo-satellites to relay and amplify GPS signals to counter signal jamming.[11]

The U.S. 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.[12] The U.S. 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,[13] as discussed below.

In response to several jamming incidents attributed to the Falun Gong, in 2005 China launched its first anti-jamming satellite, the Apstar-4 communications satellite.[14] China also reportedly upgraded its Xi'an Satellite Monitoring Center to diagnose satellite malfunctions, address issues of harmful interference, and prevent purposeful damage to satellite communications links.[15]

2010 Development

U.S. Cyber Command (USCYBERCOM) reaches Full Operational Capability

On 3 November 2010, the U.S. DOD announced that USCYBERCOM had reached full operational capability, having achieved initial operating capacity on 21 May.[16] In 2009, the Secretary of Defense had ordered the military to set up USCYBERCOM as a unified command to act as a central hub for U.S. cyber capabilities. After delays, USCYBERCOM was established in October 2009 under the leadership of the director of the National Security Agency (NSA) as an armed forces sub-unified command subordinate to U.S. STRATCOM. USCYBERCOM, headquartered at Fort Meade, MD, plans to hire as many as 1,000 cyber specialists in the near future.[17] The Pentagon will continue to develop policies for cyberspace operations.

On 21 May 2010, General Keith Alexander, NSA Director since 2005, assumed command of USCYBERCOM. The new command's powers remain somewhat unclear; for instance, can offensive action be authorized?[18] Senior policymakers have been debating whether to grant USCYBERCOM such authority, which could include the destruction or disruption of an opponent's network to prevent an attack on a U.S. target.[19] Alexander has stated that he envisions the protection of key commercial and civilian infrastructure such as power grids and banks.[20] He argues that "we have to have offensive capabilities to, in real time, shut down somebody trying to attack us."[21]

The USCYBERCOM aegis would include government-run satellite ground stations and uplinks, but it is unclear to what extent privately owned facilities will be protected. Alexander says that civilian business networks will not be part of his agency's domain, but leaves that possibility open to a "decision from the White House"[22] and has stated that "attacks and their potential effects (do) not discriminate between military and civilian users."[23] For instance, the Stuxnet virus attacks against Iran, which General Alexander calls "very sophisticated," have highlighted the vulnerability of key systems to cyber-attacks.[24]

2010 Development

Rapid Attack, Identification, Detection, and Reporting System (RAIDRS) program reaches milestones

In 2010, RAIDRS marked its fifth year of continuous deployed operations, employed by the Operation Silent Sentry of the 16th and 380th Space Control Squadrons located at Peterson Air Force Base, CO.[25] Using RAIDRS, Operation Silent Sentry has been monitoring critical satellite communications links for U.S. forces in support of military operations in Afghanistan and Iraq.[26] RAIDRS, initially deployed in July 2005 as the Satellite Interference Response System for a 120-day proof of concept, was then re-designated RAIDS Deployable Ground Segment Zero (RDGS-0) and assigned to Operation Silent Sentry.[27]

RAIDRS Block-10 (RB-10), the follow-on to RDGS-0, is a worldwide network of sensors slated to be deployed in 2012, with full operational capability expected in 2013.[28] On 1 March, RB-10 prime contractor Integral Systems Inc. announced that it had completed the Required Asset Available milestone Factory Acceptance Test of the Block-10 Central Operating Location and first deployable system,[29] which is a basic requirement for the system's Initial Operating Capability. Subsequently, on 5 January 2011 it was announced that all system requirements capable of being tested at the assembly facility have been verified.[30] This paves the way for the Developmental Test and Evaluation, the final on-site test prior to delivery.

Space Security Impact

The establishment of the unified USCYBERCOM gives new focus and integration to U.S. cyber protection, affording a new level of security to its space missions. Enhanced mechanisms to protect cyber networks make space systems more secure against negation attempts, thereby providing a viable alternative to offensive means to defend space assets. Space actors may refrain from interfering with well protected space systems if such attacks seem both futile and costly. However, if USCYBERCOM sets a precedent for offensive cyber action, such capabilities could proliferate. The full operability for RAIDRS Block 10 means that the U.S. will soon have a much improved ability to detect and defend from physical attacks on space assets, which would have a positive impact for space security.

Trend 7.2: Protection of satellites against direct attacks limited but improving

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 low earth orbit can be reached in a matter of minutes, while geostationary orbit takes about a half-day to reach by completing a Hohmann transfer orbit, illustrates the unique protection of dynamics associated with different orbits.[31] Lower orbits are also less predictable because of greater atmospheric effects, such as fluctuations in density in the upper atmosphere, which alter satellite drag. For example, at an altitude of about 800 km, the predictability of orbits is limited to an error of approximately 1 km one day in advance of the calculation, using readily available models. 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, as in the U.S. stealth satellite program Misty (cancelled in 2007).[32] 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.

Protection against conventional weapons

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. As previously discussed, however, the difficulty of attacking into and maneuvering through space facilitates the protection of satellites from conventional weapons threats. For example, tests of the Soviet co-orbital ASAT system in the 1960s and 1970s were limited to two opportunities a day, when the longitude of the interceptor launch site matched that of the target satellite. This introduced an average delay of six hours between a decision to attack a satellite in LEO and the launch of an interceptor.

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. These evasive maneuvers must avoid the weapons effects or target acquisition range of the interceptor,[33] but the extra fuel required might represent more than 10–20 per cent of the satellite cost.[34]

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.[35]

Dispersing capabilities, well established in terrestrial conflict, can be applied to satellite operations.[36] 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. The U.S. Defense Advanced Research Projects Agency (DARPA) is developing a project called System F6 (Future, Fast, Flexible, Fractioned, Free-Flying Spacecraft United by Information Exchange), which seeks to research, develop, and test a satellite architecture in which the functionality of a single satellite is replaced by a cluster of free-fly subsatellites that wirelessly communicate with each other.[37] Each subsatellite of the system can perform a separate function or duplicate the function of another module, making the constellation less vulnerable to electronic or physical interference. In December 2009, a contract valued at $74.6-million was awarded to Orbital Sciences Corporation for work on the System F6 program,[38] which is expected to become operational in 2013 with an on-orbit demonstration of a fractioned space architecture.[39]

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. In general, however, there is currently little redundancy of commercial, military, or civilian space systems, particularly of the space-based components, because of the large per-kilogram cost of launch.

Greater dependence on space systems is motivating system redundancy. China, the ESA and the EU, Japan, and India are developing satellite navigation systems that will decrease dependency on the U.S. GPS. Constellations of satellites such as GPS are inherently protected by redundancy, since the loss of one satellite might reduce service reliability, but not destroy the entire system.

Over the longer term, more active measures such as automated on-orbit repair and servicing capabilities may be able to improve the survivability of space systems. Technology developments in this area have included the DARPA/NASA Orbital Express program, which launched two spacecraft in 2007 to test automated approach and docking, fuel transfer, and component exchange.[40] The three-month, $300-million series of tests achieved a number of industry firsts — notably, the first fully autonomous capturing and servicing of a satellite without client assistance.[41] The U.S. has also explored other options for more active, direct protection of satellites such as the DARPA Tiny, Independent, Coordinating Spacecraft (TICS) program, in which 10-pound satellites could be quickly air launched by fighter jets to form protective formations, shielding larger satellites from direct attacks.[42] This program, however, was cancelled in the FY2009 budget.[43]

Protection against nuclear attack

Electronics are the foundation of satellite communications networks, and the threat of an Electromagnetic Pulse (EMP) attack through a nuclear explosion or focused microwaves is a concern for nations with space assets, as such an attack would involve an "instantaneous, intense energy field that can overload or disrupt at a distance numerous electrical systems and high technology microcircuits, which are especially sensitive to power surges."[44] Protection from a High Altitude EMP (HEMP) event involves hardening those electronics that provide essential services, in conjunction with surge protectors, which may provide an ability to withstand a HEMP blast.[45] When combined with redundancy of critical components, however, this type of protection is expensive and not practical for any but the most sensitive of military satellites.

Early space protection efforts undertaken by the U.S. and the USSR during the Cold War were aimed at increasing the survivability of strategically important satellites in the face of nuclear attack. U.S. systems such as the Defense Support Program early warning satellites, Defense Satellite Communications System communications, and GPS navigation satellites were all hardened against the radiation and EMP effects of nuclear weapon detonations, as are all current generation military satellites of advanced space actors. Robust production lines, the use of satellite constellations, and responsive launch readiness contributed to the survivability of the USSR's space capabilities from nuclear attack.

Radiation hardening enables satellites to withstand the effects of nuclear weapons through the use of radiation-tolerant components and automatic sensors designed to switch off non-essential circuits during a nuclear detonation. Photovoltaic or solar cells, employed as power sources in many satellites and particularly vulnerable to radiation effects, can be replaced by nuclear reactors, thermal-isotopic generators, or fused silica-covered radiation-resistant solar cell models built with gallium arsenide.

Similarly, EMP shielding protects sensitive satellite components from the voltage surges generated by the reactions of nuclear detonations with the environment and the internal voltages and currents generated when X-rays from a nuclear detonation penetrate a satellite.[46] Technical measures to protect satellites from external EMP effects include: 1) metal shields and conductive coatings to prevent EMP radiation from entering satellite cavities, 2) linking and grounding of the exterior components of a satellite to create a Faraday cage that will prevent transmission of EMP radiation to interior components, 3) grounding straps and surge arresters to maintain surfaces at the same electrical potential, and 4) microwave filters that isolate internal satellite electronics from external electromagnetic radiation. The use of graphite composites instead of aluminum construction panels can further reduce the number of liberated electrons capable of disrupting components. Electro-optic isolators, specialized diodes, and filters can also be used to shield internal satellite circuits.

Scintillation and blackout measures can be used to avoid the disruption and denial of communications between satellites and their ground stations caused by nuclear detonations that generate an enhanced number of charged particles in the Earth's radiation belts. Protection against these communications failures can be provided by crosslink communications to bypass satellites in a contaminated area and enable communications via other satellites. Higher frequencies that are less susceptible to scintillation and blackout effects, such as EHF/SHF (40/20 gigahertz), can also be used.

In addition to focusing on protective measures, the U.S. has examined options to reduce the duration of atmospheric ionization in the case of a HAND. For instance, the High Frequency Active Auroral Research Program (HAARP) facility in Alaska has one of the few ionospheric heaters in the world. It can protect satellites by emitting radio waves to mitigate the effects of a HAND.[47]

Most commercial spacecraft must install radiation hardening and include automated switch-off and recovery modes that protect systems from natural radiation events, such as solar flares. Generally, commercial satellites are not specifically protected from the EMP effects that would result from a HAND. However, some commercial spacecraft components may have some limited protection from radiation because they were made with materials developed to military specifications. Any physical protection normally creates an increased cost and it seems unlikely that the space industry will harden its satellites without significant prompting and subsidies from governments. Protection measures vary in cost; for example, hardening against the radiation effects of a nuclear detonation is estimated to be about 2–5 per cent of satellite costs, while hardening against the EMP effects of a nuclear detonation has been estimated to be up to 10 per cent of satellite costs.[48]

The U.S. is pursuing technologies other than hardening to reduce the damaging long-term radiation belts caused by a HAND. HAARP includes research on active measures to reduce the concentration of ionic particles in the upper atmosphere following a HAND.[49] Such measures would reduce the probability of satellite malfunction in the aftermath of a HAND.

Protection against a directed energy attack

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. Protection measures that address these threats include: 1) laser sensors, mechanical shutters, or spectral or amplitude filters to protect from intense laser illumination; 2) the use of multiple imaging frequencies, including those attenuated by atmospheric absorption, to reduce the effectiveness of the laser weapon itself; and 3) the use of indirect imaging angles to avoid direct ground-based laser illumination. While such measures can help to prevent permanent damage, they may require a temporary disruption of the satellite's functions.

Highly advanced lasers capable of damaging other satellite subsystems through heating or shock continue to require higher power. Vulnerable subsystems include solar panels and some electronics. Protection can be provided by ablative coatings and isolated shields on the exterior of spacecraft; the use of spin stabilization to dissipate heat; and the selection of power generation technology other than photovoltaic cells, which can be damaged by lasers.[50] The USAF has been developing a coating for critical system components that would offer some kind of protection from directed energy weapons such as lasers.[51] While the technology would be primarily used for ground-based assets and missiles, the coating could offer an inexpensive way to protect satellites from energy attacks. The use of higher orbits also provides significant protection from this type of attack because of the distances involved; modest shields in GEO can prevent the destruction of a non-imaging satellite by laser heating.[52] Protection against microwave weapons, which use high-powered short pulse beams to degrade or destroy unprotected electronics, can be provided by over-voltage and over-current protection circuits within a satellite's receivers.

2010 Development

U.S. moves forward with STSS, Space Fence

On 8 June, demonstration satellites built by Northrop Grumman and Raytheon for STSS successfully detected and tracked a two-stage Ground Based Interceptor missile during an MDA test.[3] This demonstration was followed by the tracking of an ICBM as it flew 4,800 miles to hit a target in the Ronald Reagan Test Site near Kwajalein Atoll of the Marshall Islands. [54] The three-stage Minuteman III missile carried a single, inert reentry vehicle atop a modernized booster, guidance set and post-boost vehicle.[55]

On 28 June, STSS performed yet another successful test by consistently following a missile launched by the Terminal High Altitude Area Defense system in what is reportedly "the most thorough indication yet of the space-based sensor's capabilities."[56] During this test, the STSS demonstration satellites detected the launch of a threat-representative missile and relayed the data to Ballistic Missile Defense System ground stations.[57] While the primary use of the system would be in ballistic missile defense, such capabilities could give satellites the warning time needed to maneuver away from an ASAT attack.[58] Especially germane to space system protection and possibly useful for negation was the STSS ability to track other satellites in orbit.[59]

In 2010, the Space Fence System entered a new phase when the USAF Electronic Systems Center (ESC) released its request for proposals for a second stage of development.[60] ESC awarded three $30-million contracts to develop more detailed proposals for an eventual Space Fence system.[61] Lockheed Martin[62] and Raytheon[63] have both responded to the request and the USAF aims to have Space Fence initially operational by 2015. In early 2011, ESC was to award two 18-month contracts worth up to a total of $214-million to develop preliminary design reviews;[64] in 2012, a final contract will be awarded to finish development, fielding, and operators of the Space Fence.

The S-Band Space Fence program is planned to replace the existing VHF Space Fence, known as the Air Force Space Surveillance System, inherited from the Navy in 2004.[65] The new fence will operate at the much higher frequency of S-Band, enabling it to track objects as small as a few centimeters in diameter. And unlike the VHF fence, which exists as three transmitting and five receiving stations located across the southern U.S., the S-Band Space Fence will consist of up to three receiver-transmitter pairs located around the globe.

Space Security Impact

In addition to increasing general space situational awareness, the launch of STSS will give the U.S. an increased ability to detect potentially hostile maneuvers against its space assets. The updated version of the Space Fence, with its ability to detect smaller space objects, could decrease the effectiveness of space mines and other attack measures that rely on smallness. Overall, the development of effective surveillance capabilities to detect potential attacks can have a positive impact on space security by increasing the ability of a space system to survive negation efforts, thus helping to ensure secure access to and use of space.

Trend 7.3: Efforts under way to develop capacity to rapidly rebuild space systems following direct attacks, but operational capabilities remain limited

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. This trend examines 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. Although efforts are under way to enable rapid recovery, no actor currently has this capability.

During the Cold War, the USSR and the U.S. 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 US, but has also launched them more often. Soviet-era pressure vessel spacecraft designs, still in use today, have an advantage over Western vented satellite designs that require a period of outgassing before the satellite can enter service.[66] In principle, Russia has the capacity to deploy redundancy in its space systems at a lower cost and to allow quicker space access to facilitate the reconstitution of its systems. For instance, 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.[67] A significant number of Russia's current launches, however, are of other nations' satellites and Russia continues to struggle to maintain existing military systems in operational condition. Thus little redundancy is actually leveraged through this launch capability.[68]

The U.S. 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.[69] 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. Indeed the USAF Space Command has noted: "An operationally responsive spacelift capability is critical to place timely missions on orbit assuring our access to space."[70] Initial steps included a Small Launch Vehicle subprogram for a rocket capable of placing 100 to 1,000 kg into LEO on 24-hours notice; however, such a program may ultimately be linked to a long-term prompt global strike capability.[71] 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.[72] In September 2008, Falcon-1 reached orbit on its fourth attempt.[73]

The USAF TacSat microsatellite series is 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."[74] A full ORS capability could allow the U.S. to replace satellites on short notice,[75] enabling rapid recover from space negation attacks and reducing general space system 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.[76] The first technology demonstrators built were the X-40 (USAF) and the

X-37A (NASA/DARPA).[77] 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.[78] The commercial space industry is contributing to responsive launch technology development through advancements with small launch vehicles, such as the abovementioned Falcon-1 developed by SpaceX, and its successor, the Falcon-9, which had its maiden test flight in June 2010.

Interest is increasing in the development of air-launched microsatellites, which could reduce costs and allow rapid launches, as they do not require dedicated launch facilities. The Russian MiG-launched kinetic energy anti-satellite weapon program was suspended in the early 1990s, but commercial applications of similar launch methods continue to be explored. As early as 1997 the Mikoyan-Gurevich Design Bureau was carrying out research, using a MiG-31 to launch small commercial satellites into LEO.[79] The Mikron rocket of the Moscow Aviation Institute's Astra Centre, introduced in 2002, was designed for launch from a MiG-31 and is capable of placing payloads of up to 150 kg into LEO.[80] The U.S. has used the Pegasus launcher, first developed by Orbital Sciences Corporation in 1990, to launch military small payloads up to 450 kg from a B-52 aircraft.[81] Other efforts include the China Aerospace Science and Technology Corporation's plan to launch small payloads released from a modified H-6 bomber.[82]

2010 Development

Progress in the research and development of low-cost launch capabilities

Seeking to cut costs, NASA has been placing more emphasis on commercial involvement for several years. On 4 June 2010, SpaceX launched its first Falcon 9 rocket with a mockup of the Dragon capsule on board. Organized under NASA's Commercial Orbital Transportation Services (COTS) program,[83] the Falcon 9 aims to be a lower cost option and uses less expensive components and systems than traditional rockets, including kerosene/liquid-oxygen-burning Merlin engines, nine of which lifted the spacecraft off the pad.[84]

On 8 December 2010, the Dragon capsule was launched aboard another Falcon 9. The capsule performed maneuvers in orbit to demonstrate capabilities for co-orbit and docking as per its intended mission of re-supply to the International Space Station. After two orbits, the Dragon became the first privately-owned spacecraft to perform reentry and splashdown.[85] While the Falcon 9 achieved major cost savings in its first launches, industry analysts remain cautious about the prospect of maintaining this edge over the long term.[86]

Another low cost alternative receiving increased attention is the use of nanosatellites for military purposes. The U.S. Army launched two nanosatellites, their first satellite launch in 50 years, aboard the Falcon 9 that carried the Dragon capsule.[87] These miniaturized satellites, part of the Operational Nanosatellite Effect or SMDC-One, completed a 35-day orbit and burned up on reentry. The mission provided a great deal of data that will be analyzed and applied to future nanosatellite programs.[88] The U.S. Navy also participated with two of their own satellites piggybacked onto the same launch.[89]

Space Security Impact

Moving to cheaper launch capabilities through innovative propulsion, privatization, and miniaturized satellites should allow space systems to become more adaptive in many ways. New technology can be integrated more quickly, and in theory losses due to offensive action could also be more quickly replaced. However, advancements have been slow, and present gains may prove temporary. Cheaper technologies will also be more widely available, making proliferation a concern. More privatization of space launches has the potential to dramatically improve innovation in space systems and save money, thereby facilitating increased access to space. It remains to be seen whether effective controls will be placed on private industry as it moves into space.

CHAPTER EIGHT

Space Systems Negation

This chapter assesses trends and developments related to the research, development, testing, and deployment of capabilities to negate the use of space systems, which includes Earth-to-space and space-to-space interference, as well as electromagnetic and cyber attacks. The focus here is on technical capabilities and not the intent of actors to use them. While this chapter touches on the development of space surveillance capabilities, which is a key enabling technology for space systems negation, Space Situational Awareness is covered as a separate space security indicator in chapter 2.

Space systems negation efforts can involve taking action from the ground or from space against the ground-based components of space systems, the communications links to and from satellites, space launchers, or satellites themselves. Negation can be achieved through the application of cybernetic or electronic interference, conventional weapons, directed energy (lasers), or nuclear capabilities used to carry out what are often referred to in the U.S. as the five Ds: deception, disruption, denial, degradation, and destruction.[1]

Many space negation capabilities are derived from widely available military equipment, technology, and practices. These include conventional attacks on ground stations, hacking into computer systems, jamming satellite communications links, using false radio transmissions (spoofing), or simple camouflage techniques to conceal the location of military space assets.

Space negation capabilities that involve attacks on satellites themselves are more sophisticated. With the exception of ground-based laser dazzling or blinding, a basic launch capability is required to directly attack a satellite. Space surveillance capabilities are also required to effectively target satellites in orbit. Some space-based negation techniques require highly specialized capabilities, such as precision maneuverability or autonomous tracking.

Degradation and destruction can be provided by conventional, directed energy, or nuclear anti-satellite (ASAT) weapons.[2] 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 in low earth orbit (LEO).[3]

Space Security Impact

Space systems negation capabilities are directly related to space security since they enable an actor to restrict the secure access to and use of space by other actors. The dynamics of space negation and space protection are closely related. For example, robust space negation efforts will more likely succeed in the face of weak protection measures. Like other offense/defense relationships in military affairs, this space negation/protection dynamic raises concerns about an arms race and overall instability as actors compete for the strategic advantages that space negation capabilities appear to offer. Different negation activities are likely to stimulate different responses.[4] While interruption of communications links would probably not be viewed as very provocative, physical destruction of satellites could trigger an arms race.

Soviet and U.S. concerns that early warning satellites be protected from direct attack as a measure to enhance crisis management were enshrined in bilateral treaties such as the Strategic Arms Limitation Talks and the Anti-Ballistic Missile treaties. Space war games have also underscored the challenges generated by space negation efforts focused on "blinding" the strategic communications and attack warning capabilities of an adversary.[5]

Security concerns arising from the development of negation capabilities are compounded by the fact that many key space capabilities are inherently 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 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, as discussed in chapter 1. In addition, a HAND is indiscriminate in its effects and would generate long-term negative impacts on space security.

Trend 8.1: Increasing capabilities to attack space communications links

The most vulnerable components of space systems are the ground stations and communications links, which are susceptible to attack from commonly accessible weapons and technologies. An attack on the ground segments of space systems with conventional military force is one of the most likely space negation scenarios. Only modest military means would be required for system sabotage; physical attack on the ground facility by armed invaders, vehicles, or missiles; and interference with power sources.

The U.S. leads in developing advanced technologies to temporarily negate space systems by disrupting or denying access to satellite communications. In 2004, the mobile, ground-based CounterCom system, designed to provide temporary and reversible disruption of a targeted satellite's communications signals, was declared operational.[6] In 2007, this system was upgraded to fully equip two squadrons with seven jamming systems, up from the original two.[7] Next-generation jammers will likely have "enhanced capabilities for SATCOM denial," using largely commercially available components.[8] Moreover, the recently released U.S. National Security Space Strategy states that the U.S. will retain the "capabilities to respond in self-defense, should deterrence fail."[9]

The U.S. Space Control Technology program sought to "continue development and demonstration of advanced counter-communications technologies and techniques…leading to future generation counter-communications systems and advanced target characteristics."[10] The mission description for this program noted that, "consistent with DOD policy, the negation efforts of this program focus only on negation technologies which have temporary, localized, and reversible effects."[11] The 2004 *Presidential Directive on Space-Based Positioning, Navigation and Timing Systems* called for development of capabilities to selectively deny, as necessary, GPS and other navigation services.[12]

Although the U.S. has the most advanced space capabilities, the technical means for electronic and information warfare, including hacking into computer networks and electronic jamming of satellite communications links, are widely available. For instance, the jamming by Libyan nationals of the Thuraya Satellite Telecommunications mobile satellite, in an effort to disrupt the activities of smugglers of contraband into Libya, lasted more than six months.[13] Similarly, reports emerged in November 2007 that China had deployed advanced GPS jamming systems on vans throughout the country.[14] Incidents of jamming the relatively weak signals of GPS are not new. Iraq's acquisition of GPS-jamming equipment during Operation Iraqi Freedom in 2003 suggests that jamming capabilities are proliferating through commercial means; the equipment was reportedly acquired from a Russian company, Aviaconversiya Limited.[15]

Reported incidents of electronically jammed media broadcasts include interruptions to broadcasts to Iran, Kurdish news broadcasts,[16] and Chinese television.[17] Computer networks linked to communications systems have also been targeted.[18] Commercial proliferation of these capabilities means that non-state actors are increasingly able to launch attacks on communications links. For example, in 2007, a group of hackers based in Indonesia collected data transmitted by an older, unidentified commercial satellite.[19] It is often difficult to determine if satellite interference conducted by individual attackers is state-sponsored. Iran has been accused of jamming the satellite transmission of the Voice of America and the BBC, as discussed below.

2010 Development

European satellite broadcasts continue to be jammed from Iran

The Iranian jamming of European satellite signals, including broadcasts of BBC Persian language, Deutsche Welle, and other media, as well as the continuous jamming of France's Eutelsat, continued throughout 2010. The interference, begun in December 2009,[20] intensified around the anniversary of the 1979 Iranian Revolution in February, when approximately 70 radio and television programs transmitted by Eutelsat were disrupted.[21]

The interference was met with widespread criticism and calls for action, especially by the European Union,[22] which called on Iranian authorities to "stop the jamming of satellite broadcasting and internet censorship and to put an end to this electronic interference immediately."[23] In March, the EU expressed its determination to "act with a view to put an end to this unacceptable situation." By the end of the year, the ITU had not officially attributed the jamming to the Iranian government and specific actions against Iran had yet to take place.[24]

According to a *Guardian* report based on a WikiLeaks cable, the U.K. was considering closing Iran's English-language IRIB television channel, based in London.[25] During the March session of the legal subcommittee of UN COPUOS, Eutelsat asked the subcommittee to look into the issue as a violation by Iran of its legal obligations under the Outer Space Treaty.[26] Iran strenuously protested, insisting that the jamming issue remain within the ITU.[27] In September, it was announced that Egypt's Nilesat's signals to Iran were also being jammed. The jamming initially included news programs, then World Cup soccer over the summer and, most recently, music programming.[28]

2010 Development

Jamming incidents and capabilities continue to proliferate

According to Ethiopian Satellite Television, an Amsterdam-based satellite service, the Ethiopian government is responsible for repeated jamming of its programming.[29] The jamming had previously affected Voice of America broadcasts, leading to protests from American officials and the international press.[30] The U.S. State Department issued a statement condemning the incident.[31]

In September, Britain approved the sale of jamming equipment to Kazakhstan.[32] Despite the potential use of this equipment for malicious interference, a report released by the British Foreign and Commonwealth Office stated that "the technical assessment of the equipment revealed that, whilst the equipment could be used for satellite jamming, this would be technically difficult."[33]

North Korea demonstrated a more sophisticated capability when it intermittently jammed GPS signals over the course of three days in August. Commenting on a potentially dangerous problem in an already volatile region, U.S. military officials said they were not surprised by this example of the North Korean "culture of military creativity."[34]

Space Security Impact

The technologies used to hack into computer networks and jam satellite communications links are widely available; the relative ease with which such attacks are carried out has a negative impact on space security. Paradoxically, more incidents of jamming and the proliferation of jamming capabilities may also have a positive effect on space security, as they seem to be creating some impetus for more assertive action from the ITU. The proven ability of even minor powers to jam satellite transmissions, including ones used by the U.S. military, should generate increased interest in protecting communications from interference.

Trend 8.2: Ongoing proliferation of ground-based capabilities to attack satellites

A series of U.S. and Soviet/Russian programs during the Cold War and into the 1990s sought to develop ground-based weapons that employed conventional, nuclear, or directed energy capabilities against satellites. As well, recent incidents involving the use of ASATs underscore the detrimental effect they have for space security, in particular should these weapons be used for hostile purposes against an adversary.

Conventional (kinetic intercept) weapons

Launching a payload to coincide with the passage of a satellite in orbit is the fundamental requirement for a conventional anti-satellite capability. To date, nine nations have confirmed autonomous orbital launch capabilities, as discussed in chapter 4. 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).[35] Kinetic hit-to-kill technology requires more advanced sensors to reach the target. Targeting satellites from the ground using any of these methods would likely be more cost-effective and reliable than space-based options.[36]

USAF *Counterspace Operations* Document 2-2.1 outlines a set of "counterspace operations" designed to "preclude an adversary from exploiting space to their advantage…using a variety of permanent and/or reversible means."[37] Among the tools for offensive counterspace operations, the document lists direct ascent and co-orbital ASATs, directed energy weapons, and electronic warfare weapons. 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.[38] For FY2005 Congress appropriated $14-million for the KE-ASAT program through the MDA Ballistic Missile Defense Products budget.[39] The KE-ASAT program was part of the Army Counterspace Technology testbed at Redstone Arsenal.[40] The U.S. 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.[41] EKVs use infrared sensors to detect ballistic missiles in midcourse and maneuver into the trajectory of the missile to ensure a hit to kill.[42] With limited modification, the EKV could be used against satellites in LEO.[43] Japan is an important international partner of the U.S. 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.[44]

Notably, in 2008, the U.S. 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 U.S. has stressed that it was a "one-time event,"[45] 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.[46] Russia has continued to observe a voluntary moratorium on anti-satellite tests since its last test in 1982. The precise status of its system is not known, but it is most likely no longer operational.[47] Russia has also developed a long-range (350-km) exoatmospheric missile, the Gorgon, for its A-135 anti-ballistic missile system.[48]

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.[49] However, China called the event an experiment, not an anti-satellite test.[50] China is not believed to currently have enough interceptors for a full ASAT system that could destroy multiple satellites in LEO, although it could produce more.[51] The U.K., Israel, and India have also explored techniques for exoatmospheric interceptors.[52]

Nuclear weapons

A nuclear weapon detonated in space generates an electromagnetic pulse that is highly destructive to unprotected satellites, as demonstrated by the U.S. 1962 Starfish Prime test.[53] Given the current global dependence on satellites, such an attack could have a devastating and wide-ranging impact on society. As noted above, both the U.S. 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.[54]

China, the member states of the European Space Agency, India, Iran, Israel, Japan, Russia, and the U.S. possess space launch vehicles capable of placing a nuclear warhead in orbit, although the placement of weapons of mass destruction in outer space is specifically prohibited by the 1967 Outer Space Treaty (see chapter 3). North Korea and Pakistan are among the 18 states that possess medium-range ballistic missiles that could launch a mass equivalent to a nuclear warhead into LEO without achieving orbit.

Eight states are known to possess nuclear weapons: China, France, India, Israel, Pakistan, Russia, the U.S., and the U.K. North Korea has an ongoing nuclear program and attempted to detonate a nuclear device in 2006.[55] Iran reportedly ended its nuclear weapons program in 2003, but the International Atomic Energy Agency continues to investigate potentially illegal uranium enrichment activities.[56]

Table 8.1: 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

Directed energy weapons

Low-powered lasers, which could be used to "dazzle" satellites in LEO, have been used to degrade unhardened sensors on satellites in LEO.[57] 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.[58] This suggests that even a commercially available low-watt laser functioning from the ground could be used to "dazzle" or temporarily disrupt a satellite.[59] 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. There is worldwide interest in adaptive optics research and development, and industrialized countries such as Canada, China, Japan, the U.S., Russia, and India have engaged in such research.[60] Nations that are developing laser satellite communications systems, such as France, Germany, and Japan, could also develop the ability to track and direct a laser beam at a satellite.

Several states have demonstrated the technical ability to generate relatively high-powered laser beams. Both Israel and the U.S. have developed prototypes of laser systems that are capable of destroying artillery shells and rockets at short ranges. The potential use of high-energy lasers against satellites has been explored by the U.S., the USSR/Russia, and China. The MIRACL system was developed by the U.S. navy to dazzle and blind sensors in GEO and heat to kill electronics on satellites in LEO — a significant ASAT capability. Similarly the USAF Starfire Optical Range at Kirtland Air Force Base has undertaken laser experiments under the Advanced Weapons Technology program that have been characterized as "experiments for applications including anti-satellite weapons;" a demonstration of "fully compensated beam propagation to Low-Earth orbit satellites" was called for in the FY2007 budget request.[61] Funding was only authorized after the USAF denied any intent to test Starfire against a satellite.[62]

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.[63] This technology is believed by some experts to have potential ASAT capabilities, despite the significant technical and cost challenges it has faced.[64] The program was initiated in 1996 and took 12 years to reach first light, at a cost of $5-billion.[65] The first ballistic missile interception was planned for late 2009[66] and finally occurred in February 2010 when the ALTB system successfully shot down a test ballistic missile.[67]

China operated a high-power laser program as early as 1986 and is believed to have since acquired multiple hundred-megawatt lasers.[68] The Chinese government has also devoted resources to high-power solid state laser research.[69] Researchers are studying adaptive optics to maintain beam quality over long distances and the use of solid state lasers in space; both technologies could be used against satellites.[70] In 2006, China reportedly used a ground-based laser to illuminate an American reconnaissance satellite flying over Chinese territory.[71] However, with only public sources available, it is difficult to verify the nature of the laser beam, the physical effects on the spacecraft, or the intent behind the illumination.[72] South Korea is also interested in developing laser systems for use against North Korean missiles and artillery shells, and had expressed hopes of deploying such a system in 2010.[73] Indian defense scientists have also reportedly experimented with "high-power laser weapons."[74]

2010 Development

Directed energy weapons continue to be developed and tested

Following a series of preliminary tests in 2009, the U.S. conducted the first successful testing of an airborne laser weapon to destroy a ballistic missile using the Airborne Laser Test Bed (ALTB) system on 3 February. The ALTB, consisting of two solid state lasers and a megawatt-class Chemical Oxygen Iodine Laser (COIL) mounted on a modified Boeing 747,[75] is a joint project of Boeing, Lockheed Martin and Northrop Grumman. Boeing supplied the jet platform, Lockheed Martin built the beam/fire control system, and Northrop Grumman was responsible for the high-energy laser.

Previous tests had demonstrated the tracking capabilities of the weapon system, but this was the first actual destruction of a missile in boost phase,[76] and Northrop Grumman described the test as "turning science fiction into fact."[77] The intercepted missile was traveling at a speed of 4,000 mph when it was destroyed by the COIL with a beam the size of a basketball.[78] During the test, an attempt to destroy a second target, a solid-fueled sounding rocket, failed when an anomaly caused the ALTB to shut down before the target was destroyed.[79]

In an October test the ALTB failed to destroy a solid fuel, short-range ballistic missile whose rocket motors were still thrusting. Officials were unsure of the cause of the failure.[80] In November, Lockheed Martin received a contract to develop a high-power microwave energy weapon with the capability of destroying sensitive electronics without human collateral damage.[81] A test scheduled for 10 January 2011 was delayed because of turbulent weather.[82]

2010 Development

Development of ASAT capabilities considered by some countries

In January 2010, the Director-General of India's Defence Research and Development Organisation announced that as part of its ballistic missile defense program India is working on development of lasers and a kill vehicle that could be used to attack satellites in LEO.[83] In the 2010 document released by the Indian Ministry of Defence, *Technology Perspective and Capability Roadmap 2010*,[84] India again spelled out its ambition to develop ASAT technologies. The roadmap specifically stated that it would focus on the following areas:

a) EMP hardening of satellite sensors and satellites against anti-satellite weapons.

b) Development of ASATs for electronic or physical destruction of satellites in both LEO and GSO.[85]

India has stated that it expects to achieve an ASAT capability by 2014.[86] Mark Stokes of the Nonproliferation Policy Education Center believes that India is developing this capability in response to Chinese ASAT tests, referring to an emerging Indian-Chinese ASAT rivalry.[87]

The overarching rationale for increased development of such capabilities is to make Indian satellites less vulnerable to anti-satellite weaponry developed in the region, according to Air Chief Marshal P. V. Naik. Such open statements of India's efforts have encouraged criticism that this action contradicts statements by Indian political leaders that deny any intent to pursue space weapons.

After the international conference Space, Science and Security: The Role of Regional Expert Discussion, held in New Delhi in January 2011, Australian delegate Dr. Brett Biddington examined India's motivations for developing ASAT capabilities and the implications for the subcontinent and for global and regional security balances. He said, "Australia may be expected to roll any consideration of India's ASAT achievement and ambitions into a more general discussion about nuclear stability, non-proliferation and the associated discussion about missile defense." Commentators argue that the development of a demonstrable ASAT by India would raise more questions than answers and should not be undertaken without serious consideration of related issues.

On 11 January, China conducted a missile defense test of a ground-based midcourse missile interception technology within its territory. Chinese foreign ministry spokeswoman Jiang Yu said that "the test is defensive in nature and is not targeted at any country."[88] At the time, a spokeswoman for the U.S. military stated that it had detected "two geographically separated missile launch events with an exo-atmospheric collision also being observed by space-based sensors."[89] She added that the U.S. had not been notified prior to the launch, and would be "requesting information from China regarding the purpose for conducting this interception as well as China's intentions and plans to pursue future types of intercept."[90]

Table 8.2: History of ground-based anti-satellite demonstrations

System	Actor	Dates	No. of Intercepts	Description of program
Bold Orion air-launched ballistic missile	US	1959, single test	0	Air-launched ballistic missile passed within 32 km of US Explorer VI satellite
SAtellite INTerceptor (SAINT)	US (USAF)	1960-1962 Idea abandoned in the late 1960s	0	Designed as a co-orbital surveillance system, the satellite could be armed with a warhead or 'blind' the enemy satellite with paint
Program 505	US (US Army)	1962-1964	1?	Nike-Zeus nuclear-tipped anti-ballistic missile system employed as an ASAT against orbital vehicles
Program 437	US (USAF)	1963-1975	1?	Nuclear-armed Thor ballistic missile launched directly into the path of the target
Co-orbital (IS) ASAT	USSR	1963-1972, 1976-1982	12?	Conventional explosives launched into orbit near target, detonated when within range of one km
Polaris submarine launched ASAT	US (US Navy)	1964-late 1960s	?	Submarine-launched ballistic missile fitted with tracking sensors and launched into orbit as satellite passed overhead to detonate a warhead filled with steel pellets
Laser ASAT	USSR	1975-1989	0	Sary Shagan and Dushanbe laser sites reported to have ASAT programs
Air-Launched Miniature Vehicle	US (USAF)	1982-1987	1	Missile launched from high-orbit F-15 aircraft to destroy satellite with a high-speed collision
MiG-31 Air-launched ASAT	USSR	1980-1985	?	Exploration of kinetic-kill ASAT to be launched from MiG-31 aircraft, never tested
MIRACL Laser	US (USAF)	1989-1990 Tested in 1997 though not acknowledged as an ASAT test	1	Megawatt-class chemical laser fired at satellite to disable electronic sensors
Ground-Based Kinetic Energy ASAT	US (US Army)	1990-2004	0	Kinetic-kill vehicle launched from the ground to intercept and destroy a satellite
* Medium-range ballistic missile-based kinetic energy ASAT	China (PLA)	2007	1	Destroyed the Feng Yun 1C weather satellite on 11 January 2007
† Modified Standard Missile-3 launched from the Aegis Ballistic Missile Defense System (not a dedicated anti-satellite program)	US (US Navy)	2008	1	Single engagement of the failed, de-orbiting US-193 satellite that resulted in the kinetic intercept and consequent destruction of the satellite on 20 February 2008

* The Chinese government states that the intercept of the Feng Yun 1C satellite was a scientific experiment and not an anti-satellite test or demonstration.

† The US government states that the engagement of the US-193 satellite was done to protect populations on Earth, and that the modification of the system was a one-time occurrence that has been reversed.

A leaked cable dated 12 January, which also references the Chinese ASAT test of January 2007, says that "the U.S. Intelligence Community assesses that on 11 January 2010 China launched an SC-19 missile from the Korla Missile Test Complex and successfully intercepted a near-simultaneously launched CSS-X-11 medium-range ballistic missile launched from the Shuangchengzi Space and Missile Center." The cable adds that the intercept, which occurred at an altitude of approximately 250 km, "is assessed to have furthered both Chinese ASAT and ballistic missile defense (BMD) technologies. Due to the sensitivity of the intelligence that would have to be disclosed to substantiate the U.S. assessment, the U.S. Government in its demarche to the PRC Government will not associate the January 2010 SC-19 intercept flight-test with past SC-19 ASAT flight-tests."[91] China's claim that no debris from this test remained on-orbit was confirmed by the leaked cable.

A senior officer in the Russian Air and Space defense forces, which are slated to be integrated by 2011,[92] claimed in an interview with Ekho Moskvy radio that they are developing a "fundamentally new weapon" to deal with space threats.[93] Col. Eduard Sigalov said in the interview that this weapon was being developed to "destroy potential targets in space,"[94] though it remains unclear what the specific characteristics of such a weapon could be.

Space Security Impact

The development of directed energy and ASAT weapons has a direct impact on space security. Such capabilities enable an actor to intentionally restrict secure access to space by others by compromising the physical and operational integrity of space assets. While possession of these capabilities does not necessarily entail their imminent use, it could foster an arms race and hasten the weaponization of space. In any case, the development and testing of ASAT capabilities remain highly contentious. Moreover, increasing proliferation of ASAT technology is also likely to be destabilizing at the regional level. India's stated intentions regarding ASAT capabilities, for instance, have already spurred Pakistan to increase its nuclear arsenal.

Trend 8.3: Increased access to 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.[95]

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 fact that the program was linked to the Advanced Weapons Technology element of the budget suggests that it could potentially evolve into an ASAT program.[96]

The MDA Near-Field Infrared Experiment (NFIRE), designed to provide support to ballistic missile defense, at one point was planning 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,[97] prompting the kill vehicle to be replaced with a laser communications payload. In 2006, the U.S. launched a pair of Micro-satellite Technology Experiment (MiTEx) satellites into an unknown geostationary transfer orbit. The MiTEx 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.[98] In January 2009, the Pentagon confirmed that the two MiTEx microsatellites had maneuvered in close proximity to a failing satellite in GEO.[99] This incident raised concerns that the ability to get in such close proximity to another satellite could potentially be used for hostile actions.[100]

An autonomous rendezvous capacity was also the objective of NASA's Demonstration of Autonomous Rendezvous Technology (DART) spacecraft, which relied on the Advanced Video Guidance Sensor and GPS to locate its target.[101] The ASAT capability of maneuverable microsatellites was demonstrated in 2005 when the DART craft unexpectedly collided with the target satellite, and bumped it into a higher orbit.[102]

Other U.S. programs developing a range of space-based, dual-use maneuvering, autonomous approach, and docking capabilities include the DARPA/NASA Orbital Express program. In 2007 it demonstrated the feasibility of conducting automated satellite refueling and repair, which could also be used to maneuver a space-based anti-satellite weapon.[103] DARPA and the Naval Research Laboratory (NRL) are also developing a space tug capable of physically maneuvering another satellite in orbit under a program called Front-end Robotics Enabling Near-Term Demonstration (FREND). It was "designed to allow interaction with geosynchronous orbit-based military and commercial spacecraft, extending their service lives and permitting satellite repositioning or retirement."[104]

The NRL has developed and ground-tested guidance and control algorithms to enable a spacecraft-mounted robotic arm to autonomously grapple another satellite not designed for docking.[105] As well, DARPA's TICS program was intended to develop 10-lb satellites that could be quickly air launched by fighter jets to form protective formations around larger satellites to shield them from direct attacks. Using advanced robotic technologies, these satellites could have potentially been used against non-cooperative satellites, but the program was cancelled in the FY2009 budget.[106]

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."[107] Sweden has developed the automated rendezvous and proximity operation PRISMA satellites, which were successfully launched in June 2010 from Yasni, Russia.[108] The PRISMA satellite project demonstrates technologies for autonomous formation flying, approach, rendezvous, and proximity operations.[109] 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, such technologies could conceivably be modified for such an application.

2010 Development

Complex rendezvous capabilities continue to be advanced

Analysis of the orbital flight plans of two Chinese satellites — SJ-12, launched in June, and SJ-06F, launched in 2008, part of the Shijian series — suggests that, between June and August,[110] the satellites performed a robotic rendezvous.[111] Although the Chinese have not officially commented on the incident, anomalies in the satellites' orbits were reported in the Russian and Chinese media and eventually confirmed by the U.S. DOD.[112] The purpose of the maneuver remains unknown and there has been much speculation about its potential implications.

Tracking data collected by the U.S. military shows that SJ-12 has performed multiple maneuvers since its launch in July. The rendezvous could be a test of space station procedures, but it also evinces the ability to approach and interfere with other satellites.[113] Former NASA engineer James Oberg said that "the silence here is suggestive of a military program."[114] Another expert noted that the technical profile of the maneuver reduces the possibility of its being an ASAT test and suggested several possible goals, including satellite formation flying and demonstrated orbital rendezvous.[115]

In October, two Swedish satellites spent days seven meters apart, as part of the Prisma mission to test new European technologies for formation flying in orbit.[116] The satellites, nicknamed Mango and Tango, were launched together on June 15 and separated in August to begin their 10-month rendezvous mission, run by the Swedish Space Corporation.[117] Clearly, the transparency with which these tests were conducted stands in stark contrast to the clandestine nature of the Chinese maneuvers and lessens concerns about the offensive use of the capability.[118]

Researchers in Spain have developed an automated robotics system that uses computer vision technology and complex algorithms to enable unmanned space vehicles to track down, capture, and perform repairs on satellites in orbit. Designed to deal with "zombie" satellites in LEO, technology like the ASIROV Robotic Satellite Chaser Prototype could be used to create unmanned chaser vehicles for negation activities.

2010 Development

Secrecy surrounds X-37B launch, raising questions about a precise mission and potential capabilities

On 22 April, the U.S. Air Force launched the X-37B robotic space plane or Orbital Test Vehicle (OTV-1) aboard an Atlas V expendable launch system. Though most reputable sources do not consider the launch to be an offensive capability, several observers have voiced concerns that the X-37B could be a space superiority weapon of some kind. For more information, see Chapter 6.

Space Security Impact

The development of more technologies that allow space-based ASAT capability will force spacefaring nations to incorporate greater protection measures into their spacecraft and invest more in responsive situational awareness. Costs could go up for almost all satellites with any military value, including those funded by private industry. More ominously, the existence of space-to-space ASAT abilities might encourage the weaponization of space for defensive purposes. Fear of such developments could lead to adoption of norms of behavior governing offensive technologies. In some cases, such capabilities have actually fostered transparency; to allay suspicion, nations that are testing rendezvous capabilities freely disclose the nature of their activities.

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Participants

Timiebi Aganaba
Institute of Air and Space Law, McGill University

Eva Bernhardsdotter
Swedish Defense Research Agency

Jean-Marc Chouinard
Canadian Space Agency

Richard DalBello
Intelsat General Corporation

Bertrand de Montluc
Institute d'Études Politiques de Paris

Laura Delgado
Space Policy Institute, George Washington University

Paul Dempsey
Institute of Air and Space Law, McGill University

Karl Doetsch
Doetsch International Space Consultants

Catherine Doldirina
Institute of Air and Space Law, McGill University

Macha Ejova
Euroconsult North America

Peter Hays
Eisenhower Center for Space and Defense Studies (US)

Diane Howard
Institute of Air and Space Law, McGill University

Ram Jakhu
Institute of Air and Space Law, McGill University

Cesar Jaramillo
Project Ploughshares

Li Juqian
China University of Political Science

David McArthur
Space Policy Institute, George Washington University

Jonathan McDowell
Harvard-Smithsonian Center for Astrophysics

Philip Meek
United States Air Force, Ret.

Paul Meyer
The Simons Foundation

Ashlyn Milligan
National Defence Canada

Audrey Schaffer
Office of the Secretary of Defense (U.S.)

John Siebert
Project Ploughshares

Dana Smith
Foreign Affairs Canada

Ronald Spencer
United States Air Force – Vandenberg AFB

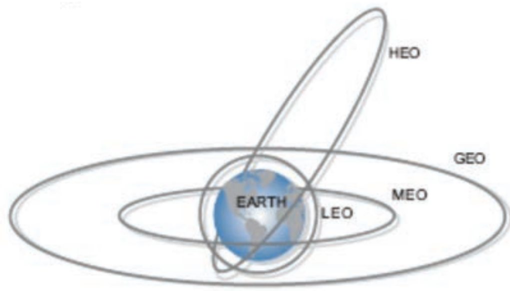
Lucy Stojak
HEC Montréal

Richard Tremayne-Smith
Consultant (U.K.); formerly with the British National Space Centre

Brian Weeden
Secure World Foundation

Ray Williamson
Secure World Foundation

Types of Earth Orbits*



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

Medium Earth Orbit (MEO) is the region of space around the Earth above LEO (2,000 kilometers) and below geosynchronous orbit (36,000 kilometers). The orbital period (time for one orbit) of MEO satellites ranges from about two to 12 hours. The most common use for satellites in this region is for navigation, such as the US Global Positioning System (GPS).

Geostationary Orbit (GEO) is a region in which the satellite orbits at approximately 36,000 kilometers above the Earth's equator. At this altitude, geostationary orbit 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 700-to-800 kilometers. 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 to the Earth, and perigee is the closest distance to the Earth.

* From the Space Foundation, *The Space Report 2008* (Colorado Springs: Space Foundation 2008), at 52.

Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies

The States Parties to this Treaty,

Inspired by the great prospects opening up before mankind as a result of man's entry into outer space,

Recognizing the common interest of all mankind in the progress of the exploration and use of outer space for peaceful purposes,

Believing that the exploration and use of outer space should be carried on for the benefit of all peoples irrespective of the degree of their economic or scientific development,

Desiring to contribute to broad international co-operation in the scientific as well as the legal aspects of the exploration and use of outer space for peaceful purposes,

Believing that such co-operation will contribute to the development of mutual understanding and to the strengthening of friendly relations between States and peoples,

Recalling resolution 1962 (XVIII), entitled "Declaration of Legal Principles Governing the Activities of States in the Exploration and Use of Outer Space," which was adopted unanimously by the United Nations General Assembly on 13 December 1963,

Recalling resolution 1884 (XVIII), calling upon States to refrain from placing in orbit around the earth any objects carrying nuclear weapons or any other kinds of weapons of mass destruction or from installing such weapons on celestial bodies, which was adopted unanimously by the United Nations General Assembly on 17 October 1963,

Taking account of United Nations General Assembly resolution 110 (II) of 3 November 1947, which condemned propaganda designed or likely to provoke or encourage any threat to the peace, breach of the peace or act of aggression, and considering that the aforementioned resolution is applicable to outer space,

Convinced that a Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, will further the purposes and principles of the Charter of the United Nations,

Have agreed on the following:

Article I

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, irrespective of their degree of economic or scientific development, and shall be the province of all mankind.

Outer space, including the moon and other celestial bodies, shall be free for exploration and use by all States without discrimination of any kind, on a basis of equality and in accordance with international law, and there shall be free access to all areas of celestial bodies.

There shall be freedom of scientific investigation in outer space, including the moon and other celestial bodies, and States shall facilitate and encourage international co-operation in such investigation.

Article II
Outer space, including the moon and other celestial bodies, is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means.

Article III
States Parties to the Treaty shall carry on activities in the exploration and use of outer space, including the moon and other celestial bodies, in accordance with international law, including the Charter of the United Nations, in the interest of maintaining international peace and security and promoting international co-operation and understanding.

Article IV
States 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, install such weapons on celestial bodies, or station such weapons in outer space in any other manner.

The moon and other celestial bodies shall be used by all States Parties to the Treaty exclusively for peaceful purposes. The establishment of military bases, installations and fortifications, the testing of any type of weapons and the conduct of military manoeuvres on celestial bodies shall be forbidden. The use of military personnel for scientific research or for any other peaceful purposes shall not be prohibited. The use of any equipment or facility necessary for peaceful exploration of the moon and other celestial bodies shall also not be prohibited.

Article V
States Parties to the Treaty shall regard astronauts as envoys of mankind in outer space and shall render to them all possible assistance in the event of accident, distress, or emergency landing on the territory of another State Party or on the high seas. When astronauts make such a landing, they shall be safely and promptly returned to the State of registry of their space vehicle.

In carrying on activities in outer space and on celestial bodies, the astronauts of one State Party shall render all possible assistance to the astronauts of other States Parties.

States Parties to the Treaty shall immediately inform the other States Parties to the Treaty or the Secretary-General of the United Nations of any phenomena they discover in outer space, including the moon and other celestial bodies, which could constitute a danger to the life or health of astronauts.

Article VI
States Parties to the Treaty shall bear international responsibility for national activities in outer space, including the moon and other celestial bodies, whether such activities are carried on by governmental agencies or by non-governmental entities, and for assuring that national activities are carried out in conformity with the provisions set forth in the present 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. When activities are carried on in outer space, including the moon and other celestial bodies, by an international organization, responsibility for compliance with this Treaty shall be borne both by the international organization and by the States Parties to the Treaty participating in such organization.

Article VII
Each State Party to the Treaty that launches or procures the launching of an object into outer space, including the moon and other celestial bodies, and each State Party from whose territory or facility an object is launched, is internationally liable for damage to another State Party to the Treaty or to its natural or juridical persons by such object or its component parts on the Earth, in air or in outer space, including the moon and other celestial bodies.

Article VIII
A State Party to the Treaty on whose registry an object launched into outer space is carried shall retain jurisdiction and control over such object, and over any personnel thereof, while in outer space or on a celestial body. Ownership of objects launched into outer space, including objects landed or constructed on a celestial body, and of their component parts, is not affected by their presence in outer space or on a celestial body or by their return to the Earth. Such objects or component parts found beyond the limits of the State Party to the Treaty on whose registry they are carried shall be returned to that State Party, which shall, upon request, furnish identifying data prior to their return.

Article IX
In the exploration and use of outer space, including the moon and other celestial bodies, States Parties to the Treaty shall be guided by the principle of co-operation and mutual assistance and shall conduct all their activities in outer space, including the moon and other celestial bodies, with due regard to the corresponding interests of all other States Parties to the Treaty. States Parties to the Treaty shall pursue studies of outer space, including the moon and other celestial bodies, and conduct exploration of them so as to avoid their harmful contamination and also adverse changes in the environment of the Earth resulting from the introduction of extraterrestrial matter and, where necessary, shall adopt appropriate measures for this purpose. 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 in the peaceful exploration and use of outer space, including the moon and other celestial bodies, it shall undertake appropriate international consultations before proceeding with any such activity or experiment. A State Party to the Treaty which has reason to believe that an activity or experiment planned by another State Party in outer space, including the moon and other celestial bodies, would cause potentially harmful interference with activities in the peaceful exploration and use of outer space, including the moon and other celestial bodies, may request consultation concerning the activity or experiment.

Article X
In order to promote international co-operation in the exploration and use of outer space, including the moon and other celestial bodies, in conformity with the purposes of this Treaty, the States Parties to the Treaty shall consider on a basis of equality any requests by other States Parties to the Treaty to be afforded an opportunity to observe the flight of space objects launched by those States. The nature of such an opportunity for observation and the conditions under which it could be afforded shall be determined by agreement between the States concerned.

Article XI
In order to promote international co-operation in the peaceful exploration and use of outer space, States Parties to the Treaty conducting activities in outer space, including the moon and other celestial bodies, agree to inform the Secretary-General of the United Nations as well as the public and the international scientific community, to the greatest extent feasible and practicable, of the nature, conduct, locations and results of such activities. On receiving the said information, the Secretary-General of the United Nations should be prepared to disseminate it immediately and effectively.

Article XII
All stations, installations, equipment and space vehicles on the moon and other celestial bodies shall be open to representatives of other States Parties to the Treaty on a basis of reciprocity. Such representatives shall give reasonable advance notice of a projected visit, in order that appropriate consultations may be held and that maximum precautions may be taken to assure safety and to avoid interference with normal operations in the facility to be visited.

Article XIII
The provisions of this Treaty shall apply to the activities of States Parties to the Treaty in the exploration and use of outer space, including the moon and other celestial bodies, whether such activities are carried on by a single State Party to the Treaty or jointly with other States, including cases where they are carried on within the framework of international intergovernmental organizations.

Any practical questions arising in connection with activities carried on by international intergovernmental organizations in the exploration and use of outer space, including the moon and other celestial bodies, shall be resolved by the States Parties to the Treaty either with the appropriate international organization or with one or more States members of that international organization, which are Parties to this Treaty.

Article XIV
1. This Treaty shall be open to all States for signature. Any State which does not sign this Treaty before its entry into force in accordance with paragraph 3 of this article may accede to it at any time.
2. This Treaty shall be subject to ratification by signatory States. Instruments of ratification and instruments of accession shall be deposited with the Governments of the United Kingdom of Great Britain and Northern Ireland, the Union of Soviet Socialist Republics and the United States of America, which are hereby designated the Depositary Governments.
3. This Treaty shall enter into force upon the deposit of instruments of ratification by five Governments including the Governments designated as Depositary Governments under this Treaty.
4. For States whose instruments of ratification or accession are deposited subsequent to the entry into force of this Treaty, it shall enter into force on the date of the deposit of their instruments of ratification or accession.
5. The Depositary Governments shall promptly inform all signatory and acceding States of the date of each signature, the date of deposit of each instrument of ratification of and accession to this Treaty, the date of its entry into force and other notices.
6. This Treaty shall be registered by the Depositary Governments pursuant to Article 102 of the Charter of the United Nations.

Article XV
Any State Party to the Treaty may propose amendments to this Treaty. Amendments shall enter into force for each State Party to the Treaty accepting the amendments upon their acceptance by a majority of the States Parties to the Treaty and thereafter for each remaining State Party to the Treaty on the date of acceptance by it.

Article XVI
Any State Party to the Treaty may give notice of its withdrawal from the Treaty one year after its entry into force by written notification to the Depositary Governments. Such withdrawal shall take effect one year from the date of receipt of this notification.

Article XVII
This Treaty, of which the English, Russian, French, Spanish and Chinese texts are equally authentic, shall be deposited in the archives of the Depositary Governments. Duly certified copies of this Treaty shall be transmitted by the Depositary Governments to the Governments of the signatory and acceding States.

IN WITNESS WHEREOF the undersigned, duly authorized, have signed this Treaty.

DONE in triplicate, at the cities of London, Moscow and Washington, the twenty-seventh day of January, one thousand nine hundred and sixty-seven.

Spacecraft Launched in 2010

COSPAR	Launch Date	Satellite Name	Actor Type	Primary Function	Owning State	Launch Vehicle	Orbit
2010-001A	1/16/2010	Compass G-1 (Beidou G1)	Military	Navigation/ Global Positioning	China (PR)	Long March 3C	GEO
2010-002A	1/28/2010	Raduga 1-M2 (Raduga 1-9)	Military	Communications	Russia	Proton M	GEO
2010-005A	2/11/2010	SDO (Solar Dynamics Observatory)	Government	Space Science	USA	Atlas 5	GEO
2010-006A	2/12/2010	Intelsat 16 (IS-16)	Commercial	Communications	USA	Proton M	GEO
2010-007A	3/1/2010	Glonass 731 (Glonass 42-1, Cosmos 2459)	Military/ Commercial	Navigation/ Global Positioning	Russia	Proton M	MEO
2010-007C	3/1/2010	Glonass 732 (Glonass 42-3, Cosmos 2460)	Military/ Commercial	Navigation/ Global Positioning	Russia	Proton M	MEO
2010-007B	3/1/2010	Glonass 735 (Glonass 42-2, Cosmos 2461)	Military/ Commercial	Navigation/ Global Positioning	Russia	Proton M	MEO
2010-008A	3/4/2010	GOES 15 (Geostationary Operational Envvironmental Satellite, GOES-P)	Government	Earth Science/ Meteorology	USA	Delta 4	GEO
2010-009A	3/5/2010	Yaogan 9A (Remote Sensing Satellite 9A)	Government	Remote Sensing	China (PR)	Long March 4C	LEO
2010-009B	3/5/2010	Yaogan 9B (Remote Sensing Satellite 9B)	Government	Remote Sensing	China (PR)	Long March 4C	LEO
2010-009C	3/5/2010	Yaogan 9C (Remote Sensing Satellite 9C)	Government	Remote Sensing	China (PR)	Long March 4C	LEO
2010-010A	3/20/2010	Echostar 14	Commercial	Communications	USA	Proton M	GEO
2010-013A	4/8/2010	Cryosat-2	Government	Earth Observation	ESA	Dnepr	LEO
2010-016A	4/24/2010	SES-1 (AMC-4R)	Commercial	Communications	USA	Proton M	GEO
2010-017A	4/27/2010	Parus-99 (Cosmos 2463)	Military	Navigation	Russia	Kosmos 3M	LEO
2010-021A	5/21/2010	Astra 3B	Commercial	Communications	Luxembourg	Ariane 5 ECA	GEO
2010-021B	5/21/2010	COMSATBw-2 (COmmunications SATellite für BundesWehr)	Military	Communications	Germany	Ariane 5	GEO
2010-022A	5/28/2010	Navstar GPS 62 (Navstar SVN62, GPS IIF-1, USA 213)	Military/ Commercial	Navigation/ Global Positioning	USA	Delta 4	MEO
2010-024A	6/2/2010	Compass G-3 (Beidou G3)	Military	Navigation/ Global Positioning	China (PR)	Long March 3	GEO
2010-023A	6/2/2010	SERVIS-2 (Space Environment Reliability Verification Integrated System)	Commercial	Technology Development	Japan	Rokot	LEO

COSPAR	Launch Date	Satellite Name	Actor Type	Primary Function	Owning State	Launch Vehicle	Orbit
2010-025A	6/3/2010	Badr 5 (Arabsat 5B)	Government	Communications	Multinational	Proton	GEO
2010-028A	6/15/2010	Picard	Government	Solar Physics	France	Dnepr	LEO
2010-028B	6/15/2010	PRISMA (Prototype Research Instruments and Space Mission Advancement)	Government	Technology Development	Sweden	Dnepr	LEO
2010-027A	6/15/2010	Shijian 12 (SJ-12)	Government	Technology Development	China (PR)	Long March 2D	LEO
2010-030A	6/21/2010	TanDEM-X (TerraSAR-X add-on for Digital Elevation Measurement)	Government	Earth Observation	Germany	Dnepr	LEO
2010-031A	6/22/2010	Ofeq 9	Military	Remote Sensing/ Reconnaissance	Israel	Shavit	LEO
2010-032B	6/26/2010	Badr 5A (Arabsat 5A)	Government	Communications	Multinational	Ariane 5 ECA	GEO
2010-032A	6/26/2010	COMS-1 (Communication, Ocean and Meteorological Satellite; Cheollian)	Government	Earth Observation/ Meteorology/ Communications	South Korea	Ariane 5 ECA	GEO
2010-034A	7/10/2010	Echostar 15	Commercial	Communications	USA	Proton M	GEO
2010-035C	7/12/2010	AISSat-1 (Automatic Identification System Satellite-1)	Government	Technology Development	Norway	PSLV	LEO
2010-035D	7/12/2010	Alsat-2A (Algeria Satellite 2A)	Government	Earth Observation	Algeria	PSLV	LEO
2010-035A	7/12/2010	CartoSat 2B	Government	Remote Sensing	India	PSLV	LEO
2010-035B	7/12/2010	STUDSat (Student Satellite)	Civil	Technology Development	India		LEO
2010-035E	7/12/2010	TISat-1 (Ticano Satellite)	Civil	Technology Development	Switzerland	PSLV	LEO
2010-036A	7/31/2010	Compass G-5 (Beidou IGSO-1)	Military	Navigation/ Global Positioning	China (PR)	Long March 3A	GEO
2010-037A	8/4/2010	Nilesat 201	Government	Communications	Egypt	Ariane 5	GEO
2010-037B	8/4/2010	Rascom-QAF 1R	Commercial	Communications	Multinational	Ariane 5	GEO
2010-038A	8/9/2010	Yaogan 10 (Remote Sensing Satellite 10)	Government	Remote Sensing	China (PR)	Long March 4C	LEO
2010-039A	8/14/2010	AEHF-1 Advanced Extremely High Frequency satellite-1, USA 214)	Military	Communications	USA	Atlas 5	GEO
2010-040A	8/24/2010	Tianhui-1	Government	Earth Observation	China (PR)	Long March 2D	LEO
2010-041C	9/2/2010	Glonass 736 (Glonass 43-1, Cosmos 2464)	Military/ Commercial	Navigation/ Global Positioning	Russia	Proton M	MEO

COSPAR	Launch Date	Satellite Name	Actor Type	Primary Function	Owning State	Launch Vehicle	Orbit
2010-041B	9/2/2010	Glonass 737 (Glonass 43-2, Cosmos 2465)	Military/ Commercial	Navigation/ Global Positioning	Russia	Proton M	MEO
2010-041C	9/2/2010	Glonass 738 (Glonass 43-3, Cosmos 2466)	Military/ Commercial	Navigation/ Global Positioning	Russia	Proton M	MEO
2010-042A	9/4/2010	Sinosat-6 (Chinasat-6A, XN-6)	Commercial	Communications	China (PR)	Long March 3B	GEO
2010-043B	9/8/2010	Gonets M-5	Commercial	Communications	Russia	Rokot	LEO
2010-043A	9/8/2010	Strela 3 (Cosmos 2467)	Military	Communications	Russia	Rokot	LEO
2010-043C	9/8/2010	Strela 3 (Cosmos 2468)	Military	Communications	Russia	Rokot	LEO
2010-045A	9/11/2010	QZS-1 (Quazi-Zenith Satellite System, Michibiki)	Government	Navigation	Japan	H-2A	GEO
2010-046A	9/21/2010	FIA Radar 1 (Future Imagery Architecture (FIA) Radar 1, NROL-41, USA 215)	Military	Reconnaissance	USA	Atlas 5	LEO
2010-047A	9/22/2010	Yaogan 11 (Remote Sensing Satellite 11)	Government	Remote Sensing	China (PR)	Long March 2D	LEO
2010-047B	9/22/2010	Zheda Pixing 1B (ZP-1B, Zhejiang University-1B)	Civil	Scientific Research	China (PR)	Long March 2D	LEO
2010-047C	9/22/2010	Zheda Pixing 1C (ZP-1C, Zhejiang Univeristy-1B)	Civil	Scientific Research	China (PR)	Long March 2D	LEO
2010-048A	9/26/2010	SBSS-1 (Space Based Space Surveillance Satellite, SBSS Block 10 SV1, USA 216)	Military	Reconnaissance	USA	Minotaur 4	LEO
2010-049A	9/30/2010	US-KS Oko 90 (Cosmos 2469)	Military	Early Warning	Russia	Molniya M	Elliptical
2010-051A	10/6/2010	Shijian 6G (SJ6-04A)	Government	Reconnaissance	China (PR)	Long March 4B	LEO
2010-051B	10/6/2010	Shijian 6H (SJ6_04B)	Government	Reconnaissance	China (PR)	Long March 4B	LEO
2010-053A	10/14/2010	Sirius XM-5	Commercial	Communications	USA	Proton M	GEO
2010-054F	10/19/2010	Globalstar M073 (Globalstar 73, Globalstar 2-6)	Commercial	Communications	USA	Soyuz-Fregat	LEO
2010-054B	10/19/2010	Globalstar M074 (Globalstar 74, Globalstar 2-2)	Commercial	Communications	USA	Soyuz-Fregat	LEO
2010-054E	10/19/2010	Globalstar M075 (Globalstar 75, Globalstar 2-5)	Commercial	Communications	USA	Soyuz-Fregat	LEO
2010-054C	10/19/2010	Globalstar M076 (Globalstar 76, Globalstar 2-3)	Commercial	Communications	USA	Soyuz-Fregat	LEO

COSPAR	Launch Date	Satellite Name	Actor Type	Primary Function	Owning State	Launch Vehicle	Orbit
2010-054D	10/19/2010	Globalstar M077 (Globalstar 77, Globalstar 2-4)	Commercial	Communications	USA	Soyuz-Fregat	LEO
2010-054A	10/19/2010	Globalstar M079 (Globalstar 79, Globalstar 2-1)	Commercial	Communications	USA	Soyuz-Fregat	LEO
2010-056B	10/28/2010	BSAT-3B	Commecial	Communications	Japan	Ariane 5 ECA	GEO
2010-057A	10/31/2010	Compass G-4 (Beidou G4)	Military	Navigation/ Global Positioning	China (PR)	Long March 3C	GEO
2010-058A	11/2/2010	Meridian-3	Government	Communications	Russia	Soyuz 2-1a	Elliptical
2010-059A	11/4/2010	Fengyun 3B (FY-3B)	Government	Earth Science	China (PR)	Long March 4C	LEO
2010-060A	11/6/2010	COSMO-Skymed 4 (Constellation of small Satellites for Mediterranean basin Observation)	Military/ Government	Earth Observation	Italy	Delta 2	LEO
2010-061A	11/14/2010	SkyTerra 1	Commercial	Communications	USA	Breeze M	GEO
2010-062E	11/20/2010	Falconsat 5 (USA 221)	Civil	Technology Development	USA	Minotaur 4	LEO
2010-062F	11/20/2010	AST 1 (Sara Lilly and Emma, USA 222)	Civil	Technology Development	USA	Minotaur 4	LEO
2010-062C	11/20/2010	O/OREOS (Organism/ Organic Exposure to Orbital Stresses, USA 219)	Civil/ Government	Scientific Research	USA	Minotaur 4	LEO
2010-062B	11/20/2010	RAX (Radio Aurora Explorer, USA 218)	Civil/ Government	Scientific Research	USA	Minotaur 4	LEO
2010-062A	11/20/2010	STPSAT 2 (USA 217)	Military	Technology Development	USA	Minotaur 4	LEO
2010-063A	11/21/2010	Orion/Mentor 5 (Advanced Orion 5, NRO L-32, USA 223)	Military	Surveillance	USA	Delta 4	GEO
2010-064A	11/24/2010	Zhongxing 20A	Military	Communications	China (PR)	Long March 3B	GEO
2010-065A	11/26/2010	HYLAS 1 (Highly Adaptable Satellite)	Commercial	Communications	UK	Ariane 5	GEO
2010-065B	11/26/2010	Intelsat 17 (IS-17)	Commercial	Communications	USA	Ariane 5	GEO
2010-068A	12/17/2010	Compass G-7 (Beidou IGSO-2)	Military	Navigation/ Global Positioning	China (PR)	Long March 3A	GEO
2010-069A	12/26/2010	KA-SAT	Commercial	Communications	KA-SAT	Proton	GEO
2010-070A	12/29/2010	Hispasat 1E	Commercial	Communications	Spain	Ariane 5	GEO
2010-070B	12/29/2010	Koreasat 6 (Mugungwha 6)	Commercial	Communications	South Korea	Ariane 5	GEO

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