SPACE SECURITY

2010

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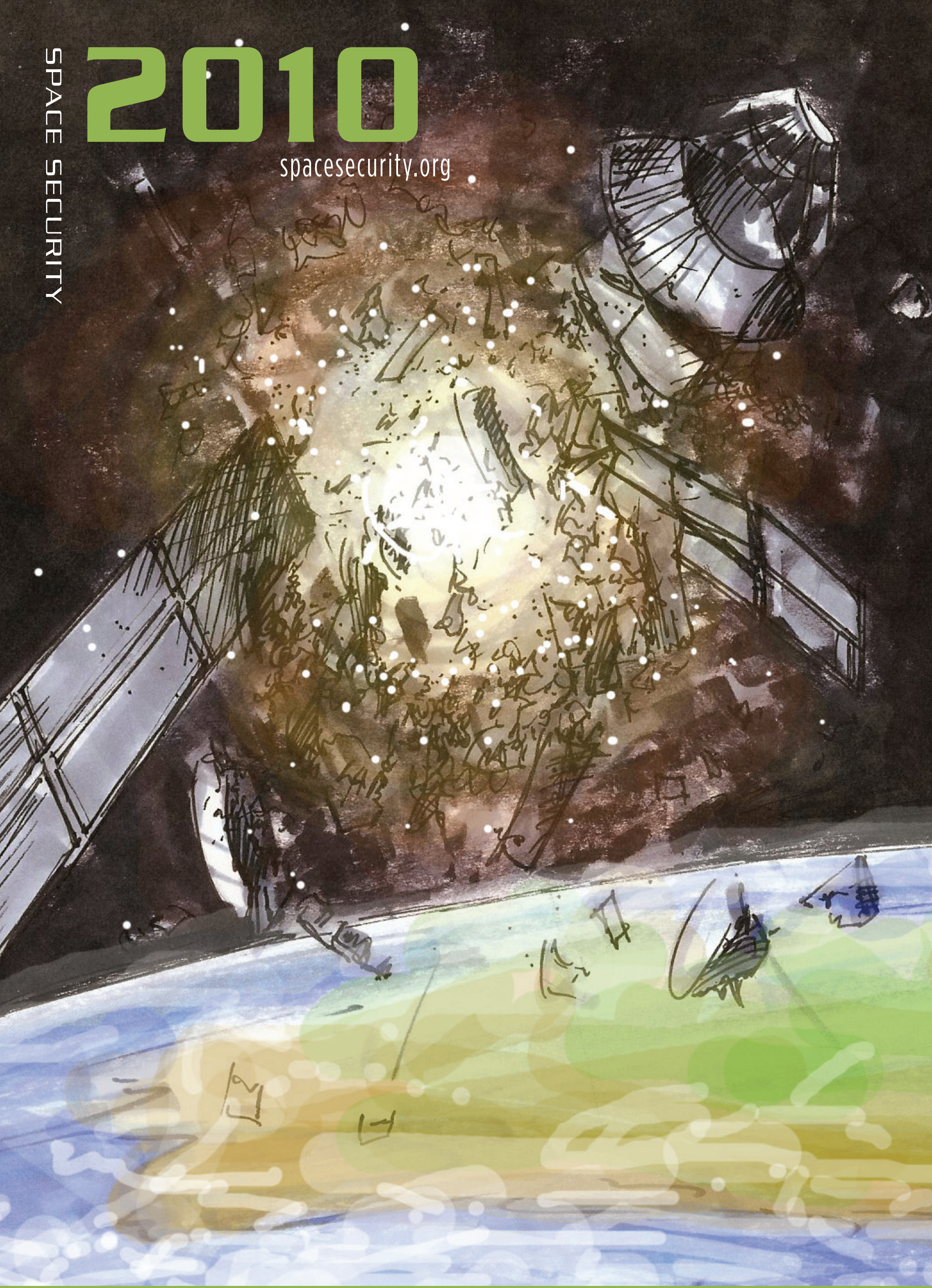

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TABLE OF CONTENTS

ACRONYMS

3GIRS	Third Generation Infrared Surveillance Program (formerly AIRSS - US)
ABL	Airborne Laser (US)
ABLT	Airborne Laser Testbed
ABM	Anti-Ballistic Missile
AEHF	Advanced Extremely High Frequency system (US)
AFI	Air Force Instruction (US)
AIAA	American Institute for Aeronautics and Astronautics
ANGELS	Autonomous Nanosatellite Guardian for Evaluating Local Space (US)
ASAT	Anti-Satellite Weapon
ASEAN	Association of Southeast Asian Nations
ASI	Italian Space Agency
ATV	Automated Transfer Vehicle or Jules Verne (Europe)
BASIC	Broad Area Satellite Imagery Collection program (US)
BBG	Broadcasting Board of Governors
BMD	Ballistic Missile Defense
BNSC	British National Space Centre
BOC	Besoin Opérationnel Commun (Europe)
BSL	Basic Space Law (Japan)
BSP	Basic Space Plan (Japan)
BX-1	BinXiang-1 (China)
CASC	China Aerospace Corporation
CBERS	China-Brazil Earth Resource Satellite
CD	Conference on Disarmament
CFE	Commercial and Foreign Entities
CFSP	Common Security and Foreign Policy (Europe)
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 (US)
CSA	Canadian Space Agency
CSpOC	Combined Space Operations Center
CSSI	Center for Space Standards & Innovation
DARPA	Defense Advanced Research Projects Agency (US)
DART	Demonstration of Autonomous Rendezvous Technology (US)
DBS	Direct Broadcasting by Satellite
DGA	Délégation Générale pour l'Armement (French Agency for Defense Development)
DISCOS	Database and Information System Characterising Objects in Space (Europe)
DLR	German Aerospace Center
DOD	Department of Defense (US)
DRDO	Defence Research and Development Organization (India)
DSCS	Defense Satellite Communications System (US)
DSP	Defense Support Program (US)

EADS	European Aeronautic Defence and Space Company
EC	European Commission
EELV	Evolved Expendable Launch Vehicle (US)
EGNOS	European Geostationary Navigation Overlay Service
EHF	Extremely High Frequency
EKV	Exoatmospheric Kill Vehicle
ELINT	Electronic Intelligence
EMP	Electromagnetic pulse (or HEMP for High Altitude EMP)
EORSAT	Electronic Intelligence Ocean Reconnaissance Satellite (Russia)
ESA	European Space Agency
ESDP	European Security and Defence Policy
EUMETSAT	European Organization for the Exploitation of Meteorological Satellites
FAA	Federal Aviation Administration (US)
FAST	Fast Access Spacecraft Testbed (US)
FCC	Federal Communications Commission (US)
FMCT	Fissile Material Cut-off Treaty
FOBS	Fractional Orbital Bombardment System (Russia)
FREND	Front-End Robotics Enabling Near-Term Demonstration (US)
FSS	Fixed Satellite Service
GAGAN	GPS and GEO Augmented Navigation (India)
GAO	Government Accountability Office (General Accounting Office until July 2004)
GEO	Geostationary Orbit
GEODSS	Ground-based Electro Optical Deep Space Surveillance
GEOSS	Global Earth Observation System of Systems
GLONASS	Global Navigation Satellite System (Russia)
GMES	Global Monitoring for Environment and Security (Europe)
GNSS	Global Navigator Satellite System
GOSAT	Greenhouse Gases Observing Satellite (Japan)
GPS	Global Positioning System (US)
GRAVES	Grande Réseau Adapté à la Veille Spatiale (France)
GSLV	Geostationary Satellite Launch Vehicle (India)
GSSAC	German Space Situatuional Awareness Center
HAARP	High Frequency Active Auroral Research Program (US)
HAARP	High Frequency Active Auroral Research Program (US)
HAND	High Altitude Nuclear Detonation
HEO	Highly Elliptical Orbit
IAA	International Academy of Astronautics
IADC	Inter-Agency Debris Coordination Committee
IADC	Inter-Agency Space Debris Coordination Committee
IAI	Israeli Aerospace Industries
ICBM	Intercontinental Ballistic Missile
IGS	Information Gathering Satellites (Japan)
IIRS	Indian Institute of Remote Sensing

ILS	International Launch Services
Inmarsat	International Maritime Satellite Organization
Intelsat	International Telecommunications Satellite Consortium
IOC	Initial Operating Capability
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 Regulation (US)
ITU	International Telecommunication Union
JAXA	Japan Aerospace Exploration Agency
JFC	Joint Force Commanders (US)
JHPSSL	Joint High-Power Solid-State Laser (US)
JSpOC	Joint Space Operations Center (US)
KARI	Korean Aerospace Research Institute
KEI	Kinetic Energy Interceptor
KSLV	Korean Space Launch Vehicle
LCROSS	Lunar Crater Observation and Sensing Satellite
LEO	Low Earth Orbit
M3MSat	Maritime Monitoring and Messaging Microsatellite (Canada)
MATRIX	Mobile Active Targeting Resource for Integrated Experiments
MDA	Missile Defense Agency (US)
MEJI	Mars Exploration Joint Initiative
MEO	Medium Earth Orbit
MEP	Multiple Engagement Payload (US)
MiDSTEP	Microsatellite Demonstration Science and Technology Experiment Program
Milstar	Military Satellite Communications System (US)
MIRACL	Mid-Infrared Advanced Chemical Laser (US)
MiTEX	Micro-satellite Technology Experiment (US)
MKV	Miniature Kill Vehicle (US)
MMOD	Micrometeoroid Orbital Debris
MPX	Micro-satellite Propulsion Experiment (US)
MSS	Mobile Satellite Service
MTCR	Missile Technology Control Regime
MUSIS	Multinational Space-based Imaging System (France)
NASA	National Aeronautics and Space Administration (US)
NATO	North Atlantic Treaty Organization
NEA	Near Earth Asteroids
NEC	Near Earth Comets
NEO	Near-Earth Object
NEOSSat	Near Earth Object Surveillance Satellite (Canada)
NFIRE	Near-Field Infrared Experiment satellite (US)
NGA	National Geospatial-Intelligence Agency (US)

NGO	Nongovernment Organization
NOAA	National Oceanic and Atmospheric Administration (US)
NORAD	North American Aerospace Defense Command
NRL	National Research Laboratory (US Navy)
NRO	National Reconnaissance Office (US)
NSSO	National Security Space Office (US)
NTM	National Technical Means
ORS	Operationally Responsive Space (US)
OST	Outer Space Treaty
PAROS	Prevention of an Arms Race in Outer Space
PGS	Prompt Global Strike program (US)
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, the Threat or Use of Force against Outer Space Objects
PRS	Public Regulated Service (for European Galileo)
PSLV	Polar Satellite Launch Vehicle
QZSS	Quazi-Zenith Satellite System (Japan)
RAIDRS	Rapid Attack Identification Detection and Reporting System
RAMOS	Russian-American Observation Satellite program
RLV	Reusable Launch Vehicle
RORSAT	Radar Ocean Reconnaissance Satellites (Russia)
Roscosmos	Russian Federal Space Agency
SALT	Strategic Arms Limitations Talks
SAR	Synthetic Aperture Radar
SASSA	Self-Awareness Space Situational Awareness program (US)
SBI	Space-Based Interceptor
SBIRS	Space Based Infrared System (US)
SBL	Space Based Laser
SBSS	Space Based Surveillance System (US)
SBSW	Space-based Strike Weapon
SDA	Space Data Association
SHF	Super High Frequency
SHSP	Strategic Headquarters for Space Policy (Japan)
SIGINT	Signals Intelligence
SLEP	Service Life Extension Programs
SM-3	Standard Missile 3 (US)
SMOS	Soil Moisture and Ocean Salinily satellite (ESA)
SOCRATES	Satellite Orbital Conjunction Reports Assessing Threatening Encounters in Space
SSA	Space Situational Awareness
SSAEM	Space Situational Awareness Environmental Monitoring

SSN	Space Surveillance Network (US)
SST	Space Surveillance Telescope
STSS	Space Tracking and Surveillance System (US)
SUIRG	Satellite Users Interference Reduction Group
System F6	Future, Fast, Flexible, Fractionated, Free-Flying Spacecraft United by Information Exchange (US)
TCBM	Transparency and Confidence-Building Measure
TICS	Tiny Independent Coordinating Spacecraft program (US)
TIRA	German Tracking and Imaging Radar
TLE	Two-line elements
TSAT	Transformational Satellite Communications system (US)
TT&C	Tracking, telemetry and command
UAV	Unmanned Aerial Vehicle
UHF	Ultra High Frequency
UNGA	United Nations General Assembly
UNISPACE	United Nations Conference on the Exploration and Peaceful Uses of Outer Space
UNITRACE	United Nations International Trajectography Centre
UN-SPIDER	United Nations Platform for Space-based Information for Disaster Management and Emergency Response
USAF	United States Air Force
USML	United States Munitions List
VTOL	Vertical Take-Off and Landing aircraft
WGS	Wideband Global SATCOM
XSS	Experimental Spacecraft System (US)

INTRODUCTION

Space Security 2010 is the seventh annual report on trends and developments related to security and outer space, covering the period January to December 2009.[1] 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.

This broad definition encompasses the security of space as a particularly unique environment, the security of Earth-originating assets in space, and security from threats originating in space-based assets. The primary consideration in the SSI definition of space security is not the interests of specific national or commercial entities using space, but the security of space as an environment that can be used safely and sustainably by all.

The actions and developments related to space security are assessed according to nine 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 and global utilities
  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 protection
  8) Space systems negation
  9) Space-based strike capabilities.

Each of the nine 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 established trends and the broader security of outer space.

The annual, systematic assessment undertaken by the Space Security Index makes it increasingly possible to note longer-term trends as well as evolving challenges. For instance, the normative regime to maintain the security of outer space remains fragile inasmuch as multilateral efforts to adopt new international treaties are being replaced by either non-binding, technical approaches to govern outer space or by unilateral national legislation on space operations. A cursory analysis of the proposals under consideration for a space security regime, which are highlighted in this volume, suggests that, despite efforts to construct a robust regulatory framework for space activities, the international community has been unable to reach consensus on an overarching and legally binding space security treaty that reflects the current challenges facing an ever more complex domain. Moreover, the predominance of multi-use space assets means that more states are using space systems for both civil and military purposes. 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.

An important distinction must be made between militarization and weaponization of space: while the former is a reality, thus far there is no documented evidence of the latter. Although the use of space assets for military applications such as reconnaissance, intelligence, and troop support has been ubiquitous for several years, space apparently has remained weapons-free. To maintain this state, the prevention of an arms race in outer space remains a priority for policymakers at various international forums, since it is assumed that once a state places weapons in space, others will follow suit.

From banking to satellite television, from search and rescue operations to weather forecasting, 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 potential battlefield.

The need for greater collaboration and data sharing among different 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 kept significant data on space activities shrouded in secrecy. Not surprisingly, a new tendency is emerging where satellite operators reduce their reliance on government-sourced information on space assets by establishing independent surveillance and data sharing mechanisms, such as the nascent Space Data Association formed by a group of major satellite operators.

The decreasing costs and wider availability of launch technologies suggest that a possible increase in spacefaring nations in the coming years. But intensifying space use creates governance challenges in managing space traffic, limiting the 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.

Developments captured in the SSI also illustrate the challenges and complexities intrinsic to outer space activity. During 2009 the Islamic Republic of Iran successfully launched its first domestically made satellite, becoming the ninth nation to design, build, and launch its own spacecraft. The launch generated intense scrutiny from some Western countries that expressed concerns about the peaceful nature of Iran's space program, given the similarity in launch systems for satellites and ballistic missiles. Another significant event in 2009 was the first ever collision between two orbiting satellites. A retired Russian communications satellite (Cosmos 2251) and a US-owned satellite that provided global mobile phone services (Iridium 33) collided in Low Earth Orbit 790 kilometers over Siberia, creating thousands of pieces of debris, most too small to be tracked with precision. While the incident is widely considered an accident, it underscores the need for greater coordination between operators of space assets so that similar debris-causing events can be prevented in the future. Space debris poses an indiscriminate and increasing risk to all space assets and cannot be removed from outer space with current technology.

Space Security 2010 does not provide absolute positive or negative assessments of 2009 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. It is the hope of the Space Security Index project partners 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 2010* is from open sources. Great effort is made to ensure a complete and factually accurate description of events based on a critical appraisal of the available information and consultation with international experts. Strategic and commercial secrecy with respect to space activities inevitably poses a challenge to the comprehensive nature of this report. But space assets and activities by their very nature are generally in plain view to those with the technical ability to observe them. Increasingly that includes so-called amateurs who make their observations of space assets such 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) The annual Space Security Online Consultation provides insights into the perceptions, concerns, and priorities of space stakeholders around the world, as well as critical feedback on the draft research report.
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.

[1] A few references to significant events that occurred in early 2010 will be developed in *Space Security 2011.*

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The content of *Space Security 2010* does not necessarily reflect the views of the Spacesecurity.org partners: McGill University's Institute of Air and Space Law, Project Ploughshares, Secure World Foundation, The Simons Foundation, and Foreign Affairs and International Trade Canada.

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Dr. Ram Jakhu
Mr. John Siebert
Dr. Jennifer Simons
Dr. Ray Williamson

The Space Environment

TREND 1.1: Amount of orbital debris continues to increase — Space debris poses a significant, constant, and indiscriminate threat to all spacecraft, regardless of the nation or entity to which it belongs. Traveling at speeds of up to 7.8 kilometers per second, each piece of space debris is, in effect, a projectile that may destroy or severely disable a satellite upon impact. The number of objects in Earth orbit has increased steadily; today, the US Department of Defense (DOD) is using the Space Surveillance Network to track more than 21,000 objects approximately 10 centimeters 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 growth rate of new debris tracked began to decrease in the 1990s, largely due to national debris mitigation efforts, but has accelerated in recent years.

2009 Developments:

- For the first time ever, two satellites collide in orbit
- Trackable space debris population increases significantly by 15.6%
- The US military continues to track and predict atmospheric reentry of space debris

Space Security Impact

While 2009 did not see another intentional debris-generating event, it did witness a first-of-its-kind event that generated a significant amount of debris that might have been avoided. Although the large spike in debris decreases space security, the event might have a positive impact as it appears to have been the catalyst for a change in the attitude of spacecraft operators. All space actors may finally be motivated to put measures into place to tackle the problem of space debris and prevent future collisions, ultimately creating greater space security.

TREND 1.2: Increasing awareness of space debris threats and continued efforts to develop and implement international measures to tackle the problem — Significant on-orbit collisions, such as the collision of the French military satellite Cerise with a portion of an Ariane rocket in 1996, as well as improved tracking abilities have encouraged the recognition of space debris as a significant threat. Moreover, several debris-generating events, such as the 2007 Anti-Satellite Weapon (ASAT) test conducted by China, the 2008 US destruction of the failed USA-193 satellite, and the 2009 collision between a Russian and a US satellite, have served to underscore the need for effective measures to curb the creation of space debris. Several spacefaring states, including China, Japan, Russia, and the US, as well as the European Union (EU) have developed debris mitigation standards, and the United Nations has adopted voluntary guidelines, but these guidelines are not universally or regularly followed.

2009 Developments:

- Orbital debris continues to have impacts on operational spacecraft
- Worldwide compliance with the UN debris mitigation guidelines still inconsistent
- Worldwide awareness of the orbital debris problem and progress on solutions continue

Space Security Impact

It is becoming increasingly evident to all space operators that the creation of space debris and other irresponsible behavior in space can have negative implications for all space users, given the indiscriminate nature of the adverse effects. While policymakers are working to implement the existing debris mitigation guidelines, scientists have begun research on the next phase – orbital debris removal – that will be a necessary complement to debris mitigation to ensure continued space security. However, creating voluntary guidelines has proven to be insufficient, as demonstrated by the continued failure of spacecraft operators to comply with end-of-life requirements in the GEO belt. To enhance the positive impact that the implementation of agreed guidelines may have on debris mitigation, the establishment of enforcement mechanisms at either the international or national level is necessary.

TREND 1.3: Growing demand for radio frequency 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 and are causing increasing frequency interference. As a result, satellite operators must spend more time addressing frequency interference issues, including conflicts such as the disagreement over frequency allocation between the US Global Positioning System and the EU Galileo navigational system. The increased competition for orbital slot assignments, particularly in GEO, where most communications satellites operate, has caused occasional disputes between satellite operators over both intentional and unintentional interference. The International Telecommunication Union (ITU) has been pursuing reforms to address slot allocation backlogs and other related challenges.

2009 Developments:

- Reports of radio frequency interference continue
- Satellite operators form entity to help prevent and resolve radio frequency interference

Space Security Impact

The scarcity of both orbital slots and radio frequencies continues to be a problem for continued use of space, with no real solution on the horizon. In fact, the demands of emerging spacefaring states are not only further stressing an already congested environment, but are calling into question the inherent fairness of an allocation system that has operated on a first-come, first-served basis. The technical ease with which both intentional and unintentional frequency interference can occur will be a significant space security concern for the foreseeable future.

TREND 1.4: Increased recognition of the threat from NEO collisions and progress toward possible solutions — Near-Earth Objects (NEOs) are asteroids and comets whose orbits bring them in close proximity to the Earth or intersect the Earth's orbit. Over the past decade a growing amount of research has started to identify such objects that pose threats to Earth and potential mitigation and deflection strategies. Deflection is a difficult challenge due to the extreme mass, velocity, and distance of any impacting NEO, and 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.

2009 Developments:

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

Space Security Impact

The difficulties inherent in an international response to a NEO impact threat are similar to many other space governance, cooperation, and data-sharing challenges. While the threat posed by a potential NEO collision may be detrimental to the overall security of outer space, cooperative multilateral efforts to address this challenge will likely yield positive results for space security. For instance, the progress being made in collaborative NEO detection, warning, and decision-making could encourage cooperation on Space Situational Awareness (SSA) data-sharing and enhanced space security.

Space Situational Awareness

TREND 2.1: US space situational awareness capabilities slowly improving — The US continues to lead the world in space situational awareness capabilities with the Space Surveillance Network. Despite having the most advanced SSA capabilities, however, events such as the February 2009 collision between a US and a Russian satellite (Iridium 33 and Cosmos 2251, respectively) underscore the necessity to further improve both the accuracy of the information collected and the way in which it is managed. Funding increases for SSA programs for FY2010, as well as the partnerships between the US Air Force and contractors such as Lockheed Martin, Raytheon, and Northrop Grumman, reflect a growing desire to improve existing SSA capabilities.

2009 Development:

- Continued US focus on improving space situational awareness capabilities begins to overcome bureaucratic inertia and produce results

Space Security Impact

In previous years there had been little real progress in enhancing US SSA capabilities, despite the gradual transition of SSA from a relatively low priority budget line into a vital tool for the tracking and protection of space assets. Prompted by the abovementioned satellite collision, in 2009 the US made the first real moves beyond rhetoric to spending political and monetary capital on this issue, a telling sign of the growing importance of SSA in overall US space operations. This is a major positive step for space security, and could become even more beneficial insofar as the US and other space actors embrace a more cooperative and collaborative approach to SSA.

TREND 2.2: Global space surveillance 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 US. 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.

2009 Developments:

- International SSA capabilities slowly increase
- Increased calls for SSA data to support commercial and civil space activities

Space Security Impact

The traditional users and providers of SSA data – militaries and intelligence agencies – are still reluctant to provide the services and information that commercial and civil space users need to operate safely, not only because of the sensitive nature of the information on space assets, but also for cultural and bureaucratic reasons. This longstanding practice of secrecy may adversely affect space security since precise information about the position and trajectory of space assets is fundamental in preventing accidental collisions and other harmful interference. The tide seems to be shifting, however, as these traditional users begin to realize the value gained from increased transparency. Both commercial and civil users are applying increased pressure for data sharing and are making strides in finding solutions of their own.

TREND 2.3: Use of SSA capabilities for protection and potential negation of satellites continues to increase — The ability to distinguish space negation attacks from technical failures or environmental disruptions is critical in maintaining international stability in space. Early warning allows for defensive responses, but the type of protection available may be limited. Several spacefaring nations have a basic capability to detect a ground-based electronic attack, such as jamming, by sensing an interference signal or by noticing a loss of communications. However, it is very difficult to obtain advance warning of directed energy attacks that move at the speed of light. The limits imposed on the availability of publicly accessible positional data further compound the complexity of the situation, as the same information can be used for benign purposes such as preventing accidental collisions, but also for potentially aggressive activities.

2009 Developments:

- Inability to attribute satellite failures sparks concerns of potential development of dual-use technology
- States continue to remove positional data on military and intelligence satellites from public databases

Space Security Impact

While increased availability of SSA information provides safety benefits, it also can be used for negation purposes and hostile activities. This concern has led an increasing number of states to try to restrict information on the location of their sensitive military and intelligence satellites. Given that anyone with a telescope and basic technical knowledge can observe these satellites, it is unclear just how effective the artificial restriction of such information will be. Still, limiting the information available for operators may have a negative impact on space security as it could increase the chances of collisions.

Laws, Policies, and Doctrines

TREND 3.1: Gradual development of legal 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 to be outdated and insufficient to address the current challenges to space security, which have been exacerbated by the growth in the number of 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' – referring to a range of non-binding governance tools, including principles, resolutions, confidence-building measures, and policy and technical guidelines – as well as unilateral regulations at the national level

2009 Developments:

- US Space Policy undergoes review process
- New US administration hints at support for banning certain types of space weapons
- China and Russia reiterate the need for multilateral measures to prevent the weaponization of space

Space Security Impact

Although there does not seem to be enough momentum right now for a major multilateral convention on a space security regime, a tendency to develop regulations can be observed at the national level. In launching a full review of US national space policy in 2009, the Obama administration has signaled a degree of willingness to enhance security in outer space through cooperation and consensus. Yet the exact outcome of the US review, slated for release in 2010, is far from clear. It remains to be seen what position the US leadership will take on treaties and Transparency and Confidence-Building Measures, which are believed by some sectors in the US Congress to constrain US freedom of action in outer space. Meanwhile, by addressing questions about their joint proposal for a legally binding agreement that would ban weapons in space, Russia and China continued to assert in 2009 that adoption of the PPWT would be the best way to enhance space security. However, the PPWT is still regarded by some as incomplete due to its lack of a verification principle, as well as its inability to shield against ground-based interceptors. Regardless of the proposals' merits, the fact that alternatives for a space security regime are being discussed by stakeholders constitutes a positive development.

TREND 3.2: COPUOS and the Conference on Disarmament continue to be the key multilateral forums for outer space governance — A range of international institutions, such as the UN General Assembly, the UN Committee on the Peaceful Uses of Outer Space (COPUOS), the ITU, and the Conference on Disarmament (CD), have been mandated to address issues related to space security. Despite the adoption of a Program of Work at the CD in 2009 after more than a decade of deliberations with no tangible results, it remains unclear whether efforts to move forward on the Prevention of an Arms Race in Outer Space (PAROS) and to reach consensus on a legal instrument to regulate space activities will bear fruit in the short term. COPUOS remains active, with a principal focus on non-binding, technical approaches to security in space.

2009 Developments:

- The Conference on Disarmament agrees on a program of work
- The EU submits a draft Code of Conduct to the CD, launches consultation process
- Canada calls for security guarantees at the CD
- COPUOS examines long-term sustainability of outer space

Space Security Impact

The adoption of a program of work for the first time in over a decade and the subsequent failure to implement that program before the closure of the session highlight the hope and frustration felt at the CD in 2009. While any progress is worth noting, the reality is that accomplishments made during one session do not carry forward to the next. Despite objections from a few states over the necessity of consensus in the CD, it will likely remain a requirement for action and continue to impede efforts to engage in substantive work on PAROS. Nevertheless, 2009 saw work proceed on a number of proposals to improve the sustainability of the space environment. Although the EU Code of Conduct was not opened to subscription, a consultation process was launched and the body of the text was shared at the CD. As well, Canada used the CD as a platform to introduce its proposal for new outer space security guarantees. And COPUOS established a timetable to formulate a report and a set of Best Practices Guidelines that address various sustainability issues in space. These proposals constitute positive developments as they may provide the basis for a future space security treaty.

TREND 3.3: National space policies emphasize cooperation and the peaceful uses of outer space — Spacefaring states consistently emphasize the importance of cooperation and the peaceful uses of space, but with caveats based on national security considerations. Several cooperation agreements on space activities have allowed emerging space-faring nations to reap benefits from space applications that are conducive to social and economic development. During 2009, for instance, countries as diverse as Brazil, China, Pakistan, Ukraine, the UAE and Switzerland, were engaged in various bilateral cooperation agreements. As well, India set a target date of around 2015 to launch its manned space program and is working aggressively to meet it.

2009 Developments:

- The US considers changes to International Traffic in Arms Regulations (ITAR)
- National space agencies strive to implement COPUOS debris mitigation standards

Space Security Impact

A significant shift in US national space policy would occur in the event that the US established a new export control system, granting the President authority to remove satellites and related components from the United States Munitions List, as stipulated in the bill referred to the Senate Foreign Relations Committee in June 2009. Fewer and less stringent regulations would constitute a positive development by opening the way for greater cooperation between NASA and such foreign civil space agencies as the European Space Agency, which has in recent years specifically cited export controls as an impediment to its cooperation with the US. Meanwhile, efforts to implement COPUOS debris mitigation standards by national space agencies constitute a positive development as they underscore the growing recognition that debris poses a major threat to peaceful space operations. Observable improvements in this area indicate that most spacefaring states are inclined to cooperate to ensure the peaceful uses of outer space.

TREND 3.4: Growing focus within national space policies on the security uses of outer space — Fueled by a technological revolution, the military doctrines of a growing number of states emphasizing the use of space systems to support national security. This tendency can be seen, for example, in the increasing development of multi-use space systems. The growing reliance on multi-use capabilities has led several states to view space assets as critical national security infrastructure. Past US military space doctrine has focused on the need to ensure US freedom of action in space through the use, when necessary, of "counter-space operations" that prevent adversaries from interfering with US ability to operate freely in space. The US is certainly not the only spacefaring nation with policies that reflect the importance of space assets as a fundamental element of national security; other countries are starting to capitalize on the military benefits of space applications.

2009 Developments:

- Australia releases new white paper on defense
- Japan announces details of Basic Space Plan
- China clarifies position on arms race in outer space
- Russia establishes national security strategy until 2020

Space Security Impact

The 2009 Australian Defence White Paper illustrates the growing realization among a number of smaller spacefaring states that outer space is a key military domain. Its emphasis on the importance of satellites for surveillance, coordination, and ground strike capabilities, as well as the threat of counter-space technologies, underscores the connection for many states between national security and outer space policy. The impact of the Japanese Basic Space Plan should not be overly negative, given that the portion of the space budget allocated to the Ministry of Defense continues to be used exclusively for defensive purposes. The clarification of China's view of an arms race in outer space as a "historical inevitability" needs to be understood in the context of the domestic political system. While the significance of a comment by one commander should not be overblown, it helps to understand that the civilian and military branches of government have different priorities and compete for authority over the direction of space affairs.

Civil Space and Global Utilities

TREND 4.1: Increase in the number of actors gaining access to space — The rate at which new states gain access to space increased dramatically in the past decade, and is expected to continue increasing as launch costs decrease and some states indigenously develop space technologies. In 2009, the Islamic Republic of Iran joined the ranks of spacefaring nations with independent orbital launch capacities and became the 10th nation to demonstrate this capability. In addition, over 60 nations or consortia currently have assets in space that have been launched either independently or in collaboration with others. In 2003 China joined Russia and the US 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.

2009 Developments:

- More countries launch new satellites
- New launch capabilities continue to be developed; Iran's success and North Korea's failure
- National and international space bodies continue to expand and increase

Space Security Impact

The launch activities of both Iran and North Korea, despite different degrees of success, caused a great deal of concern about the peaceful nature of their space programs. The launching of new satellites reflects the ever increasing interest of states in conducting space activities, but also highlights the need to adhere to relevant international treaties and other regulations, such as those setting technical standards. Increasing international cooperation (as in the development and launching of UAE and Swiss satellites) contributes to better space security, because it requires different states to coordinate their efforts, thus further entrenching the practice of international cooperation on space activities. However, a potentially negative impact of the increasing number of new actors with access to space is that space becomes a more crowded environment, thereby increasing the risk of accidental interference with space assets.

TREND 4.2: Changing priorities and funding levels within civil space programs — Civil expenditures on space have continued to increase in several countries in recent years, as the social and economic benefits derived from space activities have become more apparent. Past decreases in the space budgets of the US, the EU countries, and Russia have begun to reverse. Increasingly, civil space programs include security applications, with multi-use satellites becoming increasingly ubiquitous. Several states, such as Brazil, Nigeria, and South Africa, are placing a priority on satellites 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.

2009 Developments:

- Spacefaring states continue to fund Moon exploration programs
- Successes and failures in the development of new launch vehicles
- More countries develop human space exploration programs
- Number of scientific missions is on the rise

- Space budgets remain unchanged or increase slightly

Space Security Impact

The fact that expenditures for space activities did not drop in response to the 2008 economic crisis constitutes a positive development that indicates the high priority given by states to their space activities. The increased number of scientific missions may further encourage international cooperation on space operations and thereby enhance the level of trust among different spacefaring nations.

TREND 4.3: Continued international cooperation in civil space programs — The most prominent example of international cooperation continues to be the International Space Station (ISS), a multinational effort with a focus on scientific research with an estimated cost of over $100-billion to date. It epitomizes the benefits to be gained from peaceful cooperation on space activities. In 2009 the ISS completed nine years of uninterrupted inhabitancy. International civil space cooperation has played a key role in the proliferation of the technical capabilities needed by states to access space as it allows states to pool resources and expertise that yield shared benefits. 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.

2009 Developments:

- International cooperation continues to provide access to space for developing countries
- Increasing number of cooperation agreements between developing and developed countries

Space Security Impact

Greater cooperation on space activities has an overall positive impact on space security. It fosters an environment of multilateral cooperation in scientific research. Cooperation among countries with different levels of development also allows more opportunities for space exploration by nations not traditionally involved. Cooperation can also increase the transparency of space activities, further reducing potential conflicts in a strategic environment. However, adopting criteria to engage in space cooperation that leads to the exclusion of some states may have a negative impact on space security by further isolating such nations as Iran and North Korea, thus decreasing the likelihood of bringing them into an eventual space security regime.

TREND 4.4: 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. These systems have spawned space applications that have become almost indispensable to the civil, commercial, and military sectors. Advanced and developing economies alike are heavily dependent on these space-based systems. Currently Russia, the US, 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, the simultaneous development of competing systems faces significant challenges related to international coordination on issues such as orbital crowding use of signal frequencies.

2009 Developments:

- Satellite navigation systems around the globe continue to evolve
- Disaster relief and remote sensing capabilities continue to be developed

Space Security Impact

Earth observation satellites provide valuable data that can be used to support decision-making for peaceful national purposes. It is not yet clear if collaborative projects such as the Global Earth Observation System of Systems will succeed. It remains to be seen whether the systems that make it up will work more effectively when integrated. The growing use of remote sensing data to manage a range of global challenges, including disaster monitoring and response, is positive for space security insofar as it further links the security of Earth to the security of space, expands space applications to include additional users, and encourages international collaboration and cooperation on an important space capability. Satellite navigation activities should not have any negative impact on overall space security but, given the considerable international coordination and cooperation that is required, the interoperability of these systems may face some difficulties related to the allocation of frequencies as well as the disposal of old satellites.

Commercial Space

TREND 5.1: Continued overall growth in the global commercial space industry — Commercial space revenues have steadily increased since the industry first started to grow significantly in 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 recent years, Russia has dominated the space launch industry, having the most commercial launches, while US companies have led in the satellite manufacturing sector. International competition in both of these sectors is increasing.

2009 Developments:

- Consumer television services drive growth in space-based commercial sector
- Economic crisis impacts some aspects of commercial space while others prove immune
- Major satellite operators form coalition

Space Security Impact

The continued overall growth in the commercial space industry and the ever increasing revenues that are produced constitute a positive development for space security insofar as the pool of stakeholders with a direct interest in preserving space as a peaceful domain is steadily growing. Moreover, cooperative efforts in this industry and the resulting coalitions that lead to cost-effectiveness in commercial space operations will likely be conducive to greater space access. If demand for space resources such as orbital slots and radio frequencies exceeds supply, as is starting to be the case, the result could be friction among providers of commercial services. However, such friction need not necessarily be to the detriment of space security, as it could set the stage for a more coordinated and collaborative approach for the allocation of scarce space resources.

TREND 5.2: Commercial sector supporting increased access to space — Commercial space launches have contributed to cheaper space access. Lower launch costs for commercial satellites have enabled greater accessibility to space, particularly by developing countries. The commercial space industry is also opening up access to Earth imaging data, which until a few years ago was only available to a select number of governments. Today any individual or organization with access to the Internet can use these services through Google Maps, Google Earth, and Yahoo Maps programs. 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 suborbital trajectories and low Earth orbit.

2009 Developments:

- Private human access to space slowly continues
- Investment in commercial space on rise
- Commercial operators expand availability of imagery and satellite services
- New launchers with increased capacity under development

Space Security Impact

Increased access to space has both positive and negative impacts on space security. As more entities, both government and private, are able to reach space, the benefits of the resource spread, ideally in an equitable manner. However, increased access to space also translates into a more congested environment, thus further straining an already complex domain that lacks effective mechanisms for the allocation of scarce resources. Private access to space, although still at an embryonic stage, may yield a positive impact on space security as private citizens, many previously oblivious to the security challenges facing outer space, will expand the number of stakeholders with a vested interest in space security beyond governments and commercial operators. Such access may also challenge both the sustainability of the space environment as well as the applicability of international laws to the largely uncharted realm of space tourism.

TREND 5.3: Government dependency on the commercial space sector means that subsidies and national security concerns remain important — The commercial space sector is significantly shaped by national governments with particular security concerns. In 1999 the US placed satellite export licensing on the State Department's US Munitions List, bringing satellite product export licensing under the International Traffic in Arms Regulations (ITAR) regime and significantly complicating participation by US companies in international satellite launch and manufacturing ventures. Government regulations on export controls may gradually be influenced more and more by the way in which the controls affect the commercial sector's ability to engage in international cooperation. The US Air Force's joint development with companies such as Boeing of strike systems with possible space applications is an example of a 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. The 1998 US Space Launch Cost Reduction Act and the 2003 European Guaranteed Access to Space program provide considerable government subsidization of the space launch and manufacturing markets. The US and European commercial space industries also receive important contracts from government programs.

2009 Developments:

- Military dependence on the commercial sector continues to expand
- Public-private partnerships on the rise
- Revision of export controls considered in the US

Space Security Impact

As the relationship between the public and private sectors becomes more collaborative and cooperative, the polarity between them decreases. This interdependence has a positive impact for space security as conceptions about what constitutes space security will merge and take into consideration the needs of the commercial sector as well as the security of states. As this mutual dependence deepens, multiple-use spacecraft built by commercial operators could become military targets, resulting in an overall decrease in security. On the other hand, the proliferation of dual-use or multi-use assets in space could make a military attack less useful and, therefore, less likely. The range of peaceful space applications could potentially decrease as the commercial industry, lured by profitable government contracts, might divert much of its research and developments efforts to military applications.

Space Support for Terrestrial Military Operations

TREND 6.1: The US and Russia continue to lead in deploying military space systems — Almost half of all global spending on space is for defense-related programs that provide early warning, communications, weather forecasting, reconnaissance, surveillance, and intelligence, as well as navigation and weapons guidance applications. The US is not only the biggest spender on military space programs but is also the most dependent on space systems. While US dominance in space systems is undisputed, the level of expenditures is increasing in other countries around the world. Although the operational status of many of Russia's space systems is uncertain, Russia is known to be replacing its Soviet-era military space assets and in 2009 continued to move forward with its Global Navigation Satellite System (GLONASS). By the end of 2009 there were over 175 dedicated military satellites worldwide, of which the US operated roughly half and Russia approximately one quarter.

2009 Developments:

- Despite some setbacks in satellite capabilities, the U.S. continues to upgrade its systems
- Russia moves forward with GLONASS and maintains aggressive satellite launch schedule

Space Security Impact

Given the growing reliance by the US and Russia on military space systems, their assets in space may increasingly be seen as strategic targets by an adversary with the necessary means to interfere with them, thus making these assets more vulnerable. Thus, the continuing development and maintenance of US and Russian military space systems may have a positive impact on space security as the two countries will have a direct interest in advancing a norm of no hostile interference with space assets. On the other hand, the delicate boundary between militarization and weaponization of space risks being crossed as more states embrace the use of space-based military applications

TREND 6.2: More states are developing military and multi-use space capabilities — Traditionally, military satellites not owned by the US or Russia have been almost exclusively intended for telecommunications and imagery. Recently, however, states such as Canada, China, France, Germany, Japan, Israel, Italy, and Spain have been developing multi-use satellites with a wider range of functions. As security is becoming a key driver of these governments' space programs, expenditures on multi-use space applications are going 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. EU member states have exhibited a remarkable predisposition for collaboration by sharing several space capabilities with their partners. During 2009 such navigation systems as China's Beidou, India's IRNSS, and the EU's Galileo continued to advance.

2009 Developments:

- The Indian Space Research Organization (ISRO) begins to develop military capabilities
- Various countries pursue satellite navigation systems

- Canada's multi-use space capabilities continue to be developed
- Europe moves forward with Galileo navigation system and deepens military cooperation on space projects
- China rapidly upgrades space-related technologies
- Japan outlines military space strategy
- Australia releases defense white paper addressing, inter alia, space situational awareness and access to space-based imagery

Space Security Impact

As more states develop the technologies and partnerships required to access space, accessibility to the space environment increases, which can be positive for space security. Further, increased collaboration among states, as in Europe, will allow countries without all the requisite technology or resources to enjoy the benefits of access to space. Nevertheless, the impact of the development of space-based military capabilities by more states can be negative as outer space becomes congested and the number of potential targets increases. At the same time, states will likely have an incentive to develop temporary, reversible offensive capabilities as more actors have a direct stake in this field. Moreover, the investments being made by multiple countries in satellite-based navigation could have a positive impact on space security as more options are presented to users and more redundancy is introduced, in particular with regard to improved space situational awareness and verification capabilities. Finally, Japan's release of its military space strategy and the publication of Australia's defense white paper can be seen as positive for space security as the sharing of their plans increases transparency and reduces uncertainty.

Space Systems Protection

TREND 7.1: Efforts to protect satellite communication links increase but ground stations remain vulnerable — Many space systems lack protection from determined attacks on ground stations and communications links. Because the vast majority of commercial space systems have only one operations center and one ground station, they are particularly vulnerable to negation efforts. 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. Laser communications still have the best potential to reduce vulnerabilities of satellite communications links, but are proving difficult to implement. Furthermore, the link between cyberspace and outer space is of utmost importance as the vast majority of space assets depend on cyber networks, which constitute a critical vulnerability.

2009 Developments:

- Despite uncertainties, development of US Cyber Command moves forward
- Development of the Rapid Attack Identification Detection and Reporting System (RAIDRS) continues

Space Security Impact

The creation of USCYBERCOM can help the US achieve not only advanced capabilities to combat cyber threats, but also higher levels of security in space missions. Although the implementation of a single cyber command has the benefit of higher levels of integration among different government and military forces, it is still unclear how such integration is to be achieved. Other issues to be solved include the specification of minimum requirements, roles, and responsibilities of the entities involved in its operation. Although RAIDRS B-10 has been scaled down to five deployable sites, its development has continued and deployment is scheduled for 2010. As a result, the US military will be able, in the near future, to detect and identify attacks against their ground and space assets, which would have a positive impact on space security.

TREND 7.2: Protection of satellites against direct attacks improving but still limited — The primary source of protection for satellites stems from the difficulties associated with launching an attack into space. Passive satellite protection measures also include system redundancy and interoperability, which have become characteristic of satellite navigation systems. Most key US, European, and Russian military satellites are hardened against the effects of a high-altitude nuclear detonation. Nonetheless, physically protecting a satellite from a direct kinetic attack remains difficult. While no hostile ASAT attacks have been carried out, recent incidents, such as the ASAT test conducted by China when one of its own satellites was destroyed in 2007 or the US destruction of USA-193 in 2008 using a modified SM-3 missile testify to the availability and effectiveness of missiles to destroy even a hardened satellite should they be used in a hostile manner.

2009 Developments:

- US Air Force delays launch of space based surveillance system
- More reliable evasive maneuvers for small satellites under development

Space Security Impact

Determining the precise positioning of space objects and fine-grained maneuvering of spacecraft can be used in performing evasive operations to avoid collisions, thus contributing to higher security in space. The same capabilities, however, could be used to precisely determine the position of a foreign spacecraft, perform fly-around maneuvers, and attack it. The distribution of information processing among several picosatellites can help reduce the burden of power consumption in an individual spacecraft during onboard processing. Consequently, picosatellites could rely on enhanced attitude control to perform evasive maneuvers, thereby improving security. As well, the use of cryptographic mechanisms in System F6 could increase the overall security of its communications systems to the extent that it would become virtually immune to attackers, thereby achieving high security levels.

TREND 7.3: Efforts underway to develop capacity to rapidly rebuild space systems following direct attacks, but no operational capabilities — The ability to rapidly rebuild space systems after an attack could reduce vulnerabilities in space. Although the US and Russia are developing elements of responsive space systems, no state currently has this capability. A key US 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. As well, by the end of 2009 the X-37B Orbital Test Vehicle continued to be developed under a shroud of secrecy, with a maiden flight for the reusable, unpiloted spacecraft scheduled for April 2010 to test new reusable space launch vehicle technologies.

2009 Development:

- Research and development of low-cost launch capabilities progress

Space Security Impact

Quick launch with minimum cost can be considered primordial capabilities to allow for fast recovery of space assets following attacks. Although delayed in their schedule, Falcon launch vehicles can help reduce launch cost and time, thereby contributing to higher levels of security for space systems. The progress made with the X-37B is expected to help the further development of technologies for reusable spacecrafts, which could be used for in-orbit repairs. While the X-37B's mission has been broadly described as testing reusable space technologies, there has been some apprehension from nations like China that it could be used as part of a weapon system, which, if true, would have a negative impact on space security by promoting distrust among other spacefaring nations and potentially triggering a weapons race in space.

Space Systems Negation

TREND 8.1: Widespread capabilities to attack ground stations and 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. Several incidents of intentional jamming of communications satellites have been reported in recent years. The US leads in developing doctrines and advanced technologies to temporarily negate space systems by disrupting or denying access to satellite communications, and has deployed a mobile system to disrupt satellite communications without inflicting permanent damage to the satellite.

2009 Developments:

- Satellite communications resources remain vulnerable to attack
- Facing growing threat of cyber warfare, Pentagon plans creation of military command for cyberspace

Space Security Impact

Attackers have been successful in hijacking transponders linked to older satellites and jamming communications links, thereby drawing attention to the vulnerability of the ground components of space systems. The operations of some space systems can be compromised cheaply and with relative ease by individuals, groups, or governments, consequently reducing the security of space assets. Additionally, the number of highly sophisticated attacks against computer systems has increased. As a result, the US GAO issued a report detailing the lack of appropriate security and the consequences to national space assets; if enhanced security measures are instituted, as recommended, the renewed vigilance may help increase security levels of space systems through improved awareness of the vulnerabilities of ground stations.

TREND 8.2: Ongoing proliferation of ground-based capabilities to attack satellites — Space surveillance capabilities for debris monitoring and transparency can also support satellite tracking for space negation purposes. The US and Russia maintain the most extensive space surveillance capabilities and the US has explicitly linked its development of enhanced space surveillance systems to efforts to enable offensive counter-space operations. China and India also have satellite tracking, telemetry, and control assets essential to their civil space programs. France, Germany, Japan, and Europe are developing independent space surveillance capabilities that can also support tracking for negation purposes. Beyond surveillance systems to track for negation purposes, some spacefaring nations possess the necessary means to actually inflict intentional damage on an adversary's space assets, although such an occurrence has not yet transpired. While the development of ground-based anti-satellite weapons employing conventional, nuclear, and directed energy capabilities dates back to the Cold War, no hostile attacks using any of these means have been recorded. The US, China, and Russia lead in the development of more advanced ground-based kinetic-kill systems that have the capability to directly attack satellites. They have access to advanced laser programs, which have inherent satellite negation capabilities in LEO.

2009 Developments:

- Directed energy weapons continue to be developed and tested
- Development of indigenous launch capabilities in Iran and North Korea raises concerns about peaceful intentions of their space programs
- Development of ASAT capabilities discussed in some countries

Space Security Impact

In experiments in the US Air Force Research Laboratory, low-power lasers have successfully compromised small aircraft. Although not tested against satellites, low-power lasers could potentially temporarily or permanently damage non-hardened components of spacecraft. Although US satellites experienced only decreased performance when purportedly illuminated by Chinese laser beams in 2006, such an incident could have led to reciprocal actions and therefore have contributed negatively to security in space. Another factor potentially affecting space security is the sustained testing of launch vehicles by Iran and North Korea. Since those launch vehicles could also be employed for non-peaceful objectives, the conduct of these countries has been scrutinized. The development of ASAT weapons remains highly contentious. The actual hostile use of a weapon against a space asset could result in a weapons race in space, thus considerably reducing space security.

TREND 8.3: Increased access to space-based negation capabilities — Space-based negation efforts require sophisticated capabilities, such as precision on-orbit maneuverability and space tracking. Many of these capabilities have dual-use potential. 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. The US leads in the development of most of these enabling capabilities, although there is no evidence to suggest that they have been integrated into a dedicated space-based negation system.

2009 Development:

- US updates military doctrine on space operations and advances its rendezvous capabilities

Space Security Impact

The inclusion of sections on rendezvous and proximity operations and offensive space control in the US doctrine for planning, executing, and assessing joint space operations can have serious implications for space security. Those capabilities can be employed not only to increase the security of US space assets by allowing for evasive maneuvers, but also to rendezvous with and compromise foreign spacecrafts. Enhanced rendezvous operations have already been demonstrated by the DARPA MiTEx microsatellites when inspecting the non-operational DSP-23 satellite. Several foreign nations can interpret such developments as potential threats to their space assets. A consequence of such a development could be the acceleration of investments in enhanced negation capabilities worldwide, thereby negatively impacting space security.

Space-Based Strike Capabilities

TREND 9.1: Funding cuts in US mark move away from development of missile defense space-based interceptor — Although the US and USSR developed and tested ground-based and airborne ASAT systems from the 1960s through the 1980s, there has not yet been a deployment of space-to-Earth or space-to-space missile strike systems. Under the Strategic Defense Initiative in the 1980s, the US invested several billion dollars in the development of a space-based interceptor concept called Brilliant Pebbles, and tested targeting and propulsion components required for such a system. The US and USSR were both developing space-based directed energy strike systems in the 1980s, although today these programs have largely been halted. Similarly, in 2009 the US House Budget Committee resolved that no funding should be provided for space-based interceptor research or development for FY2010.

2009 Developments:

- Space-based missile interceptor technologies face funding cuts in the US
- US reiterates policy of not actively developing space weapons
- Development of Space Tracking and Surveillance System (STSS) moves forward while related Space Based Space Surveillance (SBSS) project remains stalled

Space Security Impact

The absence of functioning space-based strike systems undoubtedly has a positive impact on space security. The US government seems to be voluntarily backing away from the pursuit of SBI technology by cutting R&D funding for these programs. The Pentagon's reiteration of its policy to not actively develop space weapons also has a positive impact for space security. The fact that the country with the most advanced space capabilities chooses not to actively pursue space-based weapons serves to delegitimize these weapons among other spacefaring states. Although the development of the STSS continued to move forward in 2009, this technology is not necessarily applicable to space-based strike systems; the direction this system takes when operational will indicate its overall impact on space security.

TREND 9.2: Continued development of advanced technologies that could be used for space-based strike-enabling capabilities — The majority of advanced, space-based strike- enabling technologies are dual-use and are developed through civil, commercial, or military space programs. While there is no evidence to suggest that states pursuing these enabling technologies intend to use them for space-based strike purposes, such developments do bring these actors technologically closer to this capability. For example, recent successful tests conducted by the US Air Force have demonstrated the efficacy of air-based laser weapons that could potentially lead to the development of space-based weapons of a similar nature. China, India, and Israel are developing precision attitude control and large deployable optics for civil space telescope missions. Five states in addition to the European Union are developing independent, high-precision satellite navigation capabilities. China, India, and the EU are developing Earth-reentry capabilities that provide a basis for the more advanced technologies required for the delivery of mass-to-target weapons from space to Earth.

2009 Developments:

- Boeing conducts successful test of air-based laser weapon for US Air Force
- Space-based strike enabling capabilities continue to be developed

Space Security Impact

Space-based weapons designed to strike terrestrial targets will require sophisticated technological developments that, at present, few spacefaring states seem able or willing to attempt. Although there is no evidence to definitively suggest that states are developing the abovementioned technologies for space-based strike purposes, the potential for space-to-Earth strike systems will continue to challenge the international community. The technology behind the air-based laser weapons developed by Boeing, for example, would have a negative impact for space security should it be conceived as a steppingstone toward a space-based weapon. Similarly, the push for a debut of the Prompt Global Strike program by 2015 could also represent a negative for space security; this program can be seen as another step toward the development of space-based strike capabilities, even if the current program has another goal. Nevertheless, restraint in adopting these technologies is being observed. Continued restraint bodes well for space security.

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] More recently, 2009 was the third consecutive year during which a major debris-creating event occurred. 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 US satellite Iridium 33 – collided for the first time.

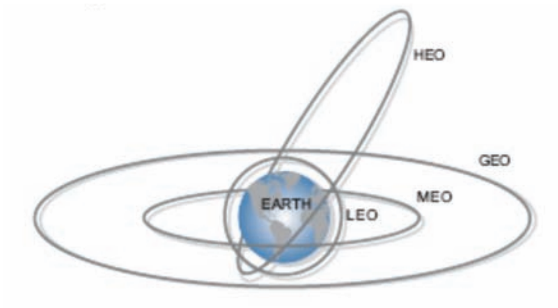
A growing awareness of the impact of space debris on the security of space assets has encouraged space actors to take steps to mitigate the production of new debris through the development and implementation of national and international debris mitigation guidelines, also examined in this chapter.

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 (ITU). 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 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

The US 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 US 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 percent are operational satellites.[2] It is estimated that there are over 300,000 objects with a diameter larger than 1 cm, and millions smaller.[3]

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 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.[4] As of 2003 it was estimated that 43 percent of tracked debris resulted mostly from explosions and collisions.[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 recent years, however, an increase in the annual rate of debris production has again been observed, as a result of the aforementioned major debris-creating events observed in three consecutive years (2007–2009). Debris events in 2009 alone resulted in more than 1,650 cataloged pieces of debris (i.e., 10 cm in diameter or larger).

Collisions between such space assets as the International Space Station and very small pieces of untracked debris are a frequent but manageable problem.[7] Collisions with larger objects remain rare. A US 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 Figure 1.2 below.

Figure 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	US 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 US satellite, Iridium 33, part of the Iridium communications constellation.

2009 Development

For the first time ever, two satellites collide in orbit

For the third year in a row, a major debris-generating event has marked the beginning of the year. On 10 February, two intact satellites collided in space for the first time. One was a retired Russian communications satellite, Cosmos 2251, and the other was Iridium 33, owned and operated by a US company and part of the Iridium communications constellation.[12] This LEO constellation provides global mobile phone service in large part to the U.S. government.

The two satellites collided at almost a 90 degree angle close to the North Pole with a relative impact velocity of around 10 kilometers per second.[13] As of the end of 2009, the US SSN was tracking just under 500 pieces of debris from the Iridium satellite and almost 1,200 pieces of debris from Cosmos 2251.[14] Many thousands more pieces that cannot be tracked by the existing surveillance systems are likely to have been generated.

Within several months, the debris dispersed into a relatively thin shell close to the original satellites' altitude of 790 kilometers. Most of the debris from the Iridium satellite had been knocked into higher orbits, thus taking a longer time to decay, while a significant portion of the Cosmos debris was knocked into slightly lower orbits.[15] As of 1 February 2010, fewer than 60 pieces of debris from this event had reentered the Earth's atmosphere.[16]

The depiction of this incident as an accident was disputed by a few opportunists in both the US and Russia. A retired general, the former head of Russia's military space intelligence, said that the collision was the result of further American testing of the on-orbit rendezvous, inspection, and servicing technology demonstrated by the Orbital Express and XSS-11 satellites.[17] Unnamed "senior military officers, intelligence analysts and space industry executives" were cited in a US media report saying that the collision was "no accident" and could have been a test of "a pre-positioned Russian space mine."[18]

Underlying some of these claims was the mistaken belief that the US military tracks and continuously watches all objects in orbit, and thus accidental collisions cannot happen. Although both the American and Russian militaries had been performing daily collision screening long before February 2009, neither detected the collision beforehand.[19,20] This was because neither military included the two satellites that collided in the list of screened objects, even though both had the highly accurate positional data gathered from their respective tracking networks to do so.[21] The primary reason cited for neither country's screening these satellites was a lack of resources, both in computer power and trained personnel. The lack of a clear requirement and responsibility for either military to screen commercial or nonfunctional payloads was also a factor.

Although a significant amount of US military tracking data is published, it was not accurate enough to be useful in predicting the collision. On the day of the collision, an automated calculation done by the SOCRATES website using this publicly available data indicated that the two satellites would have a close approach of just under 600 meters, which ranked it as the 152nd-closest approach on that day.[22] An Iridium Vice-President had said that in the past the Joint Space Operations Center (JSpOC) had given Iridium daily conjunction warnings, but it had used only the imprecise public position data and was generating over 400 close approaches within 5 kilometers every week across the entire Iridium constellation— too many for Iridium to deal with in a useful manner.[23]

After the collision, the US military added all the satellites in the Iridium constellation to its daily screening process and it has since expanded this service to include all maneuverable or active satellites (see Trend 2.1 for details).

2009 Development

Trackable space debris population increases significantly by 15.6%

After a year of relatively minor fragmentation events and an overall decrease in the orbital debris population, 2009 saw one significant debris-generating event and a number of smaller ones. By the end of the year, the total number of large- and medium-sized objects (>10cm) in orbit cataloged by the US SSN was 15,090.[24] This number represents an increase of 2,347 objects or 15.6% percent over yearend data for 2008.[25] This number does not include the objects tracked by the SSN but not catalogued, which number at least 6,000 additional objects.

In addition to the collision between the Iridium and Cosmos satellites, there were two minor fragmentation events in 2009. The first was of an ullage motor from a Russian SL-12 rocket, object 1991-025F, which was used to place three GLONASS navigation satellites into medium earth orbit (MEO).[26] Each SL-12 launch vehicle has two ullage motors (also known as aux motors), which are auxiliary motors used to boost the upper stage and accompanying payloads into a highly elliptical transfer orbit from the original LEO parking orbit. The ullage motors are usually jettisoned after this burn and left in the transfer orbit. They have a proclivity to fragment: the 2009 breakup was the 37th detected event of this type.[27]

The second minor breakup in 2009 was of Cosmos 192, a 42-year-old Russian LEO navigation satellite, on 30 August. It released as many as 20 trackable pieces at an altitude of around 710 kilometers.[28] Although the exact cause of this event is unknown, it is speculated that it was due to a breach of the pressurized spacecraft, possibly from the impact of a small piece of debris.[29]

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

Figure 1.3: Summary of 2009 Debris Events[30]

Parent Object	Country	Date	Estimated Number of Pieces*	Cataloged Number of Pieces**	Lifespan of Pieces
Iridium 33	USA	10 Feb 09	Several hundred	491	Decades
Cosmos 2251	CIS	10 Feb 09	Few thousand	1143	Decades
SL-12 Ullage Motor	CIS	8 Mar 09	20	15	Months/years
Cosmos 192	CIS	30 Aug 09	20	3	Few years

* As initially reported by the US Space Surveillance Network
** As of 1 February 2010

Figure 1.4: Total on-orbit debris by launching State[31]

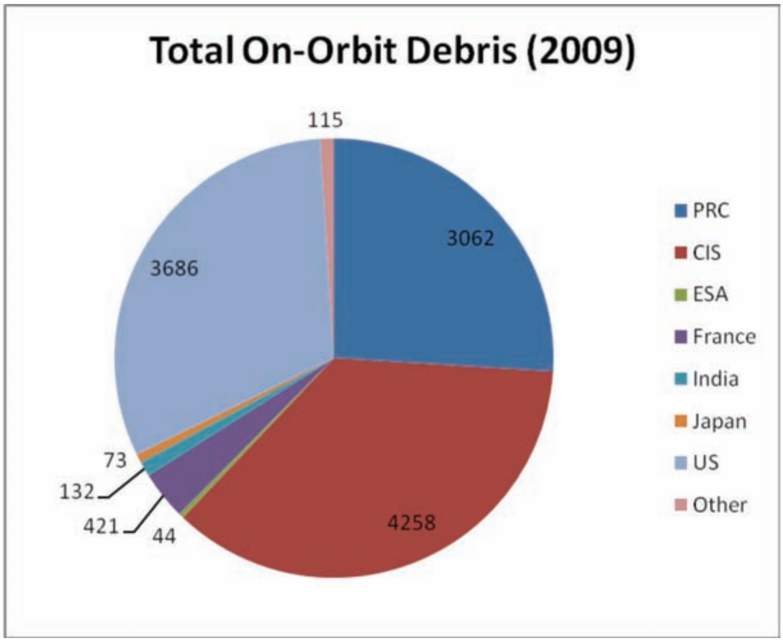
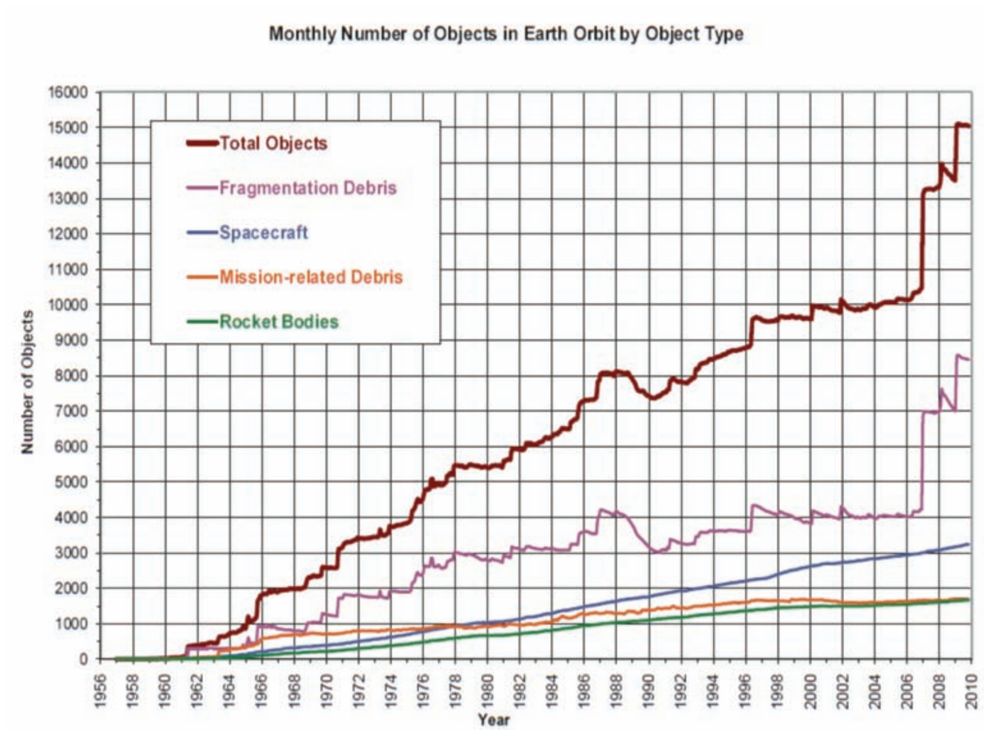


Figure 1.5: Growth in on-orbit debris population by category[32]



This chart displays a summary of all objects in Earth orbit officially cataloged by the US 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.

2009 Development

The US military continues to track and predict atmospheric reentry of space debris

During 2009, JSpOC used tracking data from the SSN to predict the atmospheric reentry of 298 objects in the satellite catalog.[33] Fifteen of these objects were considered "high interest" because they measured more than ten square meters, either from known physical characteristics or as determined by radar cross-section (RCS). There were no reported incidents of damage or injury from these reentries.

2009 Space Security Impact

While 2009 did not see another intentional debris-generating event, it did witness a first-of-its-kind event that generated a significant amount of debris that might have been avoided. Although the large spike in debris decreases space security, the event might have a positive impact as it appears to have been the catalyst for a change in the attitude of spacecraft operators. All space actors may finally be motivated to put measures into place to tackle the problem of space debris and prevent future collisions, ultimately creating greater space security.

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 US government issued formal orbital debris mitigation standards for space operators. These standards were developed by DOD and NASA. In 2004 the US Federal Communications Commission 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.[34] In 2008 NASA published the first edition of the *Handbook for Limiting Orbital Debris*, which presents the scientific background for debris mitigation procedures.[35]

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.[36] Also in 2002 ESA issued the European Space Debris Safety and Mitigation Standard[37] and issued new debris mitigation guidelines in 2003. As well, the European Union's Code of Conduct for Outer Space Activities, expected to be open for subscription in 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."[38]

Japan and Russia also appear to strongly support the mitigation of space debris production. China, although a member of the Inter-Agency Space Debris Coordination Committee (IADC), has been slow to adopt debris mitigation measures.[39] (The IADC includes representatives of the space agencies of China, Europe [ESA], France, Germany, India, Italy, Japan, Russia, Ukraine, the UK, and the US.) At the 2003 annual meeting of the UN Committee on the Peaceful Uses of Outer Space (COPUOS), China committed to "undertake the study and development of Chinese design norms to mitigate space debris, in conformity with the principles reflected in the space debris mitigation guidelines developed by the Coordination Committee."[40]

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 lifetime.[41] 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. [42]

The Scientific and Technical Subcommittee of 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.[43] 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.[44] 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.

Figure 1.6: UN COPUOS Space Debris Mitigation Guidelines[45]

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.[46] 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."[47] Currently, natural decay due to atmospheric drag remains the only feasible way to remove debris, although research into this area continues.

2009 Development

Orbital debris continues to have impacts on operational spacecraft

For the first time, NASA released a complete listing of all the collision avoidance maneuvers made by spacecraft under its control in 2009.[48] This list is summarized in Figure 1.7 below.

In addition, on 12 March the crew of the International Space Station was forced to conduct an emergency evacuation into the Russian Soyuz capsule due to a close approach of a piece of debris. The debris was a "yo weight," a small mass attached to a 1-meter cable that was used to de-spin the GPS navigation satellite placed into an elliptical transfer orbit in 1993 by a US Delta 2 rocket.[49] The rapidly changing nature of this orbit prevented early detection of the close approach and an avoidance maneuver; as a result, the crew was forced to take precautionary measures. The piece of debris was eventually determined to have passed by the ISS harmlessly at a distance of approximately 4 kilometers.[50]

NASA also predicted a 1-in-185 chance of "Loss of Crew and Vehicle" due to a potential impact from manmade or natural micrometeoroid orbital debris (MMOD) during the May Shuttle repair mission to the Hubble Space Telescope.[51] The primary source of risk was impact to the Thermal Protect System that protects the Shuttle from the intense heat of reentry. There was also concern about potential impact on the cooling system located on the inside of the Shuttle bay doors, which would be open during the repair operation, that could force an early mission abort.

Figure 1.7: Summary of 2009 NASA Collision Avoidance Maneuvers[52]

Spacecraft	Orbit	Maneuver Date	Object Avoided
TDRS 3	GEO	27 January	Proton rocket body
International Space Station	LEO	22 March	CZ-4 rocket body debris
Cloudsat	Sun-sync	23 April	Cosmos 2251 Debris
EO-1	Sun-sync	11 May	Zenit rocket body debris
International Space Station	LEO	17 July	Proton rocket body debris
PARASOL (France)*	Sun-sync	29 September	Fengyun-1C debris
AQUA	Sun-sync	25 November	Fengyun-1C debris
Landsat 7	Sun-sync	11 December	Formosat 3D

* PARASOL is owned and operated by France but is part of NASA's "A-Train" Earth observation constellation.

The Chief Operating Officer for the commercial imagery provider Geoeye, William Schuster, said that its satellite Geoeye-1 had to maneuver four times to avoid collisions during its first year in orbit. Schuster made this comment during a panel discussion at the Strategic Space Symposium in Omaha, Nebraska, in October. Geoeye-1 was launched in September of 2008 and operates in the Sun-synchronous region. Schuster also said that during 10 years of operations its Ikonos imagery satellite, also in the Sun-synchronous region, had had to conduct avoidance maneuvers seven times.

On 3 October the China Aerospace Science and Technology Corporation (CASC) announced that it had conducted a collision avoidance maneuver for a "high-value Chinese spacecraft."[53] This was reportedly the first time such a maneuver had been conducted by a Chinese satellite. Independent researchers have indicated that the satellite in question was most likely the Yaogan-1, also known as the JianBing-5 (JB-5) or Remote Sensing Satellite-1 (RSS-1). Launched in April 2006, it was China's first space-based synthetic aperture radar (SAR) system and provides radar imagery of the Earth.[54]

In December, the JSpOC Chief of Strategy, US Air Force Colonel Chris Moss, announced during a keynote address at the International Conference on Orbital Debris Removal that, since February 2009, 32 collision avoidance maneuvers had been conducted by the 52 organizations that are currently part of the US military's Commercial and Foreign Entities program.[55]

2009 Development

Worldwide compliance with the UN debris mitigation guidelines still inconsistent

NASA announced that during 2009 two retired LEO spacecraft were successfully placed in disposal orbits in compliance with the debris mitigation guidelines.[56] Both proved to be challenging, as the spacecraft were designed and flown long before implementation of debris mitigation standards. The first spacecraft was the US Navy's GEOSAT Follow-On

(GFO), which was brought from an 800-kilometer circular orbit into a 455-kilometer by 785-kilometer orbit, from which it will reenter the atmosphere within 25 years. The second spacecraft was the French SPOT 2, which was deorbited from 825 kilometers into a disposal orbit similar to that of GFO.

A yearly report on the GEO region produced by the European Space Agency found that, of the 21 GEO spacecraft that reached end-of-life in 2009, only 11 were moved 250 kilometers above the active GEO belt and into the disposal region outlined by the IADC debris mitigation guidelines.[57] Six of the noncompliant spacecraft were partially reorbited, but not to the altitude in the guidelines. Three spacecraft, all Russian, appear to have been abandoned in the active GEO region. Figure 1.8 shows the general trend of increased compliance with the guidelines since 2002; however, it should be noted that in 2009 six spacecraft were moved from the operational zone but were not boosted to the altitude outlined in the IADC guidelines.

Figure 1.8: Status off end-of-life spacecraft in the GEO belt[58]

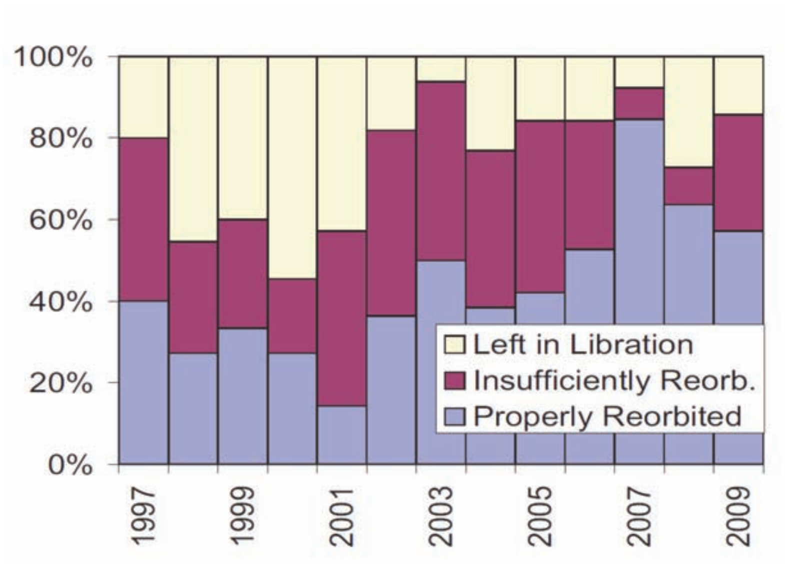
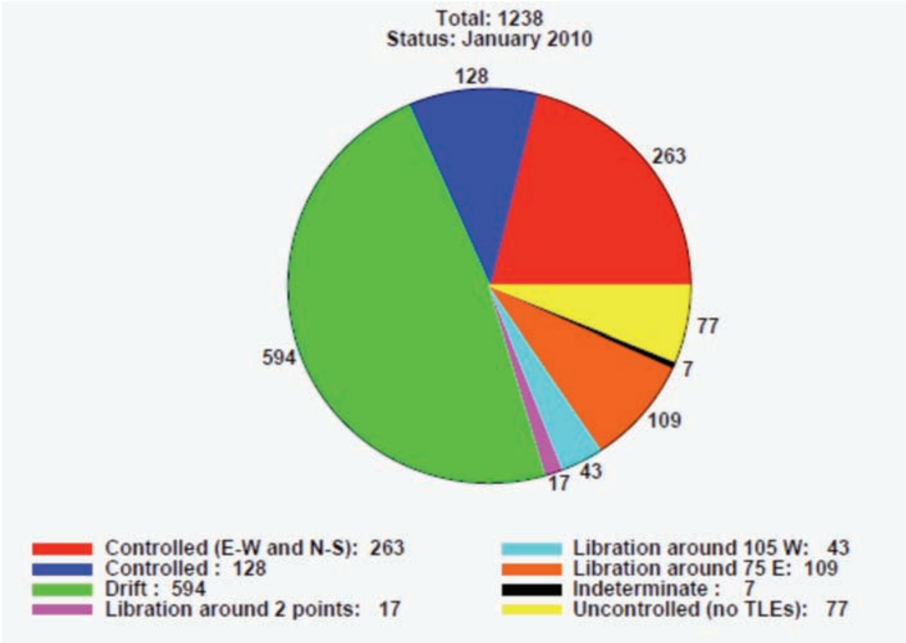


Figure 1.9 shows the current number of detected objects in the GEO belt classified by status. The controlled satellites are those still operational and being actively kept within a certain orbital location. The objects in libration are oscillating around one of two "gravity wells" in the GEO belt, with a small number oscillating between both of the wells. These wells act as gravitational traps in which drifting objects eventually accumulate, presenting a risk to active satellites also located in those regions.

Figure 1.9: Classification of geosynchronous objects[59]



2009 Development

Worldwide awareness of the orbital debris problem and progress on solutions continue

In response to the satellite collision discussed under Trend 1.1, the US House of Representatives Subcommittee on Space and Aeronautics held a hearing on "Keeping the Space Environment Safe for Civil and Commercial Users" on 28 April.[60] Experts from NASA, the US military, industry, academia, and NGOs provided testimony. According to subcommittee Chairwoman Gabrielle Giffords, the general conclusion of the hearing was that the problem is serious and the world needs to take concrete steps to address it.[61]

The US Air Force has drafted a new Space Safety Instruction, AFI-91-217, which outlines the safety and mishap prevention requirements for all existing and future US Air Force space systems.[62] The Air Force Instruction (AFI) outlines specific requirements for launch, on-orbit, and atmospheric reentry operations, as well as system development, testing, and installation. In particular, the AFI outlines requirements for pre-launch and on-orbit collision avoidance screening and end-of-life actions.

The fifth European Conference on Space Debris was held in Darmstadt, Germany in late March and early April.[63] The conference brought together international experts in space debris to present new research. The main finding of the Conference was that debris mitigation – minimizing the creation of new debris from launching of satellites and operations in space – was not enough. The mass of debris that already exists in orbit is now at a critical level and will continue to grow through debris-on-debris collisions, even without additional launches. The active removal of debris from orbit – debris remediation – is necessary.[64]

In May the Institute of Air and Space Law at McGill University hosted an International Interdisciplinary Congress on Space Debris.[65] The goal of the Congress was to examine a spectrum of potential measures to implement the debris mitigation guidelines developed by the IADC and accepted by the UN.[66] These measures could include new legal regimes, economic incentives, national regulations, and voluntary agreements. The proposals from the Montreal meeting will be discussed at a second Congress in Cologne in May 2010, with findings published in 2010.

In December 2009, NASA and the Defense Advanced Research Projects Agency (DARPA) jointly held the first International Conference on Orbital Debris Removal.[67] The conference brought together government, academia, and the private sector to discuss the problem of actively removing space debris from orbit. Various technical solutions were presented, along with discussions on the related economic, legal, and policy challenges. Although some techniques have promise, none have been operationally proven and all have significant non-technical and political challenges that need to be addressed.[68]

2009 Space Security Impact

It is becoming increasingly evident to all space operators that the creation of space debris and other irresponsible behavior in space can have negative implications for all space users, given the indiscriminate nature of the adverse effects. While policymakers are working to implement the existing debris mitigation guidelines, scientists have begun research on the next phase – orbital debris removal – that will be a necessary complement to debris mitigation to ensure continued space security. However, creating voluntary guidelines has proven to be insufficient, as demonstrated by the continued failure of spacecraft operators to comply with end-of-life requirements in the GEO belt. To enhance the positive impact that the implementation of agreed guidelines may have on debris mitigation, the establishment of enforcement mechanisms at either the international or national level is necessary.

Trend 1.3: Growing demand for radio frequency 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 US. 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, inter alia, 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 US policy to reserve the Ultra-High Frequency, X-, and K-bands (240-340 megahertz, 8-12 GHz, and 18-27 GHz, respectively) for the US military.[69]

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.[70] 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.[71] 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 International Telecommunication Union (ITU) Constitution[72] 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."[73] 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"[74] as military demand for bandwidth grows. During the US-led invasion of Afghanistan in 2001, the US military used some 700 megabytes per second of bandwidth, up from about 99 megabytes per second used during the 1991 US operations in Iraq.[75]

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.[76] 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" in Asia.[77] For example, a general manager of engineering at AsiaSat has noted that "frequency coordination is a full-time occupation for about five percent of our staff, and that's about right for most other satellite companies."[78] An official at New Skies Satellites noted, however, that while interference is common, "satellite operators monitor their systems around the clock and can pinpoint interference and its source fairly easily in most cases."[79]

The simplest way to reduce such interference is to ensure that all actors have access to reasonable and sufficient bandwidth. To this end the US Department of Defense is releasing a portion of the military-reserved spectrum from 1.710-1.755 gigahertz to the commercial sector for third-generation wireless communications.[80] India, however, has the world's fastest growing telecoms market, and there is an ongoing struggle between the commercial sector and the Indian Department of Defence over spectrum use.[81]

Bilateral efforts are also under way to harmonize radio frequency utilization. In 2004 the US and EU agreed to major principles over frequency allocation and interoperability between the US GPS and the EU Galileo navigational system;[82] 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 US military signal.[83] But added conflict has arisen from China's announcement that it too will build a global satellite navigation system; it has filed with the ITU to transmit on signals that would overlay both Galileo and the US M code.[84] Chinese sources indicate that it is willing to cooperate with the other systems, but there is no sign of efforts to reach an agreement.[85]

Orbital slots

Today's satellites operate mainly in three basic orbital regions: LEO, MEO, and GEO (see Figure 1.1). There are approximately 860 operational spacecraft, approximately 36 percent of which are in LEO, six percent in MEO, 48 percent in GEO, and about 10 percent in either Highly Elliptical Orbit (HEO) or planetary trajectories.[86] 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 US lies between 60 and 135 degrees west longitude because satellites in this area can serve the entire continental US;[87] 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.[88] 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.[89] Thus, only a limited number of satellites can occupy the prime equator (0 degree inclination) orbital path. In the equatorial arc around the continental US, 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.[90] 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."[91] 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. A fee schedule implemented in January 2006 links charges to the complexity and size of a filing. While most incur a flat fee of $500, they can reach almost $60,000 for complex requests requiring extensive coordination.[92] 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.[93]

Originally, crowding in the MEO region was not a concern, as the only major users were the US 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.

2009 Development

Reports of radio frequency interference continue

Iran claimed that its first successful satellite launch in January 2009 was delayed for several hours due to radio frequency or electromagnetic interference from various military unmanned aerial vehicles (UAVs) that were being used by other states to collect intelligence on the launch.[94] Iranian President Ahmadinejad told reporters that the jamming was intentional and forced the Iranians to use the backup communications system for the launch. There has not been any independent confirmation of these claims.

In December, it was reported by broadcasters in the United States and Britain that the Iranian government has been jamming commercial satellite transmissions directed at Iran.[95] The interference appears to be mainly targeted at the constellation of Hot Bird satellites operated by Eutelsat and analysts say Iran is the apparent source of the jamming. Iran has accused the US and the UK of interfering in its internal affairs through the broadcasts of BBC Persian and Voice of America by those satellites into Iran.[96]

2009 Development

Satellite operators form entity to help prevent and resolve radio frequency interference

A group of commercial GEO satellite operators announced in late November that they were forming the Space Data Association (SDA), a not-for-profit organization incorporated in the Isle of Man.[97] The SDA, founded by Inmarsat, Intelsat and SES, would allow participating satellite operators to share data regarding their satellites to increase safety and efficiency, including data to help avoid and resolve radio frequency interference issues.[98]

2009 Space Security Impact

The scarcity of both orbital slots and radio frequencies continues to be a problem for continued use of space, with no real solution on the horizon. In fact, the demands of emerging spacefaring states are not only further stressing an already congested environment, but are calling into question the inherent fairness of an allocation system that has operated on a first-come, first-served basis. The technical ease with which both intentional and unintentional frequency interference can occur will be a significant space security concern for the foreseeable future.

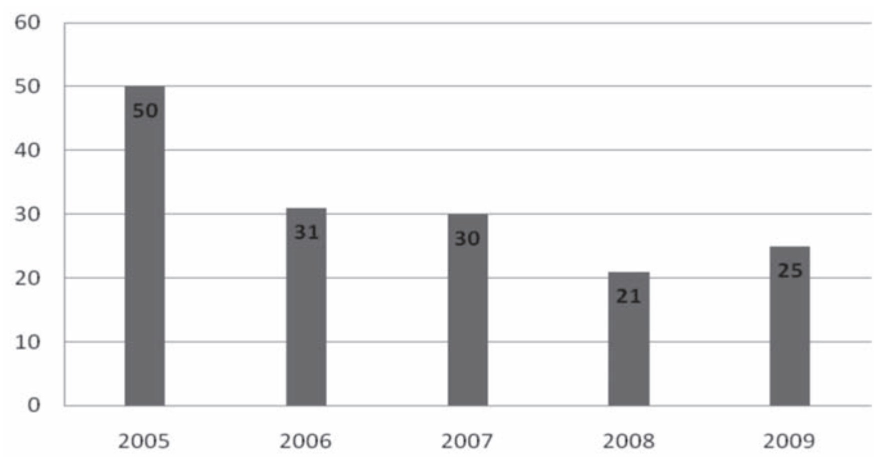
Trend 1.4: Increased recognition of the threat from NEO collisions and progress toward possible solutions

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's 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).[99]

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 percent of these objects by 2008. Of the estimated 1,100 objects in this class, NASA tracks approximately 80 percent.[100] 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.[101] 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 percent of the risk the Earth faces from NEO collisions.[102]

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 percent are estimated to pose some sort of threat of impact.[103] Although objects of that size cause much less damage, they impact the Earth at a much higher frequency the kilometer-sized objects.

Figure 1.10: Number of large NEAs discovered by year, 2005-2009[104]



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 January 2010, there are approximately 6,700 known NEOs, 1,138 of which are currently known PHAs.[105] 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 discussion of governance issues for NEO detection and mitigation.

2009 Development

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

The European Space Agency announced that one of the three pillars of its new Space Situational Awareness Program will be detection and tracking of NEOs.[106] The SSA-NEO segment will also provide information on the likelihood of impact and a risk assessment. It is uncertain how this will affect cooperation and Space Situational Awareness (SSA) data-sharing with the United States, which does not include NEOs as an element in SSA activities carried out by its military, even though NASA does have a Near Earth Object program.

In February, the issue of NEOs was again discussed at the annual meeting of the Scientific and Technical Subcommittee of UN COPUOS. The Working Group on Near Earth Objects continued to meet under its three-year work plan to develop international procedures for handling the NEO threat.[107] It endorsed the 2008 report by the Association of Space Explorers as a basis for continuing its work.

In April of 2009 the University of Nebraska-Lincoln Space Law Program held a conference on the legal aspects of NEOs.[108] International lawyers and experts discussed the legal aspects of deflecting NEOs, liability concerns, and the legal aspects of exploring and exploiting NEOs for resources.

Also in April, the first International Academy of Astronautics (IAA) Planetary Defense Conference was held in Grenada, Spain. Similar conferences had been previously held in 2004 and 2007, but under the sponsorship the American Institute for Aeronautics and Astronautics (AIAA). The IAA conference included new research on the detection, tracking, and characterization of the NEO population, potential techniques for deflecting and impacting asteroids, and modeling of impact effects.

One of the main findings of the conference was that newer search telescopes, such as Pan-STARRS and LSST, needed to be fully funded and brought online to meet the goals assigned to NASA by Congress for detecting potentially hazardous NEOs. The original NASA Spaceguard survey, established in 1995, planned to detect 90% of those objects greater than one kilometer in diameter. In 2005 and 2008, Congress mandated NASA to extend this survey to include 90% of objects larger than 140 meters in diameter. However, a report issued by the National Research Council in 2009 found that neither NASA nor Congress had allocated funds to meet this goal.

Both of these projects are designed to create so-called “survey” telescopes, which can scan large portions of the sky in very short periods. To this end, continued funding for unique and critical radars such as Arecibo in Puerto Rico and Goldstone in Massachusetts must be secured. Additionally, a space mission is required to demonstrate the feasibility of one or more potential deflection techniques.

2009 Space Security Impact

The difficulties inherent in an international response to a NEO impact threat are similar to many other space governance, cooperation, and data-sharing challenges. While the threat posed by a potential NEO collision may be detrimental to the overall security of outer space, cooperative multilateral efforts to address this challenge will likely yield positive results for space security. For instance, the progress being made in collaborative NEO detection, warning, and decision-making could encourage cooperation on Space Situational Awareness (SSA) data-sharing and enhanced space security.

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 military applications of space situational awareness (SSA) capabilities for the protection and potential negation of satellites, and the growing international efforts made to improve the predictability of space operations through data sharing.

A subset of 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 US-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 some limited degree of information exchange.

Driven by Cold War security concerns, the US 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 near Earth object (NEO) detection, but 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 US Space Surveillance Network (SSN) is the primary provider of space surveillance data. Although the US 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. China is planning upgrades to its Xi'an Satellite Monitoring Center, the primary control center for China's network of 20 ground monitoring stations and six satellite tracking ships.[4] These upgrades include increased orbit determination and capabilities to track domestic and foreign satellites, which could be used to target negation activities against space-based assets.[5] The satellite intercepted by China on 11 January 2007 was tracked and targeted from this center.[6] Canada, France, Germany, Japan, and the UK are all actively expanding their ground- and space-based space surveillance capabilities, as discussed below.

Space-based surveillance, first demonstrated by the US with the Space Visible Sensor experiment that was decommissioned in 2008,[7] is being pursued through the Space-Based Surveillance System (SBSS), 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."[8] The $823.9-million program is designed to collect real-time data and track satellites that are orbiting from Low Earth Orbit (LEO) to a higher position,[9] 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."[10] SBSS will be able to track every satellite in Geostationary Orbit (GEO) at least once every 24 hours using its two-axis, gimbaled visible light sensors.[11] The launch of the first SBSS satellite – which has been rescheduled several times, most recently on 8 July 2010 – has been indefinitely delayed due to problems with the Minotaur IV launch rocket.[12] The Canadian military's Sapphire satellite, scheduled to launch in 2011, is also intended to contribute space-based surveillance data to the US SSN.[13]

Space Security Impact

Improved space situational awareness 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 overall 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 US. 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.

To be sure, sharing SSA data could benefit all space actors as it would allow them to supplement the data collected by national assets for little to 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 US moderates access to information from its SSN.[14] Technical and policy challenges also put constraints on data sharing, although efforts among select actors are under way to overcome these challenges.

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 could also 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 be conducive to maintaining stability in space by preventing grave misunderstandings and false accusations of hostile actions.

Trend 2.1: US space situational awareness capabilities slowly improving

The US 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 US. It provides the greatest number of observations of any sensor in the network and is capable of making 5 million detections each month of objects larger than a basketball to an altitude of 10,000 km.[15] A new Space Fence, currently under development, is expected to cost more than $1-billion to design and procure. [16] The system, with a target completion date of 2015, will likely include a series of S-band radars in at least three separate locations.[17] 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:[18]

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 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 approximately 15,000 objects. A low accuracy version of this catalog is publicly available at the Space Track website,[19] but the data is not sufficiently precise to adequately support collision avoidance. The US Air Force uses a private high accuracy catalog for a number of data products.

Operators outside the US 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. More than 25,000 users have registered through CFE and efforts are currently under way to transform it into a formal system. But while some operators would like direct access to orbital data, there is some reluctance to release it widely.[20] For instance, regulations for the CFE program restrict the sharing of surveillance information to a non-US government entity only to agreements in which "providing such data analysis to that entity is in the national security interest of the United States."[21]

Since the 2009 Cosmos-Iridium satellite collision there has been increased impetus in the US to boost conjunction analysis – the ability to accurately predict high-speed collisions between two orbiting objects. Gen. Robert Kehler, commander of Air Force Space Command, has expressed his desire to provide collision data on as many satellites as possible to prevent the further creation of hazardous space debris.[22] However, this will necessitate certain changes in the way space objects are monitored by the US Department of Defense.

At the time of the Iridium collision, there were approximately 140 spacecraft being monitored for potential collisions, and the Joint Space Operations Center (JSpOC) had five operators supporting a single position for conjunction prediction.[23] To conduct more effective collision avoidance, more personnel and computing equipment are needed. According to Lt. Gen. Larry James, 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.[24]

2009 Development

Continued US focus on improving space situational awareness capabilities begins to overcome bureaucratic inertia and produce results

In June 2009 the US Air Force awarded three $30-million contracts to Lockheed Martin, Raytheon, and Northrop Grumman to begin concept development of an S-Band Space Fence.[25] The S-Band Fence is projected to add significant capability to the Space Surveillance Network, including more global coverage of LEO and MEO objects and the potential ability to track objects as small as a few centimeters in diameter.

It is projected that the S-Band Fence will consist of three geographically distributed sites, each with a receiver-transmitter pair.[26] The concept development phase is projected to take 18 months, after which two concepts will be awarded contracts to continue to the next phase. The winning contractor is expected to have Initial Operating Capability (IOC) of the first S-Band fence site no later than 2015.[27]

The US Air Force also put in a request for $44.5-million in additional funds for FY2010 for SSA programs.[28] Almost half of the funds will be spent on service life extension programs (SLEP) for two existing SSA systems – the Ground-based Electro Optical Deep Space Surveillance (GEODSS) system and the GLOBUS II tracking and imaging radar. The additional funding request also includes funds to transition the Space Surveillance Telescope (SST) program from a DARPA demonstration program to an operational USAF program, and funds to support development of the Space Situational Awareness Environmental Monitoring (SSAEM) program.[29] SSAEM seeks to add space-based sensors to provide data on the space environment.

Gary Payton, the Deputy Undersecretary for Space Programs, stated in an interview that the USAF budget request for SSA would expand in FY2011 and beyond. He added that, although in raw numbers it was still relatively small, it would experience a high percentage of growth.[30] Further, he indicated that the FY2010 request would include $177-million in SSA-related research and development for the first operational Space Based Space Surveillance (SBSS) satellite.

The launch of the US Air Force's first pathfinder SBSS satellite was delayed again due to problems with the Minotaur IV booster.[31] Originally delayed from April to October, at the end of 2009 it was tentatively scheduled for the spring of 2010. The SBSS satellite would track satellites and debris from its low Earth orbit, a function that was historically performed by the now defunct SBX/MSX satellite.

In September, the Missile Defense Agency successfully launched two satellites as part of the Space Tracking and Surveillance System (STSS) Demo.[32] The satellites were placed in LEO and are equipped with both infrared and visible sensors that can track a missile launch through all phases of flight. Although their primary mission is to support missile defense, these satellites could also be of significant use for SSA, though no official announcement has been made about this possibility.

At the Strategic Space Symposium, held in November in Omaha, Nebraska, the Commander of US Strategic Command, General Kevin Chilton, said that future missile warning sensors should be built with SSA requirements in mind. Although not exactly the same, missile warning and tracking shares many requirements with SSA, so designing sensors to do both missions could be cost-effective. Additionally, General Chilton said that the Air Force should study how MDA was able to develop and field new sensors so quickly and apply those lessons to new SSA sensors.

2009 Space Security Impact

In previous years there had been little real progress in enhancing US SSA capabilities, despite the gradual transition of SSA from a relatively low priority budget line into a vital tool for the tracking and protection of space assets. Prompted by the abovementioned satellite collision, in 2009 the US made the first real moves beyond rhetoric to spending political and monetary capital on this issue, a telling sign of the growing importance of SSA in overall US space operations. This is a major positive step for space security, and could become even more beneficial insofar as the US and other space actors embrace a more cooperative and collaborative approach to SSA.

Trend 2.2: Global space situational awareness capabilities slowly improving

Russia is the only other state with a dedicated space surveillance system called the Space Surveillance System (SSS), which uses mainly early warning radars and more than 20 optical and electro-optical facilities at 14 locations on Earth.[33] The main optical observation system, Okno (meaning “window”), located in the mountains near the Tajik city of Nurek, is used to track objects from 2,000 to 40,000 km in altitude.[34] 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.[35] 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.[36] While information from the system is not classified, Russia does not have a formal process to widely disseminate space surveillance information.[37]

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 US does not publish orbital information.[38] France has cited the necessity of developing this system to decrease reliance on US surveillance information and to ensure the availability of data in the event of a data distribution blackout.[39] 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.[40] Also, the British National Space Centre (BNSC) is developing a new space surveillance system to map large areas of the sky quickly and has existing optical telescope capabilities.[41]

The European Space Agency maintains information in its own Database and Information System Characterising Objects in Space (DISCOS), which also takes inputs from the US public catalog, Germany’s Tracking and Imaging Radar (TIRA) system located at the Research Establishment for Applied Science (FGAN) 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 1000 km range- has a 34-meter dish antenna operating in L-band for debris detection and tracking.[42] As of 2009, 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.[43] 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 in that orbit.[44] According to ESA, during GEO observation campaigns with the Space Debris Telescope, approximately 75 percent of detections are objects *not* contained in the US space surveillance catalog.”[45] Other optical sensors in Europe, including three Passive Imaging Metric Sensor Telescopes operated by the UK 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.[46] The ESA has defined space surveillance as one of three main security priorities.[47]

Figure 2.1: Space surveillance capabilities[48]

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*	■						

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

Since joining the Inter-Agency Space Debris Coordination Committee (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.[49] Space surveillance is an area of growth for China, which announced new investments in optical telescopes for debris monitoring in 2003. Prior to the launch of the Shenzhou V in 2003, it was revealed that the spacecraft had a debris "alarm system" to warn of potential collisions.[50] 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.[51] 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.[52] 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 information 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 to support manned space missions. 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.[53] 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[54] – are dedicated to space debris surveillance in GEO.

Canada's Microvariability and Oscillations of Stars (MOST) microsatellite hosts a space telescope and was a technology demonstrator for space surveillance efforts.[55] As well, Canada's planned Near Earth Object Surveillance Satellite (NEOSsat) asteroid discovery and debris tracking mission, being developed by Defence Research and Development Canada and the Canadian Space Agency[56] and scheduled for launch in 2011,[57] is expected to provide observations for the US SSN.

2009 Development

International SSA capabilities slowly increase

In February a media story on leading members of the amateur satellite-tracking community revealed more details about their capabilities. Using a combination of binoculars, stopwatches, and backyard telescopes, the core group of about 20 international observers have collected more than 21,000 observations on more than 1,400 objects in space.[58] About 18,000 of those observations are on approximately 200 classified objects for which states do not release information. The amateur observer community was the first to publicly reveal the impending reentry of USA 193, the failed US satellite that was destroyed in February 2008, as well as the failure of DSP Flight 23, which is adrift in the heavily populated GEO belt.[59] The orbital locations of DSP Flight 23, the Delta 4 Heavy rocket body that placed it in orbit, and 30 pieces of debris are still being withheld from the US military's public satellite catalog.[60]

In 2009 Germany inaugurated the German Space Situational Awareness Center (GSSAC) in Uedem, which has a mission to coordinate the efforts to protect German satellites from on-orbit collisions.[61] Included are the five satellites in the SAR-Lupe radar imaging constellation, which in 2009 faced more than 800 conjunctions, based on data from the American JSpOC. Thirty-two of these were closer than one kilometer, and one required a collision-avoidance maneuver. German officials indicated that the GSSAC would rely heavily on American SSA data until the new European program can get under way, but that data from the GSSAC would be made available to international bodies.[62]

In September 2009 the United States and Russia announced a renewed effort to establish a Joint Data Exchange Center (JDEC) to share information on space and missile launches.[63] The announcement also included establishment of a Pre-Launch Notification System (PLNS). The original JDEC agreements were signed in 2000 and designed to promote confidence between the US and Russia over space and missile launches. However, the effort has stalled over the last decade due to funding issues and political and diplomatic foot-dragging.

During his speech at the Strategic Space Symposium, Brigadier General Yves Arnaud from the French Air Force said that a French-US Space Cooperation Forum was held in November of 2009, and that SSA and data sharing was a priority on the agenda. At the same event, Air Commodore David Steele from the Royal Australian Air Force stated that the US and Australia were exploring a SSA data-sharing partnership, which might include basing future US sensors in Australia, to provide much needed Southern Hemisphere coverage.

Europe is making progress on various aspects of both national and European SSA. In January, the Joint Air Power Competence Center (JAPCC), 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.[64] 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.[65] Germany is also planning to set up an operational SSA center near its national airspace control facility in 2010.[66]

2009 Development

Increased calls for SSA data to support commercial and civil activities

In response to the February satellite collision (see Chapter 1 for details), the US 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.[67] As part of this development, it would expand the number of outside partners and "push" them information about potential collisions. The US military also announced that it was transferring oversight of its CFE program from Air Force Space Command to US Strategic Command and making changes to CFE policy,[68] including a name change to the Space Situational Awareness Data Sharing Program. Head of Air Force Space Command, General Robert Kehler, announced that this transfer was complete on 22 December 2009.[69]

In its final report for 2009, the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS) noted that several member states acknowledged the importance of having a means of distributing space situational awareness information to support the safe and sustainable use of space.[70]

The US military indicated that it will provide more data and services under its SSA Data Sharing Program (formerly known as CFE). In March, it was reported that the US military also planned to widen access to its high accuracy catalog data.[71] For several years the US military has provided public access to low accuracy data through a website, www.Space-Track.org, but did not publicly offer high accuracy data, which is necessary to detect possible collisions and perform avoidance maneuvers.[72] The US military has not elaborated on how, when, or to whom it plans to distribute the more accurate data.

In the spring of 2009 the US military held the 5th Schriever Wargame and for the first time invited non-US government personnel to participate in a substantial way.[73] This event uses future scenarios to examine space operations, capabilities, policy, and strategy in response to potential threats. Schriever V saw significant participation by military personnel from Canada, the United Kingdom, and Australia, as well as representatives of commercial satellite operators and industry.

The primary conclusion from the war game was that decisions regarding the assessment of space attacks and protection of satellites cannot be made by the US military alone.[74] During the war game, a sub-group developed a notional Cooperative Security Space Defense Agreement (CSSDA) to provide a framework for cooperation and a Combined Space Operations Center (CSpOC) to collate and distribute data among all the coalition partners.[75]

Three major commercial satellite operators – Intelsat, SES, and Inmarsat – announced in November that they had created the Space Data Association (SDA).[76] The not-for-profit entity was established in the Isle of Man to serve as a central hub for sharing data between participants. The SDA issued a Request for Proposal to solicit bids for a contract to provide the infrastructure and data-sharing services. Several other commercial satellite operators have indicated support for the SDA and may join it at a later date.[77] The SDA will mainly deal with sharing data on the positions of participation members' satellites and information to help prevent electromagnetic interference.

2009 Space Security Impact

The traditional users and providers of SSA data – militaries and intelligence agencies – are still reluctant to provide the services and information that commercial and civil space users need to operate safely, not only because of the sensitive nature of the information on space assets, but for cultural and bureaucratic reasons. This longstanding practice of secrecy may adversely affect space security since precise information about the position and trajectory of space assets is fundamental in preventing accidental collisions and other harmful interference. The tide seems to be shifting, however, as these traditional users begin to realize the value gained from increased transparency. Both commercial and civil users are applying increased pressure for data sharing and are making strides in finding solutions of their own.

Trend 2.3: Use of SSA capabilities for protection and potential negation of satellites continues to increase

Most satellite operators have a basic capability to detect a ground-based electronic attack on their space systems, such as jamming, by sensing the interference signal of the attacker or detecting the loss of communications with the system under attack. Many satellite operators also have the capability to use multiple sensors to geo-locate the source of jamming signals, which helps to determine if the interference is intentional. It is also reasonable to assume that all satellite operators have at least some capability to detect spoofing (feeding a false signal), since basic electronic error code checking routines are relatively simple to implement. However, early warning and precise attribution of such attacks remains a challenge.

Directed energy attacks such as laser dazzling or blinding and microwave attacks move at the speed of light, so advance warning is very difficult to obtain. These attacks can be detected either by the loss of a data stream from optical or microwave instrumentation or by thermal sensors. Onboard satellite-specific laser sensors can detect either the key laser frequencies or radiant power. Such capabilities could trigger a variety of reactive passive protection measures, such as automated mechanical shutters or the release of smoke to block the laser, which might prevent damage, depending on the sophistication of the attacker.[78]

During the Cold War the US and USSR developed significant space-based early warning systems which use infrared satellites to detect ballistic missile and space rocket launches. The USSR launched its first space-based early warning US-KS or Oko satellite in 1972 and had fully deployed the system by 1982.[79] The Oko system uses satellites in highly elliptical orbits (HEO) with infrared sensors to provide coverage of US intercontinental ballistic missile fields about 18 hours a day. Reportedly, the system can detect massive attacks but not individual missile launches.[80] In July 2009 three more military satellites, believed to be additions to the Oko system, were launched and successfully placed in orbit.[81] The Oko system is complemented by two additional early-warning satellites in GEO, which are believed to be next-generation US-KMO satellites capable of detecting missiles against the background of the Earth.[82] The complete US-KMO system would consist of up to seven GEO satellites to provide global coverage. A new Integrated Space System, initially planned to become operational in 2010, appears to be delayed.[83]

Russia's space-based early warning capabilities are complemented by land-based radar stations, including a new Voronezh meter-band early warning radar near Lekhtusi in the Leningrad Region, which was put online in 2006, closing a seven-year coverage gap in its northwestern region.[84] However, Russia intends to stop using five of these stations, which are located outside of Russian territory in Azerbaijan, Belarus, Kazakhstan, and Ukraine.[85]

Figure 2.2: Russia's Early Warning System Land-Based Radars[86]

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

The US military launched its first space-based early warning satellite, the US Defense Support Program (DSP), in 1970 and since then the system has provided the US with the capability to detect missile/rocket launches worldwide. By 2002 the DSP system had increased from four to seven GEO satellites, enhancing reliability by allowing certain areas to have additional satellite coverage.[87] The intended replacement for DSP is the US Air Force's next-generation Space Based Infrared System (SBIRS). The original SBIRS plan was for three constellations of satellites in GEO, HEO, and LEO. The current plan calls for four satellites in GEO to provide global coverage plus additional sensors in HEO.[88] While two of the hosted SBIRS payloads are now in HEO orbit on classified satellites,[89] the dedicated geosynchronous satellites are more than eight years behind schedule and the SBIRS program has exceeded its original $3.5-billion budget by nearly $8-billion.[90] Additional funding of $143-million was recently approved by the US Senate for a 2010 follow-on program called the Third Generation Infrared Surveillance system.[91]

The second layer of US next-generation space-based ballistic missile detection and tracking is the Space Tracking and Surveillance System (STSS) developed by the US Missile Defense Agency. Originally known as SBIRS Low, STSS is intended to track missiles through space, differentiate missile warheads from decoys and debris, and provide targeting data for a missile defense interceptor using a system of 20–30 sensor satellites in LEO. The program has been restructured and renamed several times since 2001 and has experienced significant cost growth.[92] The system, made up of two long-delayed satellites designed to track missiles through all stages of flight,[93] was launched in September 2009.[94]

While only the US and Russia currently have space-based early warning capability, France has been developing its own infrared satellite warning system called SPIRALE. The first two SPIRALE satellites, part of a demonstration mission, were launched in February 2009.[95]

2009 Development

Inability to attribute satellite failures sparks concerns of potential development of dual-use technology

In January 2009 the Pentagon confirmed that it had used the two MiTEx micro-satellites to inspect Defense Support Program (DSP) Flight 23 at the end of 2008.[96] Launched in November of 2007, DSP Flight 23, the newest GEO infrared missile warning satellite in the DSP constellation, failed in late 2008.[97] The inability to determine whether the cause of the failure was due to environmental factors, a manufacturing flaw, or potentially hostile action caused the US military significant concern.

The MiTEx satellites were launched in 2006 as part of a DARPA experiment to test new technologies, including orbital rendezvous and inspection. The fact that the US military refused to publicly release their orbital locations raised concerns about other possible missions in the GEO belt, although there is no evidence to support these suspicions.[98]

2009 Development

States continue to remove positional data on military and intelligence satellites from public databases

In December, soon after US Strategic Command took over control of the CFE program, the US military stopped publishing positional data on several French military satellites on its Space Track website.[99] The satellites include the four Essaim electronic intelligence satellites and the five functional Helios GEO communications satellites. The positions of the nonfunctional Helios 1B and Parasol imagery satellites are still being updated.

These French satellites join the two Japanese Information Gathering Satellites (IGS) as the only international satellites whose positions are not included in the US military's public satellite catalog. In 2007 a French military officer gave a media interview in which he indicated that France was collecting positional data on classified US military satellites with its GRAVES radar and that France would agree to not publish that data if the US agreed to stop publishing data on sensitive French satellites.[100]

2009 Space Security Impact

While increased availability of SSA information provides safety benefits, it also can be used for negation purposes and hostile activities. This concern has led an increasing number of states to try to restrict information on the location of their sensitive military and intelligence satellites. Given that anyone with a telescope and basic technical knowledge can observe these satellites, it is unclear just how effective the artificial restriction of such information will be. Still, limiting the information available for operators may have a negative impact on space security as it could increase the chances of collisions.

CHAPTER THREE

Space Laws, Policies, and Doctrines

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

International space law has gradually expanded to include, inter alia, the 1967 Outer Space Treaty, 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 UN 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 work on the Prevention of an Arms Race in Outer Space (PAROS). Matters related to the allocation of space resources such as orbital slots and radiofrequencies by the International Telecommunication Union (ITU) are addressed in Chapter 1.

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 actors' ability to access and use space in a safe and sustainable manner, 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. It is there that member states can discuss, for instance, solutions to potential disagreements over the allocation of scarce space resources in a peaceful manner, 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. Some spacefaring nations' policies place a great emphasis on 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 designed to 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 legal 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 OST represents the primary basis for legal order in the space environment, establishing outer space as a domain to be used by all humankind for peaceful purposes (see Figure 3.1). However important this treaty may be for international space law, the fact that it is more than four decades old underscores the need for an updated security 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]

Figure 3.1: Key provisions of the Outer Space Treaty[4]

Article	Key provisions
Preamble	Mankind has an interest in maintaining the exploration of space for peaceful purposes.
Article I	Outer space, including the Moon and other celestial bodies, is "the province of all mankind" and "shall be free for the exploration and use by all states without discrimination of any kind, on a basis of equality."
Article II	Outer space, including the Moon and other celestial bodies, is not subject to national appropriation by claim of sovereignty, use, occupation, or any other means.
Article III	The UN Charter and general principles of terrestrial international law are applicable to outer space.
Article IV	It is prohibited to place in outer space objects carrying nuclear weapons or any other kinds of weapons of mass destruction. The Moon and other celestial bodies are to be used exclusively for peaceful purposes. Military fortifications and the testing of any other kind of weapons on the Moon are prohibited. However, the use of military personnel and hardware are permitted, but for scientific purposes only.
Article VI	States are internationally responsible for national activities in outer space, including activities carried on by nongovernmental entities.
Article VII	States Parties that launch, procure a launch, or from whose territory an object is launched are internationally liable for damage to another State Party
Article IX	In the exploration and use of outer space, States shall be guided by the principles of cooperation and mutual assistance and shall conduct all their activities in outer space with due regard to the corresponding interests of all other States. States Parties are to undertake international consultations before proceeding with any activity that would cause potentially harmful interference with the peaceful exploration and use of outer space.
Article XI	States Parties are to inform the UN Secretary-General, the public, and the international scientific community of the nature, conduct, location, and results of outer space activities.

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.[5] However, space assets have been developed extensively to support terrestrial military operations, and the position maintained by the US, that "peaceful" in the context of the OST means "non-aggressive," has generally been supported by state practice.[6] 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.[7] However, others contest this interpretation of the OST.[8] While space actors have stopped short of actually deploying weapons in space or attacking the space assets of another nation from Earth, ground-based anti-satellite weapons (ASATs) have been tested by some states against their own satellites – most recently by China in 2007[9] and the US in 2008.[10]

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 ground-based ASATs and anti-ballistic missile weapons, constitute space weapons.[11]

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."[12] 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.[13] 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 United Nations. The following information must be made available by launching states "as soon as practicable"[14]:

- 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 (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 2010, 51 states have ratified, 4 have signed and two international intergovernmental organizations (European Space Agency and European Organization for the Exploitation of Meteorological Satellites) have declared their acceptance of the rights and obligations provided for in the Registration Convention.[15] The UN also maintains a separate register with information provided by states not party to the Convention (the Resolution Register), based on UNGA Resolution 1721 B of 20 December 1961.[16]

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 a launching state to 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.[17]

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.[18] However, it is not widely ratified due to contentious issues surrounding lunar exploration.[19] 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.

Figure 3.2: Status of major space treaties as of 1 January 2010[20]

Treaty	Date	Total R*	Total S**
Outer Space Treaty	1967	100	26
Rescue Agreement	1968	91	24
Liability Convention	1972	88	23
Registration Convention	1975	53	4
Moon Agreement	1979	13	4

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

UN space principles

In addition to treaties, five UN resolutions known as UN principles have been adopted by the General Assembly for the regulation of special categories of space activities (see Figure 3.3). Though these principles are not legally binding, they establish a code of conduct reflecting the conviction of the international community on these issues.

Figure 3.3: 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)
Voluntary guidelines for the mission planning, design, manufacture, and operational phases of spacecraft and launch vehicle orbital stages to minimize the amount of debris created.

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 them.[21] 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."[22] A summary of the key space provisions of these agreements is provided in Figure 3.4.

Figure 3.4: 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 [23]
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[24]
Hotline Modernization Agreement (1973)*	Sets up direct satellite communication between the US/USSR[25]
Anti-Ballistic Missile Treaty (1972)*†	Prohibition of space-based anti-ballistic missile systems and interference with national technical means of verification[26]
Environmental Modification Convention (1977)	Bans using as weapons modification techniques that have widespread, long-lasting, or severe effects on space[27]
Strategic Arms Limitation Treaty II (1979)*	Acceptance of, and prohibition of interference with, national technical means of verification Prohibits fractional orbital bombardment systems (FOBS)[28]
Launch Notification Agreement (1988)*	Notification and sharing of parameters in advance of any launch of a strategic ballistic missile[29]
Conventional Armed Forces in Europe Treaty (1990)	Acceptance of, and prohibition of interference with, national and multinational technical means of verification[30]
Strategic Arms Reduction Treaty I (1991)*	Acceptance of, and prohibition of interference with, national technical means of verification[31]
Intermediate-Range Nuclear Forces Treaty (1997)	Acceptance of, and prohibition of interference with, national technical means of verification [32]
Memorandum of Understanding establishing a Joint Data Exchange Center (2000)*	Exchange of information obtained from respective early warning systems[33]
Memorandum of Understanding establishing a Pre- and Post-Missile Launch Notification System (2000)*	Exchange of information on missile launches
* Indicates a bilateral treaty between US and USSR/Russia † US withdrew according to the terms of the treaty in 2002	

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.[34] PAROS resolutions have had overwhelming support in the UNGA, demonstrating a widespread desire on the part of the international community to prohibit the deployment and use of weapons in space.[35] Starting in 1995, however, the US and Israel consistently abstained from voting on the resolution, and they cast the first negative votes in 2005.[36] Israel has since reverted to abstaining.

Other laws and regimes

Coordination 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, primarily within the context of the CD. 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 at the CD, the PPWT has failed to garner sufficient support and has, notably, encountered resistance from the US government. In recent years, efforts to clarify or strengthen international law regarding the use of weapons or force in outer space have been informed by a greater sense of urgency, following renewed use of weapons against space objects by China in 2007 and the US in 2008.

In 2005 the UNGA first adopted what has become an annual resolution sponsored by Russia entitled "Transparency and confidence-building in outer space activities," inviting states to inform the UN Secretary-General of transparency and confidence-building measures, and reaffirming that "the prevention of an arms race in outer space would avert a grave danger to international peace and security."[48] The United States 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 anti-satellite weapons (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 meeting, "Space Security 2010: From Foundations to Negotiations," was held in Geneva with the support of the Secure World Foundation and the governments of Russia and China.

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, is expected to be open for signatures in the latter half of 2010.

2009 Development

US Space Policy Undergoes Review Process

In May 2009 newly elected United States President Barack Obama issued Presidential Study Directive-3 (PSD-3), which orders a comprehensive review of the National Space Policy introduced by former President George W. Bush in 2006.[53] PSD-3 covers a wide range of issues, including space protection, international cooperation, and acquisition reform, and takes a 'whole-of-government' approach that combines the efforts of the White House Office of Science and Technology Policy; NASA; the US Commerce, Defense, Homeland Security, Interior, State, Treasury, and Transportation departments; and US intelligence agencies.[54]

PSD-3 is expected to lead to deliberations in the executive branch that will produce a new national space policy by mid-2011. There are indications that the White House may depart from the unilateral agenda pursued under the preceding administration and chart a course that emphasizes international cooperation.[55] Garold Larson, the alternate representative for the United States to the UN First Committee on Disarmament and International Security, said in a statement to the 64th General Assembly on 19 October 2009 that "bilateral transparency and confidence-building measures with Russia and with China could form the foundation for establishing a set of multilateral voluntary Transparency and Confidence-Building Measures" (TCBMs).[56] TCBMs, he said, can build trust and help diminish uncertainty over intentions and the possibility of misinterpretation or miscalculation. Larson also indicated that the US will seek to discuss the outcomes of the US space policy review at the 2010 Conference on Disarmament as part of a consensus program of work during PAROS discussions. He also emphasized that PSD-3 "includes a 'blank slate' analysis of the feasibility and desirability of options for effectively verifiable arms control measures that enhance the national security interests of the United States and its allies."[57] This could represent a break with the longstanding US position that any regime for preventing the weaponization of outer space cannot be verified and therefore should not be pursued.[58]

It is also reported that the overall review will be informed by the results from another national security space policy review, the Defense Department's Space Posture Review (SPR), which was initiated by the Duncan Hunter National Defense Authorization Act for FY2009.[59] The purpose of the SPR is to establish the definition, policy, requirements, and objectives for numerous topics, including "space situational awareness; space control; space superiority, including defensive and offensive counterspace and protection; force enhancement and application; space-based ISR; integration of space and ground control systems, and other matters deemed [by Department of Defense (DOD)] 'relevant to understanding the space posture of the United States.'"[60] DOD sources expect that the release of the SPR could be delayed up to a year, until late 2010.[61] However, there is speculation that when it is released, the SPR will favor scrapping current plans to build five more GPS satellites and instead focus on working with the European Space Agency on sharing its proposed Galileo global navigation satellite system – an idea that appears to have support from Air Force Chief of Staff Gen. Norton Schwartz.[62]

The national space policy review also coincides with and is expected to incorporate elements from the blue ribbon panel on human space flight, known as the Review of U.S. Human Space Flight Plans Committee.[63] The Committee was established by the Obama White House on 7 May 2009; its task is "to examine ongoing and planned … NASA development activities, as well as potential alternatives, and present options for advancing a safe, innovative, affordable, and sustainable human space flight program in the years following Space Shuttle retirement."[64] The committee's major finding was that the US human spaceflight program is on an unsustainable trajectory because the growing scope of the program is outstripping the government's ability to adequately fund it.[65] In its final report, the Committee suggests two possible solutions to the problem of limited resources:

1. As the civilian spaceflight program moves from complex reusable shuttles to smaller, simpler capsules, transporting astronauts to low-Earth orbit could be turned over to the commercial sector.[66] If this option is chosen, the government should create a competitive bidding process.
2. Levels of international cooperation between the US and other national space programs could be increased.

It noted that space exploration has become a global enterprise and advised that the US could cooperate with other space agencies to reduce its budgetary burden as well as to improve diplomatic relations with other spacefaring states. In particular, the Committee took favorable notice of the management structure for the International Space Station and suggested that it could serve as the basis for the next significant space exploration program.

The final report singles out China as offering “significant potential in a space partnership.”[67] The potential for US-Chinese cooperation in space exploration began to receive serious consideration in 2009. In an interview on 8 April, newly minted presidential science advisor and chief of the White House Office of Science and Technology, John Holdren, expressed his belief that the US could develop human spaceflight partnerships with Russia and China, depending on how the relationship between the two states develops. He stated, “I think it’s possible in principle to develop the required degree of confidence in the Chinese. I put it out there only as speculation, but I don’t think it should be ruled out.”[68] Then on 17 November, President Obama and Chinese President Hu Jintao signed a joint statement during Obama’s state visit to Beijing that, among other things, calls for the heads of the US and Chinese civil space agencies to exchange visits in 2010 to discuss potential cooperation in space exploration, including human spaceflight.[69]

2009 Development

New US administration hints at support for banning certain types of space weapons

Shortly after President Obama’s inauguration, the official website of the White House was updated to reflect a pledge by the new administration to seek a global ban on weapons that interfere with military and commercial satellites, under the heading “ensure freedom of space.”[70] The website also stated that the White House would study “threats to U.S. satellites, contingency plans to keep information flowing from them, and what steps are needed to protect spacecraft against attack.”[71] However, some commentators observed that the language used on the website was vague and that the pledge to ban space weapons does not resolve the problem of defining a space weapon.[72]

The pledge generated some optimism among ambassadors to the CD, with Canada’s Marius Grinius stating that “this advance signal should bode well for our current discussions of space security within the Conference on Disarmament.”[73] However, the website has since been modified and this pledge removed. Under the heading “Rebalance Defense Capabilities for the 21st Century,” the White House webpage on Defense Policy asserts (as of the end of 2009) that “to maintain [the US] technological edge and protect assets in this domain, we will continue to invest in next-generation capabilities such as operationally responsive space and global positioning systems. We will cooperate with our allies and the private sector to identify and protect against intentional and unintentional threats to U.S. and allied space capabilities.”[74]

2009 Development

China and Russia reiterate the need for multilateral measures to prevent the weaponization of space

On 7 March 2009, Russian Minister of Foreign Affairs H.E. Sergey Lavrov spoke before the CD, where he emphasized the need to prevent the deployment of weapons in outer space and called on world powers to combine their efforts to counter missile threats from common enemies.[75] This proposal reflected Moscow’s firm and continuing opposition to US plans to situate components of its anti-missile shield in states that border Russia.[76] Lavrov further stated that it would be easier to prevent the weaponization of space than to eliminate stockpiles of weapons already deployed in space, and added that all states using space for peaceful purposes share an interest in creating a predictable strategic situation that preserves the integrity of their space assets.[77]

In discussing the CD's draft program of work, Valery Loschinin, the Russian ambassador to the CD, said on 26 May 2009 that Russia's top priority was the prevention of an arms race in outer space.[78] He also pushed for a draft program that more clearly defined the process of negotiating a comprehensive treaty based on the Russia-China draft Treaty on the Prevention of the Placement of Weapons in Outer Space or the Threat or Use of Force against Outer Space Objects (PPWT), which was introduced to the CD on 12 February 2008.

China's Foreign Minister Yang Jiechi addressed the Conference on Disarmament on 12 August 2009 and also called for international diplomacy to prevent an arms race in outer space.[79] In his remarks, Yang emphasized that "countries should neither develop missile defense systems that undermine global strategic stability nor deploy weapons in outer space."[80] He also observed that the international community has a common responsibility to create credible and effective multilateral measures to prevent the weaponization of space and that the CD has a key role to play in this regard.[81]

Yang called on all members of the CD to begin substantive discussions on the PPWT.[82] Article II of the draft treaty says, "States Parties undertake not to place in orbit around the Earth any objects carrying any kind of weapons, not to install such weapons on celestial bodies, and not to station such weapons in outer space in any other manner; not to resort to the threat or use of force against outer space objects; not to assist or encourage other states, groups of states or international organizations to participate in activities prohibited by the Treaty."[83] The treaty does not propose a method for verification, although Article VI says this may be the subject of an additional protocol.[84]

Six days after Yang's remarks, China and Russia offered a joint response to questions about the draft PPWT at the CD.[85] It argues that verification of a space weapons prohibition is achievable and that an international consensus on the term "weapons in outer space" can be reached. The response clarifies that the draft PPWT bans devices specially produced or converted to cause harm as well as "possible weapons" (i.e., spacecraft used for peaceful purposes) that are used as a means of exercising force, such as by causing them to collide with a satellite. The joint response also makes clear that the draft PPWT does not expressly forbid the development of ground-based, air-based, or water-based interceptors.

Despite Yang's plea that states not develop missile defense systems, China claimed to have successfully tested a missile interceptor on 12 January 2010.[86] The Chinese Foreign Ministry emphasized that the test was a defensive maneuver and that it did not leave debris orbiting in space.[87]

2009 Space Security Impact

Although there does not seem to be enough momentum right now for a major multilateral convention on a space security regime, a tendency to develop regulations can be observed at the national level. In launching a full review of US national space policy in 2009, the Obama administration has signaled a degree of willingness to enhance security in outer space through cooperation and consensus. Yet the exact outcome of the US review, slated for release in 2010, is far from clear. It remains to be seen what position the US leadership will take on treaties and Transparency and Confidence-Building Measures, which are believed by some sectors in the US Congress to constrain US freedom of action in outer space. Meanwhile, by addressing questions about their joint proposal for a legally binding agreement that would ban weapons in space, Russia and China continued to assert in 2009 that adoption of the PPWT would be the best way to enhance space security. However, the

PPWT is still regarded by some as incomplete due to its lack of a verification principle, as well as its inability to shield against ground-based interceptors. Regardless of the proposals' merits, the fact that alternatives for a space security regime are being discussed by stakeholders constitutes a positive development.

Trend 3.2: COPUOS and the CD continue to be the key multilateral forums for outer space governance

An overview of the relationships among key institutions mandated with addressing issues related to outer space activities is provided in Figure 3.5. The UN General Assembly is the main deliberative organ of the United Nations and issues of space security are often debated at the Assembly's First Committee (Disarmament and International Security). While the decisions of the Assembly are not legally binding, they are considered to carry the weight of world opinion. The General Assembly has long held that the prevention of an arms race in outer space would make a significant contribution to international peace and security.

The UN General Assembly created COPUOS in 1958 to review the scope of international cooperation in the peaceful uses of outer space, develop UN programs in this area, 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 General Assembly and Member States. There are currently 69 Member States of COPUOS, which works by consensus. In addition to member states, 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 US in particular has maintained that COPUOS should exclusively address issues related to peaceful uses of outer space.[88]

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.[89] 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."[90] 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.[91]

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-President of the CD, 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. To date, there is still no consensus on negotiation of a PAROS treaty.

2009 Development

The Conference on Disarmament agrees on a program of work

On 29 May 2009, the Conference on Disarmament adopted a program of work (CD/1864) for the first time since 1998.[92] Previously, the CD had been unable to reach this milestone, in part because the US refused to accept the emphasis China and Russia placed on negotiating the prevention of an arms race in outer space and because, in turn, those countries refused to accept US efforts to outlaw the production of new fissile material.[93]

As part of its 2009 work program, the CD established a Working Group led by Canadian ambassador Marius Grinius on the prevention of an arms race in outer space, to "discuss substantively, without limitation, all issues related to the prevention of an arms race in outer space."[94] The creation of formal working groups was important because many delegations view them as more legitimate than the informal special coordinators used in the 2007 and 2008 proposals and also because the goals and substance of the working groups were more ambitious than the mandates proposed in previous years.[95] These developments led some delegates to express their optimism that the CD might finally accomplish substantive work. The Russian ambassador, for example, expressed his belief that the joint Russia-China PPWT could "provide a good basis for the working group on [PAROS] when it starts its activities."[96]

The CD could not, however, adopt a framework to implement its program of work before the closure of session on 19 September, largely due to the opposition of Pakistan over matters unrelated to space security. Islamabad is concerned that progress at the CD could limit its ability to produce fissile material, which it closely links to its national security strategy, and expressed its worry that the draft fissile material treaty was being prioritized at the expense of other issues.[97] Concerns were also expressed by China, Iran, and Egypt.[98] Because work programs do not carry forward to the next session, the CD must start from square one in 2010, when it seems likely that Pakistan will continue to prevent the CD from engaging in substantive talks.[99]

2009 Development

The EU submits draft Code of Conduct to CD, launches consultation process

On 12 February 2009, the European Union spoke about its draft Code of Conduct during a meeting of the CD.[100] Speaking on behalf of the EU, the Czech ambassador, Ivan Pinte, elaborated on the draft Code's two overarching goals:

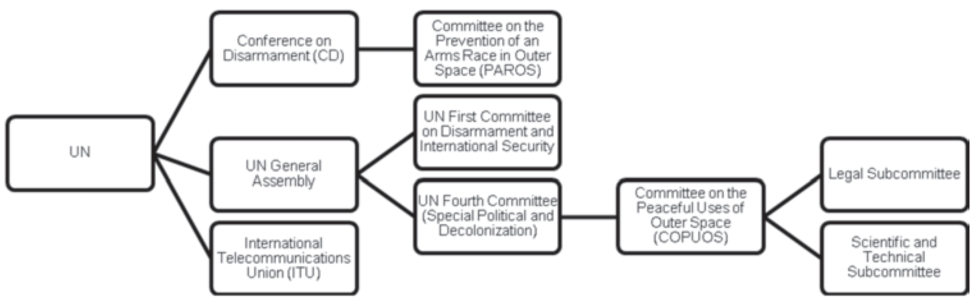
- "To strengthen the existing United Nations treaties, principles and other arrangements, as the subscribing parties would commit to comply with them, to make progress towards adherence to them, to implement them, and to promote their universality, and
- To complement them by codifying new best practices in space operations including measures of notification and of consultation that would strengthen the confidence and transparency between space actors and contribute to developing good faith solutions that would permit the performance of space activities and access to space for all."[101]

Pinte noted that the draft Code is voluntary, that it would be open to all states but not be a legally binding treaty, and that it does not directly address the issue of space weaponization. Although the EU appreciates the Russian and Chinese efforts to enhance space security, he added that the PPWT is inadequate because any legally binding treaty would need to include robust measures of verification and address the issue of anti-satellite weapons.[102]

Reaction in the CD to the EU proposal was mixed. EU states such as Austria reacted favorably and expressed their support. Pakistan made known its position that "outer space must not be weaponized or colonized."[103]

The EU also began consulting with non-EU spacefaring states in 2009, with the goal of reaching the exact wording of the Code that would be acceptable to the greatest number of states possible.[104] When the consultation is complete, it is expected that states will gather at an ad hoc conference to ratify the Code. While the consulting process for the Code of Conduct will not take place in the context of the CD, the EU will keep the CD informed of progress on this matter.[105]

Figure 3.5: International space security-relevant institutions



2009 Development

Canada calls for security guarantees at CD

On 26 March 2009, Canadian ambassador to the CD Marius Grinius tabled a working paper titled "The Merits of Certain Draft Transparency and Confidence Building Measures and Treaty Proposals for Space Security." In his statement to the forum, Grinius presented the paper's main argument, "that transparency and confidence-building measures can serve as important instruments in their own right, as well as elements towards an eventual treaty."[106] To that end, Canada proposed that the CD adopt a set of security guarantees, such as a declaration of legal principles, or a pledge, to:

a. Ban the placement of weapons in space,

b. Prohibit the test or use of weapons on satellites so as to damage or destroy them, and

c. Prohibit the use of satellites themselves as weapons.[107]

The working paper observes that "these rules can be crafted without the need to define a weapon, a satellite or even outer space, since the effects of the weapon are included within the proposed prohibitions, a satellite is an object that orbits around the Earth or other celestial body, and the prohibition on the placement of any weapon in outer space can be modeled on the language of Article IV of the Outer Space Treaty."[108]

With respect to the PPWT, the working paper notes that the joint Russian-Chinese proposal to ban the use of force against outer space objects and prohibit the deployment of weapons in outer space would not have necessarily prevented or outlawed China's anti-satellite weapon test in 2007.[109] As for the Code of Conduct advanced by the EU, the working paper observes that the Code was formulated during a time when the administration in the United States was unwilling to consider treaties that would restrict its freedom of action in outer space. However, the working paper continues to say that the draft Code is inadequate because "it allows for a proliferation path for anti-satellite weapons that ought to be closed when judged against other possible or viable proposals for a more robust security guarantee."[110]

Speaking before the First Committee of the 64th Session of the UN General Assembly in October, Grinius again advocated for the adoption of the same three rules for outer space security originally promoted in the CD working paper, and added that the most appropriate forum for reaching a consensus about security guarantees is the Conference on Disarmament.[111]

2009 Development

COPUOS examines long-term sustainability of outer space

Alongside the 46th session of the COPUOS Scientific and Technical Subcommittee, the informal working group on "Long-term Sustainability of Outer Space Activities"[112] held its third meeting in Vienna on 17 February 2009, under the leadership of former COPUOS Chair Gérard Brachet.[113] France, in its capacity as coordinator of this working group, presented a "Draft Outline" document that was distributed to the working group during informal consultation. This report outlined what it considers to be the main issues concerning long-term sustainability of outer space activities. Specifically, these are:

a. The proliferation of space debris;
b. The safety of space operations, with emphasis on the problems involved in operations in the geostationary orbit, in mid-Earth orbits (at an altitude of about 20,000 km) and in low-Earth orbits (at an altitude of between 1,000 and 1,500 km);
c. The management of the radio frequency spectrum;
d. The natural causes of disturbances affecting space systems (space weather, solar flares, micrometeorites etc.).[114]

The COPUOS Plenary Committee, at its 52nd session in June 2009, agreed that the Scientific and Technical Subcommittee should include a new agenda item entitled "Long-Term Sustainability of Outer Space Activities."[115] This new item will be on the Subcommittee agenda for the 47th session and will proceed according to the following multiyear work plan:

> 2010: General exchange of views on present and future challenges facing outer space activities, as well as potential measures that could enhance the long-term sustainability of outer space activities, with a view to establishing a working group open to all member states of the Committee.
>
> 2011: Preparation of a report on the long-term sustainability of outer space activities and examination of measures that could enhance their long-term sustainability; preparation of a draft set of best practices guidelines.
>
> 2012/2013: Continuation of consideration and finalization of the report and of the set of best practices guidelines for presentation to and review by the Committee.[116]

At the UN Institute for Disarmament Research Space Security Conference in Geneva on 15-16 June 2009, former COPUOS Chairman Gérard Brachet, acting as the working group's Coordinator, delivered an update on progress. He said that the working group's report was undergoing its fourth revision and that he expected it to be completed by the end of 2009.[117] Some analysts believe that the report could eventually be taken into consideration as "possible implementation guidelines for political agreements such as the EU draft Code of Conduct."[118]

These efforts have been met with enthusiasm by some states. For example, Garold Larson, the US alternate representative to the UN First Committee on Disarmament and International Security, said in a statement to the 64th General Assembly on 19 October 2009 that the US looks forward to "playing an active role" in formulating best practices guidelines and that doing so "will serve as a valuable opportunity for cooperation with established and emerging members of the spacefaring community to enhance spaceflight safety and preserve the space environment for future generations."[119]

2009 Space Security Impact

The adoption of a program of work for the first time in over a decade and the subsequent failure to implement that program before the closure of the session highlight the hope and frustration felt at the CD in 2009. While any progress is worth noting, the reality is that accomplishments made during one session do not carry forward to the next. Despite objections from a few states over the necessity of consensus in the CD, it will likely remain a requirement for action and continue to impede efforts to engage in substantive work on PAROS. Nevertheless, 2009 saw work proceed on a number of proposals to improve the sustainability of the space environment. Although the EU Code of Conduct was not opened to subscription, a consultation process was launched and the body of the text was shared at the CD. As well, Canada used the CD as a platform to introduce its proposal for new outer space security guarantees. And COPUOS established a timetable to formulate a report and a set of Best Practices Guidelines that address various sustainability issues in space. These proposals constitute positive developments as they may provide the basis for a future space security treaty.

Trend 3.3: National space policies emphasize international cooperation and the peaceful uses of outer space

All spacefaring states explicitly support the principles of peaceful and equitable use of space in their space policies. Similarly, almost all emphasize the goals of using space to promote national commercial, scientific, and technological progress, while countries such as China, Brazil, and India also emphasize economic development. Virtually all space actors underscore the importance of international cooperation in their space policies, and it is through such cooperation that several developing nations have been able to secure access to space.

While the US is perhaps the nation least dependent upon collaborative efforts to achieve its national space policy objectives, the recently released 2010 US National Space Policy nonetheless "calls on all nations to work together to adopt approaches for responsible activity in space"[120] and affirms that the US "renews its pledge of cooperation in the belief that with strengthened international collaboration and reinvigorated US leadership, all nations and peoples – space-faring and space-benefiting – will find their horizons broadened, their knowledge enhanced, and their lives greatly improved."[121] Such cooperation is particularly linked to space exploration, space surveillance, and Earth observation. The US also aims to build an understanding of, and support for, US national space policies and programs and to encourage the use of US space capabilities and systems by friends and allies.[122]

Russia is deeply engaged in cooperative space activities, asserting that international cooperation in space exploration is more efficient than breakthroughs by individual states.[123] Russia is a major partner of the European Space Agency (ESA),[124] with other key partners in space cooperation including China and India.[125] Russia has also undertaken cooperative space ventures with Bulgaria, Canada, France, Germany, Hungary, Israel, Pakistan, and Portugal on various occasions.[126] Similar to those of the US, Russian space cooperation activities have tended to support broader access and use of space. But Russian policy also aims to maintain Russia's status as a leading space power, as indicated in the Federal Space Program for 2006–2015, which significantly increased the resources of the Russian Federal Space Agency, Roscosmos.[127]

China's 2006 White Paper on space declares a commitment to the peaceful use of outer space in the interests of all mankind, linking this commitment to national development and security goals, including protecting China's national interest and building the state's "comprehensive and national strength."[128] While China actively promotes international exchanges and cooperation, it has stated that such efforts must encourage independence and self-reliance in space capabilities.[129] China has emphasized Asia-Pacific regional space cooperation, which in 1998 led to the signing of the Memorandum of Understanding on Cooperation in Small Multi-Mission Satellite and Related Activities with Iran, Mongolia, Pakistan, South Korea, and Thailand, thus supporting broader access to space.[130] China has pursued space cooperation with more than 13 states.[131]

India is a growing space power that has pursued international cooperation from the inception of the Indian Space Research Organisation (ISRO), although its mandate remains focused on national priorities. India has signed Memoranda of Understanding with almost 30 states and the ESA. India also provides international training on civil space applications through the Indian Institute of Remote Sensing (IIRS) and the Centre for Space Science and Technology Education in the Asia Pacific Region to support broader use of space data.[132]

The ESA facilitates European space cooperation by providing a platform for discussion and policymaking for the European scientific and industrial community.[133] Many see this cooperation as one of the most visible achievements of European cooperation in science and technology. Historically Europe lacked the resources to meet its stated space policy, leading it to establish strong links of cooperation with larger space powers, specifically the US and Russia. In addition France, Germany, Italy, and the UK all have extensive cooperative ventures with the US, Russia, and, to a lesser extent, Japan and others.

In 2007 the first European Space Policy was adopted jointly by the ESA and the European Union. While stressing the peaceful use of outer space, the policy notes that "the economy and security of Europe and its citizens are increasingly dependent on space-based capabilities which must be protected against disruption"[134] and emphasizes the need for European states to maintain independent access to space. The European Parliament has noted that "freedom from space-based threats and secure sustainable access to, and use of, space must be the guiding principles of the European Space Policy."[135] Autonomy is a longstanding goal of European national space policies, as exemplified by the Ariane launch and Galileo navigation programs. The draft of the EU Code of Conduct for Outer Space Activities, mentioned above, also places great emphasis on the need for international cooperation and stipulates that "all States should actively contribute to the promotion and strengthening of international cooperation relating to the activities in the exploration and use of outer space for peaceful purposes."[136]

In 2007, 14 national space agencies jointly released the document *The Global Exploration Strategy: the Framework for Coordination*.[137] The document marked the culmination of efforts toward international collaboration in outer space exploration initiated by NASA in 2006 and sets out an action plan to share strategies and efforts for exploration. According to the document, "this new era of space exploration is intended to strengthen international partnerships through the sharing of challenging and peaceful goals."[138]

2009 Development

The US considers changes to International Traffic in Arms Regulations

The International Traffic in Arms Regulations (ITAR) are a collection of government regulations that control the export and import of defense-related goods and services on the US Munitions List (USML). Pressure for ITAR reform mounted in 2009. The American Institute of Aeronautics and Astronautics, an industry group, released a white paper in May that said that certain outdated export controls should be reformed "before the damage becomes irreversible."[139] In September the Space Foundation issued its own white paper, "ITAR and the U.S. Space Industry," which advises that "[e]xport regulations should be modernized to prevent further damage to the U.S. space industry and especially lower-tier suppliers."[140] Then in August 2009 the world's two largest commercial satellite fleet operators, Intelsat and SES, began a joint effort to persuade policymakers that ITAR should be modified to allow China and India to launch US commercial satellites.[141] Additionally, in its final report issued to NASA and the White House in October 2009, the independent Review of U.S. Human Space Flight Plans Committee deemed ITAR to be "outdated and overly restrictive for the realities of the current technological and international political environment."[142] It concluded that ITAR was a major impediment to increased cooperation between the US and its international partners.

Legislation currently making its way through Congress would partially reform ITAR. Section 826 of the Foreign Relations Authorization Act for fiscal years 2010-2011, entitled "Authority to Remove Satellites and Related Components from the United States Munitions List," would grant the President the authority to remove satellites and related components from the USML. However, the Act contains one notable exception: the president's authority "may not be exercised with respect to any satellite or related component that may, directly or indirectly, be transferred to, or launched into outer space by, the People's Republic of China."[143] On 10 June 2009, this bill passed in the US House of Representatives. On 22 June it was referred to the Senate Foreign Relations Committee.[144]

In August 2009 President Obama created a special task force to conduct a full review of US export controls.[145] Then on 21 December, Obama issued Presidential Study Directive-8 (PSD-8), which directs the task force to prepare a comprehensive set of recommendations to establish a new US export control system no later than 29 January 2010.[146] The directive instructs the task force to examine the findings of earlier studies as well as past and present legislation addressing export control reform. PSD-8 also directs the task force to "draw upon the expertise of U.S. industry and allies, particularly from those countries with regulatory regimes that could serve as a model."[147] According to a Pentagon spokesperson, Defense Secretary Robert Gates is keen to enact wholesale export control reform, in part "to keep our friends and allies equipped well enough to contribute in a meaningful way to global security."[148] This is significant because the Defense Department has "traditionally been an impediment" to export control reform.[149]

2009 Development

National space agencies strive to implement COPUOS debris mitigation standards

The 48th Session of the COPUOS Legal Subcommittee (23 March–3 April 2009) had a general exchange of information on national mechanisms relating to space debris mitigation measures.[150] The Subcommittee heard presentations from Russia, Germany, Japan, and the ESA. Delegations from Canada, China, France, India, Italy, Japan, the Russian Federation, and the United States also presented information about their efforts to mitigate space debris and comply with the Guidelines. The Subcommittee noted in its annual report for 2009 that participating states are using a variety of strategies to alleviate the problem of space debris, including "the nomination of governmental supervisory authorities, the involvement of academia and industry and the development of new legislative norms, instructions, standards and frameworks."[151]

Of particular interest was the Japanese presentation to the Subcommittee, which noted that there are two areas in which it feels that industries and space users cannot perfectly comply with UN Guidelines. First, there are times when releasing objects cannot be avoided, such as the support structure of multiple payloads in launch. Second, the requirement to meet orbital lifetime limits is difficult to carry out in the case of small satellites and orbital stages.[152] In a separate announcement, Russia declared that its national regulations for space debris mitigation were harmonized with the UN Guidelines as of 1 January 2009. The Russian delegation to the International Interdisciplinary Congress on Space Debris singled out the prohibition on creating intentionally long-lived space debris for praise, "because it establishes limitations on tests of any anti-satellite systems and decreases the danger of collisions."[153]

2009 Space Security Impact

A significant shift in US national space policy would occur in the event that the US established a new export control system, granting the President authority to remove satellites and related components from the United States Munitions List, as stipulated in the bill referred to the Senate Foreign Relations Committee in June 2009. Fewer and less stringent regulations would constitute a positive development by opening the way for greater cooperation between NASA and such foreign civil space agencies as the European Space Agency, which has in recent years specifically cited export controls as an impediment to its cooperation with the US. Meanwhile, efforts to implement COPUOS debris mitigation standards by national space agencies constitute a positive development as they underscore the growing recognition that debris poses a major threat to peaceful space operations. Observable improvements in this area indicate that most spacefaring states are inclined to cooperate to ensure the peaceful uses of outer space.

Trend 3.4: Growing focus within national space policies on the security uses of outer space

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.

The best way to ensure the security of vulnerable space assets remains a top priority within US military doctrine. The 2003 US Air Force *Transformation Flight Plan* calls for onboard protection capabilities for space assets, coupled with offensive counterspace systems to ensure space control for US forces.[154] The 2004 Air Force document *Counterspace Operations* makes explicit mention of military operations conceived "to deceive, disrupt, deny, degrade, or destroy adversary space capabilities."[155] The authoritative US 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 US national interests"[156] and adds: "Military, civil, and commercial sectors of the US are increasingly dependent on space capabilities, and this dependence can be viewed by adversaries as a potential vulnerability."[157] 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.[158]

Russia has repeatedly expressed concern that attacks on its early warning and space surveillance systems would represent a direct threat to its security.[159] Hence, a basic Russian national security objective is the protection of Russian space systems, including ground stations on its territory.[160] These concerns are rooted in Russia's assessment that modern warfare is becoming increasingly dependent on space-based force enhancement capabilities.[161] 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.[162] 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 US missile defense systems.[163] 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. As well, its National Security Strategy, signed by President Medvedev in 2009, cites the potential dangers posed by the increased militarization of space activities. (See related development below.)

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.[164] 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.[165] 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.[166] Nonetheless, in contemporary Chinese military science, the military use of space is inextricably linked to attaining comprehensive national military power.[167] 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.[168] A recent statement by a high-ranking official of the People's Liberation Army (PLA) about the inevitability of an arms race in outer space[169] proved highly controversial and is discussed below in greater detail.

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,[170] which has been 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.[171] 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.[172] 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.[173] 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."[174]

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.[175] 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.[176] Indian Army Commanders also adopted *Space Vision 2020* – "its philosophy for using space in future warfare" – that reportedly emphasizes aspects of force modernization[177] and intends to join the ranks of the US and Russia with plans to launch a dedicated military satellite in the near future.[178]

2009 Development

Australia releases new white paper on defense

In May 2009 Australia released Defending Australia in the Asia Pacific Century: Force 2030, its first white paper on national defense in nine years.[179] The paper recognizes as emergent areas of risk space warfare as well as counter-space technologies that can deny, disrupt, or destroy space-based capabilities on which Australia depends for operational success in military affairs.[180] It also recognizes that space-based surveillance systems, including intelligence collection satellites, are important in developing an "information superiority capability" that is needed to give its forces an edge in situational awareness, decision-making, networked capabilities, and the precise application of force.[181] According to the report, "the Government has placed a priority on space situational awareness and has requested that Defence explore means by which to strengthen our space situational awareness and mission assurance capability."[182] The report also mentions that the Government has decided to acquire a satellite with remote sensing capability to meet its mapping, charting, navigation, and targeting data requirements. The white paper views this satellite as an important contribution to Australia's alliance with the US, which will be granted access to imagery collected by it.[183] While the paper says that all efforts should be made to chart an independent course, it also acknowledges that it will continue to rely on its principal ally, the United States, for some defense capabilities, including space-based assets, because of limitations in its defense budget and indigenous industrial base.[184]

2009 Development

Japan announces details of Basic Space Plan

On 21 May 2008, Japan adopted the Basic Space Law (BSL), which reverses its longstanding prohibition on national security and military space activities, based on the widely accepted interpretation of the Outer Space Treaty that allows for the military use of outer space for peaceful purposes.[185] The law allows the Ministry of Defense to deploy satellites for non-aggressive purposes, including surveillance and military support functions, but "does not permit the deployment of offensive capabilities" in space.[186]

As part of its effort to create a comprehensive national space strategy, Japan issued a five-year Basic Space Plan (BSP) in June 2009 to give the BSL more direction and substance. Government officials view the adoption of a comprehensive space strategy as way to catch up to other major spacefaring states. Keiji Tachikawa, the President of Japan's Aerospace Exploratory Agency (JAXA), said in an interview that the BSL and BSP represent "very significant progress, as the United States, Russia, China and India have already made space development a part of their national strategies."[187] The Plan consists of six pillars that address various issues, including environmental research and awareness, stimulating domestic R&D, and national security.[188]

A major element of the national security pillar is the Satellite System for National Security. The BSP will "strengthen the information gathering capability and promote research in the field of early warning and signal information gathering, while maintaining our exclusively defense-oriented policy, in accordance with principle of pacifism enshrined in the Constitution of Japan."[189] Some observers contend that since the BSL was adopted, the overall budget for space activities has become weighted more heavily toward "military purposes," including the appropriation of ballistic missile defense as a space-related project,[190] although this shift can be mainly attributed to the reallocation of a portion of the space budget to the Ministry of Defense. According to the Nuclear Threat Initiative, the new law grants the Ministry of Defense the authority to "manufacture, possess and operate its own satellites to support its military operations, including ballistic missile defense."[191]

A 2009 Ministry of Defense paper details Japan's plan up to 2012 to build up its missile defense capabilities, including additions to its missile arsenal and upgrades to its ground-based radar sensors.[192] The BSP adds that the number of information-gathering satellites should be increased to four within five years, a decision that some commentators attribute to North Korea's long-range missile launch in April 2009.[193] Although the BSP is set to last only until FY2013, it includes a satellite procurement projection for FY2014–FY2020, bringing the estimated total of new satellites to 60.[194] This number would include several new optical and radar satellites as part of the satellite system for national security.[195]

2009 Development

China clarifies position on arms race in outer space

Multilateral measures to prevent the weaponization of space have long been a cornerstone of China's official diplomatic space policy. However, that position appeared to shift somewhat on 1 November 2009, when a top air force commander in the PLA was quoted as saying that an arms race in outer space is a "historical inevitability."[196] This follows the publication of a book in 2008 by the state-run China Arms Control and Disarmament Association that concluded that the weaponization of outer space is "unstoppable."[197] The authors, two PLA experts, argue that actions taken by the US to maintain its dominant position in outer space compel other states, including China, into competition and even confrontation. Similar language was reportedly used following China's 2007 anti-satellite missile test, when a Senior Colonel at the PLA's Academy of Military Sciences declared that "outer space is going to be weaponized in our lifetime," and that, "if there is a space superpower, it's not going to be alone, and China is not going to be the only one."[198]

One US Congressman responded to the recent comments by the PLA commander by accusing China of demonstrating "a clear intent to pursue offensive space capabilities," despite Beijing's routine public declarations to the contrary.[199] General Kevin Chilton, head of US Strategic Command, reacted with more moderation, stating that China's space program is "an area that we'll want to explore and understand exactly what China's intentions are here, and why they might want to go in that direction and what grounds might accommodate a different direction."[200] Shortly after the comment was made, a spokesperson for the Chinese foreign ministry clarified, "China has not, and will never, participate in any kind of arms race in outer space. We have not changed our stance."[201] Then on 6 November, President Hu Jintao repudiated the words of his commander, stating that "China will unswervingly uphold a national defense policy that is defensive in nature, and will never seek military expansion and an arms race."[202]

The PLA commander might have been expressing views similar to those found in China's latest white paper on national defense, *China's National Defense in 2008*, released on 21 January 2009. It states that "the existing legal instruments concerning outer space… [are insufficient] to effectively prevent the spread of weapons to outer space."[203] This position allows for the possibility of an arms race in outer space while still maintaining the need for effective multilateral instruments to forestall the weaponization of space. Similarly, Xu Nengwu of China's National Defense Science and Technology University expressed his opinion that "outer space will certainly become a stage for struggle between countries" in the near future; yet he also called for urgent efforts to prevent the weaponization of space.[204] One analyst suggested that English-language translations might have misinterpreted the PLA commander's comments. Rather than weaponizing space, the commander might have been discussing something more benign like the militarization of space, entailing satellite reconnaissance and communications. And instead of increased conflict, it is possible that he was instead stressing the likelihood of increased competition in the space domain.[205]

2009 Development

Russia establishes national security strategy until 2020

On 13 May 2009, Russian President Dmitry Medvedev authorized a new national security strategy, which is intended to remain in effect until the year 2020. The decree replaces an earlier national strategy dating from 1997 and includes an index of measures purporting to track improvements in Russia's overall level of security.[206] With respect to military security, the document says that Russia is threatened by the policies of "a number of leading foreign states" that attempt to gain "dominant superiority in the military sphere."[207] It goes on to say that "the unilateral formation of the global missile defense system and militarization of outer space," among other things, are exacerbating the risk to Russia's military security.[208] Although specific countries are not named, most observers interpret the comments as a veiled reference to the US. One defense analyst commented that the strategy reveals that "Russia is seriously concerned about the growing gap between the US and Russia in the military field, and about America's attempts to dwarf Russia's nuclear potential by creating new arms systems, placed close to Russia's borders and in space."[209]

This concern was reflected in recent comments by Deputy Defense Minister Gen. Vladimir Popovkin about Russia's potential anti-satellite capabilities. During a press conference on 5 March 2009, a reporter asked the deputy minister his opinion on the use of anti-satellite weapons by China in 2007 and the US in 2008. Popovkin, former chief of his country's military Space Force, responded that Russia "can't sit and watch others do it. I can only say similar works are done in Russia too."[210] He also said that Russia already possesses some "basic, key elements" of technology that could be used for anti-satellite purposes, although he added that Moscow hopes to avoid an arms race in outer space.[211] It is longstanding Russian policy to oppose the weaponization of space (see Trends 3.2 and 3.3).

2009 Space Security Impact

The 2009 Australian Defence White Paper illustrates the growing realization among a number of smaller spacefaring states that outer space is a key military domain. Its emphasis on the importance of satellites for surveillance, coordination, and ground strike capabilities, as well as the threat of counter-space technologies, underscores the connection for many states between national security and outer space policy. The impact of the Japanese Basic Space Plan should not be overly negative, given that the portion of the space budget allocated to the Ministry of Defense continues to be used exclusively for defensive purposes. The clarification of China's view of an arms race in outer space as a "historical inevitability" needs to be understood in the context of the domestic political system. While the significance of a comment by one commander should not be overblown, it helps to understand that the civilian and military branches of government have different priorities and compete for authority over the direction of space affairs.

Civil Space Programs and Global Utilities

CHAPTER FOUR

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 US 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 (ISS). 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 the number of 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 are space-based applications provided by civil, military, or commercial actors, which can be freely used by anyone equipped to receive their data, either directly or indirectly. Some global utilities include remote sensing satellites that monitor the Earth's changing environment using various sensors, such as weather satellites. Satellite navigation systems that provide geographic position (latitude, longitude, altitude) and velocity information to users on the ground, at sea, or in the air, such as the US 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 with the wherewithal 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 outer space exploration, thereby increasing global awareness of the importance of space exploration.

Likewise, international cooperation remains a key aspect of both civil space programs and global utilities that affects space security in a positive way by enhancing transparency regarding 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 make it difficult for any one actor to pursue them independently.

Conversely, civil space programs can have a negative impact on space security by diverting technological advances for peaceful space exploration to military applications, thereby enabling 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 radiofrequencies. Competition for access to and use of space resources in the longer term could generate tensions insofar as emerging spacefaring states as well as commercial providers of space-related services find opportunities to secure access to these resources quite limited.

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, however, it may encourage adversaries to target dual-use civil-military satellites during conflict or make such targeting too costly depending on how other space actors react.

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 who have access to space data and, thus, 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 during conflict.

Trend 4.1: Increase in the number of actors gaining access to 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 2009, nine states (of which Iran was the latest in February 2009) in addition to the European Space Agency had demonstrated an independent orbital launch capability (see Figure 4.1). 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.

A further 17 actors have suborbital capability, which is required 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, Iran, 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 increased dramatically in the past decade. By the end of 2009 a total of 50 states had placed satellites in states either independently or through cooperation agreements, with Switzerland's SwissCube being the latest successfully launched satellite. This number is expected to continue to grow as more states seek the socio-economic benefits that space provides through the efforts of the commercial sector and countries such as China, which are helping states to develop affordable small satellites. Companies such as the former Surrey Satellite Technologies Limited and China have assisted states including Algeria, Egypt, Malaysia, Nigeria, Portugal, South Korea, Thailand, Turkey, and South Africa in efforts to build their first civil satellites.[2]

Many civilian spacecraft are also used for military purposes. This trend is increasing as more states with fewer resources to spend 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 multi-use civilian applications that may serve military purposes.

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

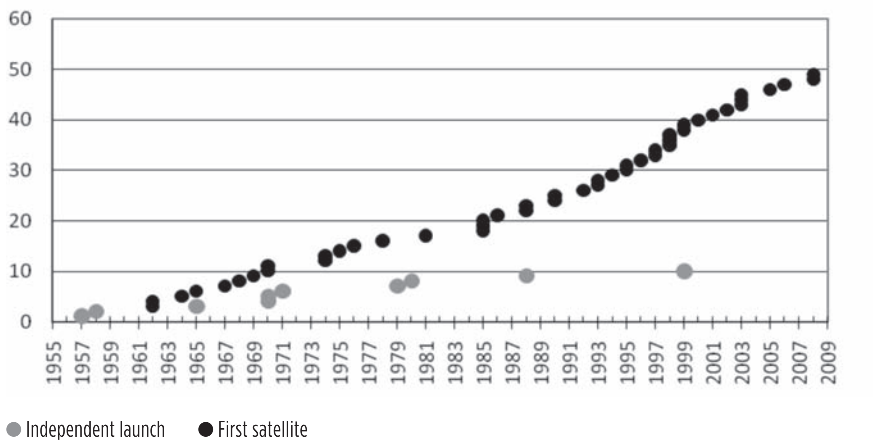
Dark grey indicates an independent orbital launch capability and dots indicate launch sites.

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
UK*	1971	Black Arrow	Prospero X-3
India	1980	SLV	Rohini
Israel	1988	Shavit	Ofeq 1
Iran	2009	Safir-2	Omid

* France and the UK 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 can be launched at a decreased cost. One of the first microsatellites to implement this technology was the US Clementine lunar mission in 1994. The ongoing enhancement of microsatellite capabilities is driving increased access to space at reduced cost because these satellites are cheaper to produce and to launch. For instance, in 2007 the Indian Space Research Organisation (ISRO) 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.

Figure 4.2: Growth in the number of civil actors accessing space[5]



2009 Development

More countries launch new satellites

The United Arab Emirates launched its first space asset, an optical earth observation (EO) satellite called DubaiSat-1 in July 2009.[6] The minisatellite is owned by the Emirates Institution for Advanced Science and Technology (EIAST) and was developed and built by Satrec Initiative of South Korea.[7] The satellite is being used for such purposes as urban and infrastructure planning and disaster monitoring.

In September 2009 Switzerland launched its first satellite on the Polar Express Launch Vehicle from the Sriharikota space station in India. The microsatellite called SwissCube weighed only 820 grams and was built by students of the Ecole Polytechnique Fédérale de Lausanne (EPFL). Its mission, which is expected to last between three months and one year, is to observe and collect data on airglow,[8] primarily for use by students and researchers. Turkey announced a plan to launch its first domestically built EO satellite in 2010.[9] The satellite, called Rasat and equipped with a high resolution imaging system, will be used mainly for mapping, disaster monitoring, and urban planning.[10]

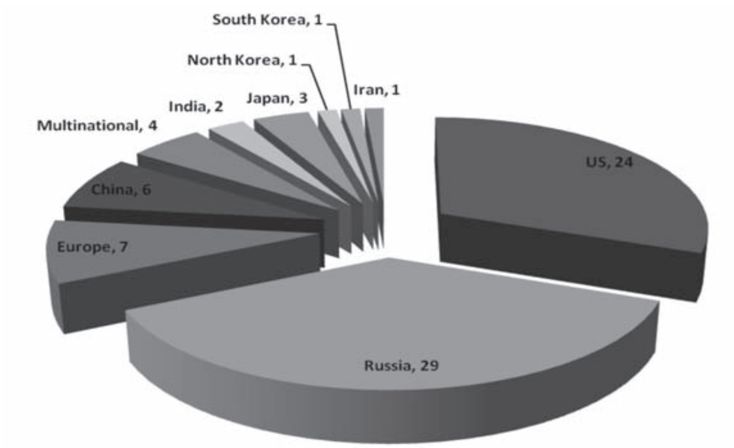
2009 Development

New launch capabilities continue to be developed; Iran's success and North Korea's failure

In early February, Iran became the ninth nation to design, build, and domestically launch its own spacecraft.[11] The launch of communication satellite Omid (Hope) triggered both Western concern and widespread admiration for Iran's rapid rise as a space power.[12] The satellite was designed to last only two or three months, and it burned up on re-entry to the atmosphere in April.[13] Iran's launch capabilities are particularly troubling to the West because the same rocket technology used to launch satellites can also deliver warheads.[14] Iran has also announced that it will launch a communication satellite on its own by the end of 2011.[15] This announcement follows earlier reports that Russia, and then Italy, would launch the satellite. While Iran has stated that the proposed satellite, named Misbah (Lantern), will be used to assist in data communication, Israeli media have claimed that it is a spy satellite.[16] The international community is increasingly concerned about the development of missile capabilities by Iran and the overall peaceful intentions of its space program.[17]

In preparation for launching a satellite into orbit by 2014, Indonesia successfully launched its first domestically made rocket, but only on a suborbital trajectory.[18] The launch of a domestically developed rocket in North Korea was not successful.[19] South Korea's launch of its first rocket with an EO satellite (for monitoring the Earth's radiant energy) was a partial failure, since the satellite was not delivered to the proper orbit.[20] A second launch is scheduled for April or May 2010.[21] Brazil also announced that it would be resuming tests of its launch vehicle VLS (Alfa) in 2010.[22]

Figure 4.3: Worldwide orbital launch events in 2009[23]



* The launch attempts of North Korea and South Korea were not successful and their respective payloads were not placed in orbit.

2009 Development

National and international space bodies continue to expand and increase

In December 2009, Lord Drayson, the UK Science and Innovation Minister, announced that the UK would soon establish its own space agency.[24] The new agency, which would replace the British National Space Centre (BNSC), would be in charge of overall space policy and programs, currently handled by a variety of government departments and research councils.[25] Mexico is also in the process of establishing a national space agency to take charge of the space projects being developed by different ministries, although no timeline has been set.[26]

In September 2009 Mikhail Myasnikovich, Chairman of the National Academy of Sciences of Belarus (NASB), announced plans by Belarus to set up a national space agency as part of its 2008-2012 national program for the peaceful exploration of outer space.[27] He added that a satellite command and tracking station is being constructed in the Logoisk region of the country and will relay satellite data to NASB satellite control center headquarters.

2009 Space Security Impact

The launch activities of both Iran and North Korea, despite different degrees of success, caused a great deal of concern about the peaceful nature of their space programs. The launching of new satellites reflects the ever increasing interest of states in conducting space activities, but also highlights the need to adhere to relevant international treaties and other regulations, such as those setting technical standards. Increasing international cooperation (as in the development and launching of UAE and Swiss satellites) contributes to better space security, because it requires different states to coordinate their efforts, thus further entrenching the practice of international cooperation on space activities. However, a potentially negative impact of the increasing number of new actors with access to space is that space becomes a more crowded environment, thereby increasing the risk of accidental interference with space assets.

Trend 4.2: Changing priorities and funding levels within civil space programs

Space agencies

The main agency in the US 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:[28] *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.[29] 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.[30]

In 1961 France established its national space agency, the Centre National d'Études Spatiales (CNES), which remains the largest of the EU national-level agencies. Italy established a national space agency (ASI) in 1989, 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 ESA, which is now the principal space agency for the region. The latest member of ESA is the Czech Republic, which became ESA's 18th Member State on 12 November 2008.

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 Chinese National Space Administration (CNSA). 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 merged into the Japanese Aerospace Exploration Agency (JAXA).[31] 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

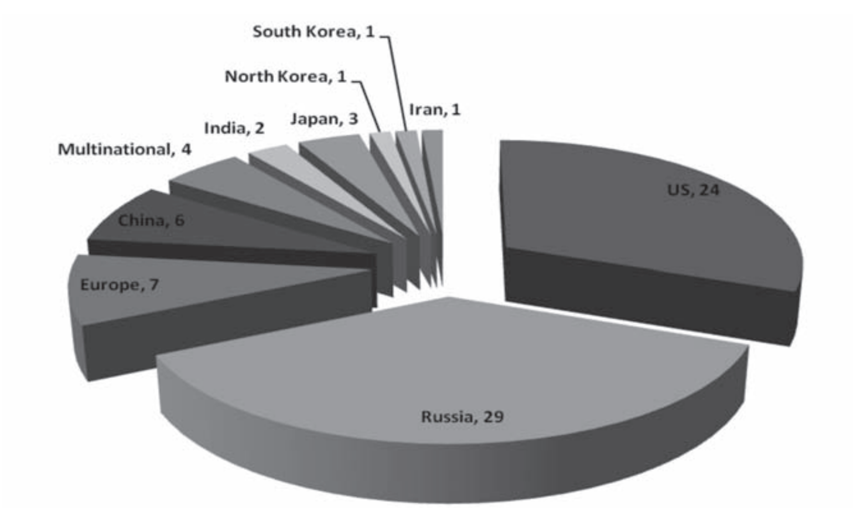
Although still dwarfing the civil space budgets of all other actors put together, the NASA budget dropped 25 percent in real terms between 1992 and 2001.[32] The ESA budget dropped nine percent in the same period. This follows a long period of growth for both NASA and ESA from 1970 to 1991, in which the NASA budget grew 60 percent in real terms and the ESA budget grew 165 percent in real terms.[33] 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 percent of the 1989 expenditure and less than the cost of a single launch of the US space shuttle.[34] This steady decline was reversed in 2005, however, when Russia approved a 10-year program with a budget of approximately $11-billion.[35] The annual budget reached $2.2-billion in 2009, not including funds for the GLONASS satellite navigation system, which had a separate budget allocation of close to $1-billion.[36]

Civil expenditures on space continue to increase considerably in India and China, due in large part to the growth of civil program activities, including large satellites and human spaceflight programs. Since 2005 India's space budget has dramatically increased and is currently around $1-billion.[37] 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 budget closer to $2-billion. It is safe to speculate that it falls somewhere between these two figures.[38] 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.[39]

The ESA budget is approximately $3.6-billion per year. The Agency has 18 member states, all of which make financial contributions to the Agency's General Budget on a scale based on their Gross Domestic Product.[40]

Figure 4.4: Top contributors to ESA's 2009 General Budget[41]



* This chart includes ESA member states that contribute 5 percent or more of ESA's budget

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.[42]

The first US human mission was completed on 5 May 1961, with the suborbital flight of the Mercury capsule launched on an Atlas-Mercury rocket. This was followed by the Gemini flight series and then the Apollo flight series, which ultimately took humans to the Moon. The US 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 US initiated the Space Shuttle, which is capable of launching as many as seven people to low Earth orbit (LEO). The first Space Shuttle, Columbia, was launched in 1981. By the end of 2008 the program had completed 124 launches and is currently the only human spaceflight capability for the US.[43] 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, with the Space Shuttle scheduled for retirement in 2010-2011 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. (See related development below, and trend 5.2.) In 2004 the US 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.[44] Future plans include a permanent human presence on the lunar surface.[45] These plans were examined in 2009 by the Review of United States Human Space Flight Plans Committee, whose findings are examined in trend 3.1.

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.[46] 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.[47] 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.[48] In 2007 both Japan and China launched robotic lunar missions: Kaguya and Change'e-1.[49] Germany, India, and South Korea are also planning lunar missions.[50]

New directions for civil 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.[51] 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.[52] African states such as 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 is to serve the public in the area of "environment, development, and global climate change."[53]

Efforts are also being 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.[54] 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.[55] 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.[56]

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 (GMES) 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."[57]

2009 Development

Spacefaring states continue to fund Moon exploration programs

Space agencies from several major spacefaring states have active Moon exploration programs under way. The renewed attention given to these programs has been interpreted by some analysts as a race that additional states are expected to join.[58]

The Chinese orbiter Change'e-1 impacted the Moon on March 1, 2009[59] after a successful mission as part of China's Moon exploration program. The launch of Change'e-2, equipped to obtain clearer and more detailed data about the lunar surface,[60] is planned for October 2010, to be followed by the launch of Change'e-3, China's first lunar lander and rover (in the prototype stage in 2009), some time before 2013.[61]

A similar mission conducted by India, Chandrayaan-1, was considered successful, and it was announced that despite the fact that the ISRO lost radio contact with the spacecraft, approximately 95% of mission objectives were accomplished.[62] ISRO plans to launch Chandrayaan-2 by 2013.[63] The new mission, whose design was completed in 2009, includes an orbiter, a lander, and a rover,[64] and is being carried out in cooperation with Russia.[65] The Indian government approved the project budget of Rs 425 crore (approximately $90-million).[66]

The US Lunar Crater Observation and Sensing Satellite (LCROSS) experiment,[67] whose primary purpose was to determine the existence of water on the Moon,[68] was widely considered a success by the international scientific community. According to NASA, the presence of water on the Moon was confirmed by analyses of the data it received from the satellite following impact on the Moon's surface.[69] This experiment was conducted as part of the Lunar Reconnaissance Orbiter mission[70] that aims to create a comprehensive atlas of the Moon's features and resources that may be used for the creation of a lunar outpost.[71]

The Japanese Kaguya mission was also successfully completed[72] after the spacecraft impacted the Moon in June 2009. The orbiter, together with two small satellites, was intended to gather data for the future utilization of the Moon,[73] by mapping the lunar surface and measuring its magnetic field.

2009 Development

Successes and failures in the development of new launch vehicles

The Universal Rocket Module URM-1 -the modular liquid fuelled first stage for Russia's Angara family of space vehicles- was successfully fire-tested in November 2009.[74] This family of rockets will include several launch vehicles with payload capacities ranging from 1.5 to 25 tons. The engine of the rockets is going to use ecologically friendly fuel consisting of kerosene/liquid oxygen.[75] Russia's space vehicle Soyuz, with the new digital operation system, is expected to be launched to the ISS in 2010 instead of 2011 as was initially planned.[76] The President of Energia announced that the company intends to build six vehicles in 2010: two Soyuz and four Progress freighters for ISS logistics.[77]

NASA investigated the complications involved in the test of Ares 1-X. Although the test of the Ares rocket itself was for the most part successful,[78] one of the three parachutes did not open and the landing was too hard.[79] The assessments regarding the success and feasibility of the Ares-1 project were very mixed.[80]

The Review of U.S. Human Space Flight Plans Committee, also known as the Augustine Commission, assessed the feasibility of the development of a new generation of launchers and spaceships for flights to the Moon and beyond, and urged the US government to reassess priorities in funding and the development of NASA's missions and projects[81] to match the goals and allocated resources.[82] It included recommendations for further steps regarding the Shuttle, the ISS, the Constellation program,[83] heavy launchers, future destinations of human space exploration, and commercial launch services.

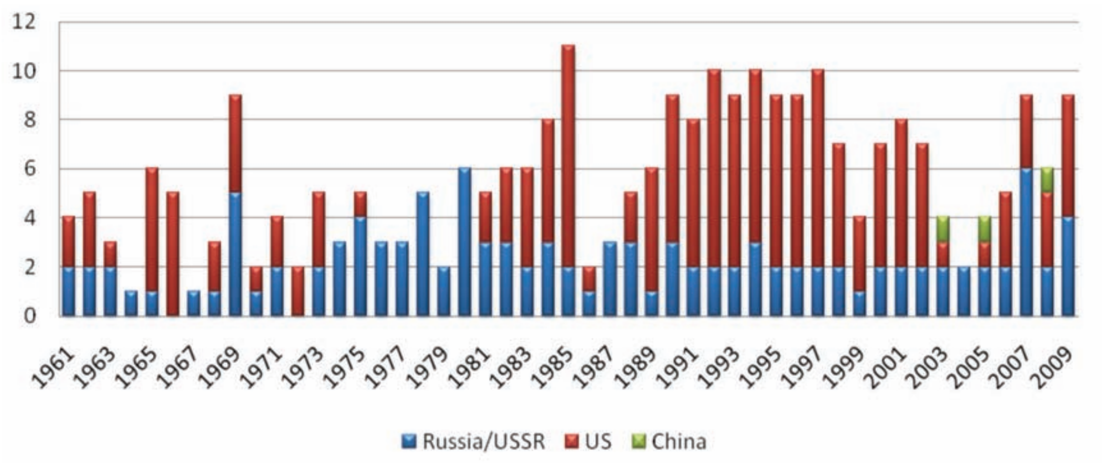
Japan cancelled the development of the GX launcher,[84] after a government decision to stop funding the project.[85] The GX launcher was to be an expendable launch system for launching small and midsize commercial satellites developed by Galaxy Express Corporation, a joint venture between IHI Corporation and other private firms with JAXA. IHI Corporation, which had a 40% stake in the venture, deemed the project to be commercially unsustainable without government involvement.[86] In related developments, the European Vega launchers underwent further tests in November[87] And China announced that Tiangong I, or Heavenly Palace I, which is scheduled for launch before 2011, will serve as a platform to test the space docking technology.[88]

2009 Development

More countries develop human space exploration programs

India revealed plans to start its own human space program, with a target launch date around 2015.[89] The announcement came after the success of the first Chandrayaan moon mission from October 2008 to August 2009, during which ISRO was able to place an unmanned probe in lunar orbit.

Figure 4.5: Human spaceflight 1961 – 2009



Six new astronauts joined the ESA astronaut corps in May 2009. The astronauts, from the UK, Italy, Germany, and Denmark, were to begin 18 months of training in September, and will likely have to wait approximately 3.5 years before they have the opportunity to go into orbit.[90] The Canadian Space Agency also chose two new astronauts nearly 25 years after the first Canadian astronaut flew into space.[91]

2009 Development

Number of scientific missions on the rise

The UN declared year 2009 the year of astronomy,[92] and it was marked by the launch of three new telescopes.

ESA's Planck[93] and Herschel[94] telescopes were launched in 2009. Herschel is the largest infrared space observatory ever launched[95] and will be used to study the creation of galaxies and stars, observe the chemical composition of the atmosphere of different celestial bodies, and examine the molecular chemistry of the universe. Planck's mission is to collect, characterize, and map radiation from the Cosmic Microwave Background.[96]

The Hubble telescope was repaired one last time in 2009.[97] In March NASA launched[98] the Kepler telescope[99] with a mission to search for habitable planets. In addition, in December NASA launched the Wide-field Infrared Survey Explorer (WISE),[100] which is designed to image the sky and increase knowledge of the solar system, the Milky Way, and the Universe.[101]

Russia planned two major planetary scientific missions: Koronas-Foton for solar exploration[102] and the Phobos-Grunt Mars mission. The first mission -whose name is an abbreviation for 'complex orbital near-Earth observations of solar activity' (in Russian) - was successfully launched on 30 January 2009, but experienced some spacecraft operational throughout 2009.[103] The second mission, with a Chinese orbiter aboard, [104] was not launched as planned in 2009.[105]

Russia launched two important scientific spacecraft for ESA.[106] Proba-2, one of the smallest ESA satellites, is to be used in studying solar and space weather.[107] The Soil Moisture and Ocean Salinity (SMOS) satellite is designed to monitor climate change on the global level and improve our understanding of ocean circulating patterns.[108]

2009 Development

Civil space budgets remain unchanged or increase slightly

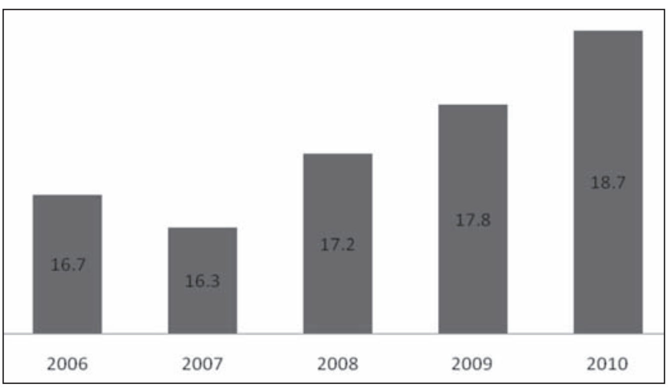
The ISRO budget increased by 27% during 2009, with a major portion intended for moon exploration programs and the development of a semi-cryogenic engine for future advanced satellite launch vehicles. ISRO was allocated Rs 4,459 crore (approximately $1-billion) as opposed to the previous year's budget of Rs 3,499 crore (approximately $730-million).[109]

Russian President Medvedev approved the Russian federal budget for 2010, allocating 67.2-billion Russian rubles ($2.2-billion) for space activities in general, and 27.9 billion rubles ($917-million) exclusively for Global Navigation Satellite System (GLONASS). This represents extra funding that is not included in the Roscosmos budget. Because of uncertainty about global economic recovery, the budget is only planned for one year.[110]

The ESA budget for 2010 was reported to be roughly the same as the 2009 budget. When the moratorium on spending ended in December, the ESA signed new contracts worth more than €500-million ($659-million).[111] The total budget is €3,744-million ($4.938-billion).[112] The EU, together with the ESA, held the first international conference on human space exploration, the main result of which was the plan, not yet approved by EU member states, to spend $3.9-billion a year on human exploration. The roadmap should be developed by the November 2010 conference in Brussels and will be used as guidance for the budget negotiations.[113]

NASA's 2009 budget allocation was $18.7-billion — an increase of more than $2.4-billion over the amount allocated in 2008. The budget covers US manned and robotic space missions and support of the ISS, the development of new space flight systems, aeronautics research, as well as the research and monitoring of global climate change.[114]

Figure 4.6: NASA 2006-2010 budget (in $B)[115]



DLR's budget was increased by €73-million ($96-million),[116] and the budget of the German National Space Program was increased to €229-million ($302-million) in 2009 from €191-million ($252- million) in 2008. According to the new budget for 2011-2013 DLR should get an increase of funding of €53-million ($70-million) for these three years.[117]

The president of the Italian Space Agency (ASI) announced that its budget will remain roughly the same for both 2010 and 2011 at approximately €7-million ($9-million).[118] The Japanese budget was increased by almost 11% in FY2009 to 348.8-billion yen ($3.87-billion).

Canada's Economic Action Plan 2009[119] provided the Canadian Space Agency with $108.8-million over three years for the development of terrestrial prototypes of space robotics vehicles, such as the Mars Lander and Lunar Rover, and for the further development of other technologies and space robotics.

2009 Space Security Impact
The fact that expenditures for space activities did not drop in response to the 2008 economic crisis constitutes a positive development that indicates the high priority given by states to their space activities. The increased number of scientific missions may further encourage international cooperation on space operations and thereby enhance the level of trust among different spacefaring nations.

Trend 4.3: Continued 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 been a driver of cooperation.[120] One of the first scientific satellites, Ariel-1, was launched in 1962 and was the world's first international satellite, built by NASA to carry UK experiments.

The earliest large international cooperation program was the Apollo-Soyuz Test Project, which saw two Cold War rivals working collaboratively on programs that culminated in a joint docking in space of US/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."[121] Moreover, 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 other countries — including the US, Afghanistan, Austria, Bulgaria, Canada, France, Germany, Japan, Slovenia, Syria, and the UK — to enable those states to send astronauts to conduct experiments onboard the MIR space station.[122] The nature of international space cooperation has changed since the end of the Cold War, as many barriers to partnership have been overcome. 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 US Space Shuttle to the MIR space station, with various crew exchanges.[123] 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 (CSA). Brazil participates through a separate agreement with NASA. The first module was launched in 1998. By the end of 2009, 88 launches had carried components, equipment, and astronauts to the station, which remains unfinished.[124] The ISS is projected to cost approximately $129-billion over 30 years of operations.[125]

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 solar system destinations such as 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.[126] 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 Change'e-1 lunar orbiter and India's Chandrayaan-1 lunar orbiter. However, export controls remain a hindrance to increased cooperation, particularly in the US, as discussed in Trend 3.3.

2009 Development

International cooperation continues to provide access to space for developing countries

Brazil and China reaffirmed intentions to cooperate in space activities by signing a new agreement in 2009, and stressed that cooperation on the CBERS project had been one of the biggest achievements for the developing countries so far.[127] The launch of the UAE DubaiSat-1 highlighted earlier in Trend 4.1 also highlights successful cooperation by developing countries in conducting space activities. Moreover, China declared its willingness to provide financial assistance to Pakistan in launching its first satellite.[128] Brazil and Ukraine are still working on the Tsyklon-4 space complex at Alcantara, Brazil.[129]

2009 Development

Increasing number of cooperation agreements between developing and developed countries

The focus on space activities in developing countries has made some of them attractive partners for possible cooperation. For instance, India and France agreed to launch a joint weather satellite "to monitor air and water movements over the tropic areas of the world" in 2010.[130] Brazil and Belgium signed a cooperation agreement on space technology.[131]

Russia expanded its cooperation network by discussing further cooperation opportunities with China, including Mars exploration.[132] Moreover, it will launch Angola's first satellite[133] for $327-million.[134] Also, in an effort to make GLONASS more viable, Russia offered Thailand access to GLONASS for naval and terrestrial navigation.[135] Azerbaijan might start negotiations with Russia on the use of GLONASS as well.[136] Russia also signed a cooperation agreement with Italy on the Spektr-M project,[137] is a Space Observatory Millimetron that will enable astronomical observations with super high sensitivity.[138]

China and the US are currently considering future cooperation on scientific space missions, as well as human space flight and space exploration. Plans will be discussed during meetings of the heads of national space agencies planned for 2010.[139] In addition, the US signed civil space cooperation agreements with France[140] and Canada[141] in 2009.

Cooperation regarding launchers

Russia and Kazakhstan agreed on procedures for the ecological security of the launches from Baikonur.[142] In the wake of the signing of a new space cooperation agreement in December 2008,[143] India and Russia plan to jointly build a reusable launch vehicle and extend cooperation in constructing vehicles for human space flight.[144] The first launch of the Russian Soyuz from ESA's Kourou was rescheduled from December 2009 to April 2010, but all the preparations were said to be under way.[145] Russia's Roscosmos and the French satellite launch firm Arianespace signed a contract, worth an estimated $300–$400-million, to launch 10 Russian Soyuz-ST carrier rockets from Kourou.[146]

ESA and NASA signed a Memorandum of Understanding on cooperation in space transportation, including human spaceflight.[147] It allows for the exchange of technical information and personnel in case of the development of a new transportation system. Likewise, there are unconfirmed indications that North Korea assisted Iran in launching its first domestic satellite.[148]

Exploration

ESA and NASA signed a Mars exploration agreement that is based on the jointly developed Mars Exploration Joint Initiative (MEJI), according to which the first European spacecraft heading to Mars should leave the Earth in 2016, and in 2019 several Mars rovers should be sent to the planet's surface. The ultimate goal of the cooperation is a joint NASA-ESA Mars sample return mission. Cooperation on Mars explorations missions is underpinned by the high cost of the national Mars missions both in the USA and in Europe.[149]

International Space Station

In November 2009 the ISS celebrated nine years of constant inhabitancy; starting in May the number of ISS inhabitants increased to six.[150] In November the Russian mini research module Poisk (Search) was delivered to the ISS.[151] The unpiloted and freeflying Japanese HII Transfer Vehicle (HTV) was successfully captured by Canadarm2 and then docked to the ISS. This was the first Canadian cosmic catch for the robotic arm.[152]

The new Russian module (MRM1) for the ISS is ready to be shipped to the US and launched with the shuttle in 2010.[153] The partners are thinking about extending the ISS operations until at least 2020.[154] Russia intends to save its ISS modules beyond 2020 and use them as a new orbital outpost for other space missions.[155]

2009 Space Security Impact

Greater cooperation on space activities has an overall positive impact on space security. It fosters an environment of multilateral cooperation in scientific research. Cooperation among countries with different levels of development also allows more opportunities for space exploration by nations not traditionally involved. Cooperation can also increase the transparency of space activities, further reducing potential conflicts in a strategic environment. However, adopting criteria to engage in space cooperation that leads to the exclusion of some states may have a negative impact on space security by further isolating such nations as Iran and North Korea, thus decreasing the likelihood of bringing them into an eventual space security regime.

Trend 4.4: 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 US 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 Medium Earth Orbit (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 US Department of Defense and its military allies.

Initially conceived as a military system, GPS military applications include navigation, target tracking, missile and projectile guidance, search-and-rescue, and reconnaissance. The system gradually diversified and grew to the point that, by 2001, military uses of the GPS accounted for only about two percent of its total market. For instance, the commercial air transportation industry, which carries over two billion passengers a year, relies heavily on GPS.[156] US companies receive about half of GPS product revenues, but US customers account for only about one-third of the revenue base. Demonstrating the growing importance of satellite navigation for civilian uses, former US President George W. Bush announced in 2007 that next-generation GPS Block III satellites will not have the selective availability 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."[157]

The Russian GLONASS system 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.[158] 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.[159] 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.[160] Russia has extended cooperation on GLONASS to China and India[161] and continues to allocate significant funding for system upgrades, independent of the Roscosmos budget. For 2009, the budget for GLONASS alone was close to $1-billion.

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.[162] After a delay of five years, 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.[163] 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.[164]

The Chinese Beidou system is experimental and limited to regional uses. It works on a different principle from that of the GPS or GLONASS, operating four satellites in geostationary orbit.[165] In 2006 China announced that it will extend Beidou into a global system called Compass or Beidou-2 for military, civilian, and commercial use.[166] 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.[167] Similarly, Japan is developing the Quazi-Zenith Satellite System (QZSS), which is to consist of a few satellites interoperable with GPS in Highly Elliptical Orbit to enhance regional navigation over Japan, but operating separately from GPS, providing guaranteed service.[168] The system is expected to be operational by 2013.[169]

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 the US system. 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 (see Trend 1.3).

Remote sensing

Remote sensing satellites are used extensively for a variety of Earth observation (EO) functions, including weather forecasting; surveillance of borders and coastal waters; monitoring of crops, fisheries, and forests; and monitoring natural disasters such as hurricanes, droughts, floods, volcanic eruptions, earthquakes, tsunamis, and avalanches. Access to EO data is spreading worldwide, although not without difficulties.[170] To ensure truly broad access to data, agencies across the globe are working to enhance the efficiency of data sharing with international partners.[171]

The European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) provides meteorological data for Europeans. The US National Oceanic and Atmospheric Administration (NOAA), founded in 1970, provides the US with meteorological services.[172] Satellite operators from China, Europe, India, Japan, Russia, and the US, 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.[173]

The Global Earth Observation System of Systems (GEOSS) has the goal of "establishing an international, comprehensive, coordinated and sustained Earth Observation System."[174] It is coordinated by the Group on Earth Observation, whose members currently include 77 states and the European Commission.[175] Begun 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.[176] The European GMES initiative is another example of a centralized database of Earth observation data made available to users around the world.[177]

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."[178] Other member organizations include the CSA, NOAA, ISRO, the Argentine Space Agency, the US Geological Survey, the British National Space Centre, CNSA, and DMC International Imaging, which bring together resources from over 20 spacecraft.[179] DMC International Imaging operates satellites for the Disaster Monitoring

Constellation, which is a collaboration of Algeria, China, Nigeria, Spain, Thailand, Turkey, the UK, and Vietnam. The project, initiated by China, utilizes dedicated microsatellites to provide emergency Earth imaging for disaster relief as well as daily imaging capabilities to partner states.[180]

In 1979 COSPAS-SARSAT, the International Satellite System for Search and Rescue (SAR) was founded by Canada, France, the USSR, and the US 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 SAR authorities worldwide, with no discrimination, independent of country participation in the management of the program.[181] 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.[182]

2009 Development

Satellite navigation systems around the globe continue to evolve

The Chinese Beidou (Compass) system is expected to start providing free navigation services by 2020.[183] The second satellite of the system was successfully launched and deployed in April 2009. Another 10 are planned for launch within the next two years.[184]

Despite the finding that the Galileo project was "ill-prepared" and lacked proper governance by the European Commission,[185] it continues to be developed and the EU held the Growing Galileo conference in January 2009.[186] In addition, the European Commission pronounced the European Geostationary Navigation Overlay Service (EGNOS) operational as of October 2009.[187] The Commission acquired ownership of EGNOS in April 2009.

Russia did not reduce funding for GLONASS is spite of the economic crisis.[188] In February 2009, the Russian parliament also adopted a new federal law on navigation activity.[189] In December it launched three modernized satellites, bringing the number of satellites to 22, 16 of which are operational. Three more launches are planned for 2010.[190] Alongside these developments, it was widely discussed[191] that the US GPS system might start deteriorating as soon as 2010.[192]

2009 Development

Disaster relief and remote sensing capabilities continue to be developed

The UK-DMC2 and Spanish Deimos-1[193] spacecraft were launched to support the Disaster Monitoring Constellation,[194] which includes five other satellites: AlSat-1 (Algeria), NigeriaSat-1 (Nigeria), UK-DMC, Beijing-1, and BilSat-1(Turkey).

The Group on Earth Observations (GEO) adopted its 2009–2011 work plan in December 2009.[195] GEOSS Data Sharing Principles may be adopted at GEO-VII in November 2010.[196] As well, the 2010–2011 work plan for UN SPIDER was adopted in April 2009.[197] And ESA and EUMETSAT entered a framework cooperation agreement regarding the implementation of the GMES initiative, particularly relating to Environment and Climate Change.[198]

A number of EO satellites were launched during 2009. Russian's new weather satellite Meteor-M was launched together with the Sterkh-2. In September India launched Oceansat-2, a 900-kg earth remote sensing satellite.[199] The satellite will monitor the oceans and is capable of covering up to 70% of the surface of the earth.[200] In April, ISRO also launched two other EO satellites — a radar-imaging satellite (RISAT2) and an education cubesat ANUSAT.[201]

China launched two remote sensing satellites: Yaogan VI (for land resources survey, environmental surveillance and protection, urban planning, crop yield estimates, disaster prevention and reduction, and space science experiments)[202] and VII (for scientific purposes, land resources survey, crop yield estimates and disaster prevention and reduction).[203]

As mentioned earlier, ESA's SMOS satellite was successfully launched in 2009.[204] Japan launched Greenhouse Gases Observing Satellite (GOSAT) Ibuki in January 2009.[205] About a month later NASA attempted to launch its Orbiting Carbon Observatory (OCO) satellite, but the satellite did not reach orbit.[206] Apparently a replacement satellite will be developed soon.[207]

Countries such as the United Arab Emirates,[208] South Africa (SumbandillaSat),[209] and Malaysia[210] acquired their first earth observation satellites in 2009. South Korea is planning to join the club in 2010 with its first meteorological geostationary satellite.[211]

2009 Space Security Impact

Earth observation satellites provide valuable data that can be used to support decision-making for peaceful national purposes. It is not yet clear if collaborative projects such as the Global Earth Observation System of Systems will succeed. It remains to be seen whether the systems that make it up will work more effectively when integrated. The growing use of remote sensing data to manage a range of global challenges, including disaster monitoring and response, is positive for space security insofar as it further links the security of Earth to the security of space, expands space applications to include additional users, and encourages international collaboration and cooperation on an important space capability. Satellite navigation activities should not have any negative impact on overall space security but, given the considerable international coordination and cooperation that is required, the interoperability of these systems may face some difficulties related to the allocation of frequencies as well as the disposal of old satellites.

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 individuals. In 2009 alone, the world satellite industry had revenues in excess of $160-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. Global revenues from 24 commercial launch events in 2009 were close to $2.5-billion,[2] almost duplicating the amount from five years before.[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 impending retirement of the space shuttle in the US, 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 have constrained 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 multifaceted 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. The lack of clarity on the implications of this clause could stifle entrepreneurship and growth in the commercial space industry and future conflicts over the issue could decrease space security if not addressed in a timely manner.

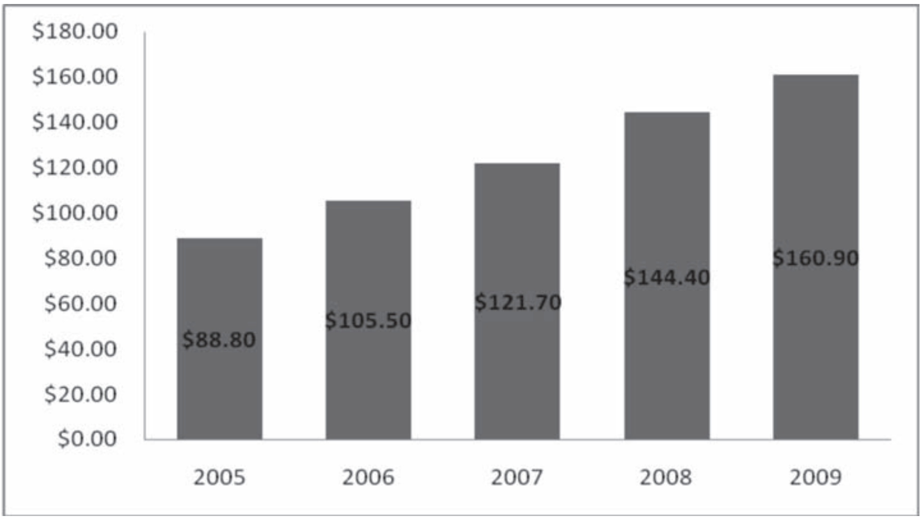
Growth in space commerce has already led to greater competition for scarce space resources such as orbital slots and radiofrequencies. To date, the International Telecommunication Union (ITU) and national regulators have been able to manage inter- and intra-industry tensions. However, strong terrestrial 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: Continued overall growth in the global commercial space industry

Commercial space revenues have steadily increased since the mid-1990s, when the industry first started to grow significantly. Between 2008 and 2009 all four sectors of the satellite industry (ground equipment, satellite services, launch industry, and satellite manufacturing) grew, led by satellite services. Unlike the manufacturing and launch industry, satellite services such as telecommunications have seen growth that has been largely driven by commercial rather than government demand, in a trend that is rapidly being 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.[4] Satellite industry revenues were first reported in 1978, when *US Industrial Outlook* reported 1976 Communication Satellite Corporation operating revenues of almost $154-million.[5] By 1980 it is estimated that the worldwide commercial space sector already accounted for $2.1-billion.[6] Individual consumers are becoming important stakeholders in space through their demand for telecommunications services, particularly Direct Broadcasting Services but also their use of global satellite positioning and commercial remote sensing images.

Figure 5.1: World satellite industry revenues by year (in $B)[7]



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, 1999) and International Telecommunications Satellite Organization (Intelsat, 2001) were privatized in 1999 and 2001 respectively.[8] 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.

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, but are beginning to recover and stood at 24 globally in 2009.[9] In 2009 revenues from commercial launch events increased about $520-million from their 2008 levels and the commercial launch market continues to be dominated by Russia and Europe, followed by the US (See Figure 5.5). In recent years, Europe and Russia have dominated the commercial launch market. As well, of the 36 commercially launched payloads in 2009, 20 satellites went to GEO[10] — a reflection of the growing demand for telecommunication services.

More satellite launches and a growing satellite services sector have a direct impact on the commercial manufacturing industry. Although satellite manufacturers continue to suffer from pressure to lower prices, strong demand for broadcasting, broadband, and mobile satellite services combined with a strong replacement market to drive an increase in orders that is projected to continue.[11] A total of 36 payloads were commercially launched into orbit in 2009, of which 24 provide commercial services and 12 perform civil government or military missions.[12]

The shape of the commercial space industry is beginning to shift as it becomes more global. Though still dominated by Europe, Russia, and the US, other countries like India and China are starting to become involved in this industry. India is reportedly positioning itself to compete for a portion of the commercial launch service market by offering lower-cost launches,[13] and it also intends to compete in the satellite manufacturing industry.[14] For the first time in 2007, China both manufactured and launched a satellite for another country, Nigeria's Nigcomsat-1.[15] Developing countries are the prime focus of these efforts.[16] Moreover, because it uses no US components, China is marketing its manufactured satellites as free of International Traffic in Arms Regulations (ITAR) restrictions, reportedly at prices below industry standard.[17] (See chapter 3 for details on ITAR.)

2009 Development

Consumer television services drive growth in space-based commercial sector

Overall, the largest space industry companies continued to exhibit rising revenue figures in 2009.[18] SES held fast to its projections of 5 percent growth, in spite of weaknesses in its ground services business and the soft North American market,[19] losing to Norway's Telenor a major capacity-lease contract with conglomerate Liberty Global's UPC.[20] Both SES and Telenor cited continued health in the European DTH market as a factor in the desirability of UPC's business.[21] Although there are fewer viewers, these numbers are offset by higher priced multi-room and high definition subscriptions.[22] SES stated that "satellite prices are holding steady in the worst cases and trending slightly upward otherwise."[23]

Eutelsat's revenue growth was 7.2 percent better than forecast for 2008-09.[24] Television subscriber services and higher contract-renew rates for government businesses were responsible for the increases, which existed even when the increased value of the US dollar relative to the Euro was removed from calculations.[25] The volume of orders rose at Thales but its revenue was flat.[26]

Consistent with these figures is India's report that the number of Indian households subscribing to DTH pay television rose by nearly 18 percent in the three months ending 31 March 2009 compared to 31 December 2008.[27] Although the Indian regulatory environment has created obstacles to non-Indian satellite fleet operators, ISRO and its Antrix commercial arm have allowed non-Indian systems into the market conditionally. The caveat is that the government operator can purchase the capacity for future resale to Indian subscribers.[28]

EADS Astrium was the big winner in 2009, reporting a 29 percent increase in revenue and a 22 percent increase in order backlog compared to the year prior.[29] However, some of this boost is attributable to catch-up payments for incentive milestones, paid to the company by unnamed commercial satellite customers.[30] Globalstar and Orbital Sciences both exhibited declines, the former in subscriber and revenue growth and the latter in revenue and profit related to satellite, launch vehicle, and missile defense programs.[31]

2009 Development

Economic crisis impacts some aspects of commercial space while others prove immune

Despite the declines suffered by global business in general, including some space industries, space insurance is becoming neither more expensive nor more difficult to obtain.[32] Space premiums totaled approximately $930-million, while paid-out claims came to $320-million. As a result, the space market is attracting new entrants, forcing premium rates downward. Because of the decline in global stock markets, insurers were forced to rely more heavily on premium income as a revenue source in 2009.[33] Space insurance has resisted the trend to raise premiums during the global economic crisis, apparent in other classes of insurance. In fact, rates have dropped from 2.5 percent to 2 percent for in-orbit insurance.

In an effort to reorganize its debt, Sea Launch filed Chapter 11 in US Bankruptcy Court, listing assets of up to $500-million against liabilities of more than $1-billion.[34] Although Sea Launch's troubles date back to a launch failure in 2007, the company attributed its bankruptcy filing to factors flowing from the global economic crisis, such as the weak commercial launch industry, skyrocketing hardware costs, the credit crunch, and intense competition from other launch providers.[35] Managers from the two companies selling US Delta and Atlas rockets also blame pricing for the soft launch market.[36] As well, the US division of ICO Global Communications filed for protection under Chapter 11 in an effort to recover investment costs associated with its ICO-G1 satellite and restructure the substantial debt associated with its hardware suppliers.[37]

ProtoStar filed for Chapter 11 bankruptcy protection in July, after problems with interference and frequency coordination.[38] The company's second Ku band satellite was scheduled to operate a mere half a degree away from the SES New Skies NSS-11 satellite.[39] The ITU determined that SES New Skies' claim had priority, making it unlikely that ProtoStar 2 could operate in the scheduled frequencies.

The decline of the US dollar had a negative impact on performance of some European aerospace contractors. The EADS Astrium space unit implemented front-end cost-cutting measures to offset the effects of both the decline of the dollar and the downturn in the global credit market.[40] Thales was in a better situation, as a smaller proportion of its revenues are subject to valuation swings based on the exchange rate. ILS actually benefited from currency exchange fluctuation; the drop in the Russian ruble's value against the US dollar gave ILS the necessary edge to capitalize on Russian government launch delays and to capture some of Sea Launch's lost business.[41]

President Obama signed into law the American Recovery and Reinvestment Act on 17 February 2009.[42] Satellite-based services are eligible to compete for grants and loans under the Act as part of President Obama's initiative to extend broadband communications to underserved communities in the US.[43] The Act has three stated goals: 1) create new jobs and retain existing ones, 2) drive economic activity and long-term growth, and 3) facilitate accountability and transparency in government spending.[44] Ideally, investment in broadband infrastructure will promote the creation of new jobs with equipment dealers, installers, customer care agents, spacecraft manufacturers, and launch firms.[45] To that end, the National Telecommunications and Information Administration (NTIA), US Department of Agriculture (USDA) Office of Rural Development, and the FCC hosted informational meetings to discuss the national broadband plan.[46]

As well, Australia's Prime Minister Kevin Rudd announced plans to invest approximately A$43-billion ($31-billion) in national broadband infrastructure.[47] The plan is to provide access to 100 megabits per second for 90 percent of Australian homes and businesses by 2018 and involves both private and public sector funding.[48]

2009 Development

Major satellite operators form coalition

EchoStar, Intelsat, SES, and Telesat formed a coalition to develop worldwide competition for the provision of commercial satellite launches in hopes that this will afford increased cost-effective access to space.[49] The coalition was formed in response to two developments that have restricted commercial access to space. First, the Atlas and the Delta are now manufactured by a single company, ULA, which sells almost its entire launch capacity to the US Government. Second, one of the world's most reliable launchers is manufactured in China, rendering it off-limits to US satellite companies.[50] In a similar vein, satellite operators launched an industry initiative, the Space Data Association Ltd. (SDA), "dedicated to sharing critical operational data in support of satellite operations, improving flight safety and preserving the space environment."[51] The SDA was incorporated in November 2009.

2009 Space Security Impact

The continued overall growth in the commercial space industry and the ever increasing revenues that are produced constitute a positive development for space security insofar as the pool of stakeholders with a direct interest in preserving space as a peaceful domain is steadily growing. Moreover, cooperative efforts in this industry and the resulting coalitions that lead to cost-effectiveness in commercial space operations will likely be conducive to greater space access. If demand for space resources such as orbital slots and radio frequencies exceeds supply, as is starting to be the case, the result could be friction among providers of commercial services. However, such friction need not necessarily be to the detriment of space security, as it could set the stage for a more coordinated and collaborative approach for the allocation of scarce space resources.

Trend 5.2: Commercial sector supporting increased access to space

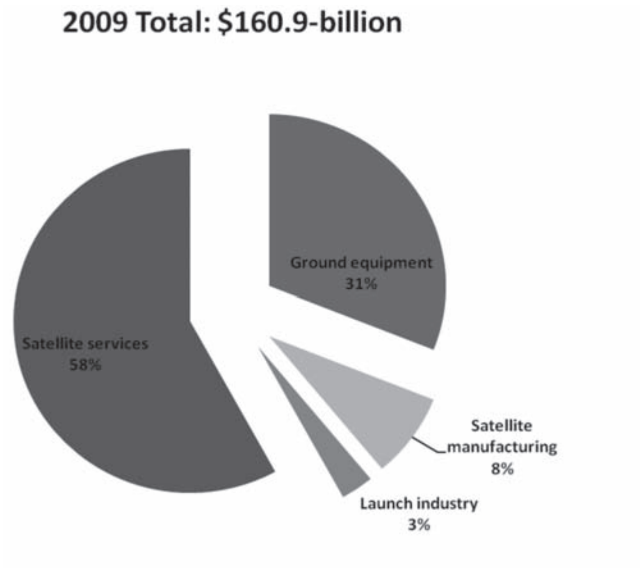
Space Launches

A commercial launch is defined as one in which at least one of the payload's launch contracts was subject to international competition, so that, in principle, a launch opportunity was available to any capable launch services provider. Russian, European, and American 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, except in the case of Sea Launch, which is designated as "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 US competitors during the period when the US 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 percent of the commercial launch market during the period 1988-1997.[52] The Chinese Long March and the Russian Proton rocket entered the market in the early and mid-1990s. The Long March was later pressured out of the commercial market due to "reliability and export control issues."[53] However, China has opened the possibility of reentering the commercial spaceflight market.[54] Today Ariane, Proton, and Zenit rockets dominate the commercial launch market.

Figure 5.2: Worldwide satellite industry revenue by sector (2009).[55]



Japanese commercial efforts have suffered from technical difficulties and its H-2 launch vehicle was shelved in 1999 after flight failures.[56] Although the H-2 was revived in 2005, Japan lags behind Russia, Europe, the US, and China in global launches.[57] In May 1999 India's Augmented Polar Satellite Launch Vehicle performed the country's first Low Earth Orbit (LEO) commercial launch, placing German and South Korean satellites in orbit.[58]

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 US; 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 Service (ILS), Eurockot Launch Services GmbH, and Starsem. Sea Launch — comprised of Boeing (US), 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 (US), and RSC-Energiya (Russia). In 2006 Lockheed sold its share to US 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 builder 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 UK's Surrey Satellite Technology Ltd. have used piggyback launches — a small satellite is attached to a larger one to avoid costs for a dedicated launch. It is now also common to use dedicated launches to deploy clusters of smaller satellites on small launchers such as the Cosmos rocket and India's PSLV.

Commercial Earth Imagery

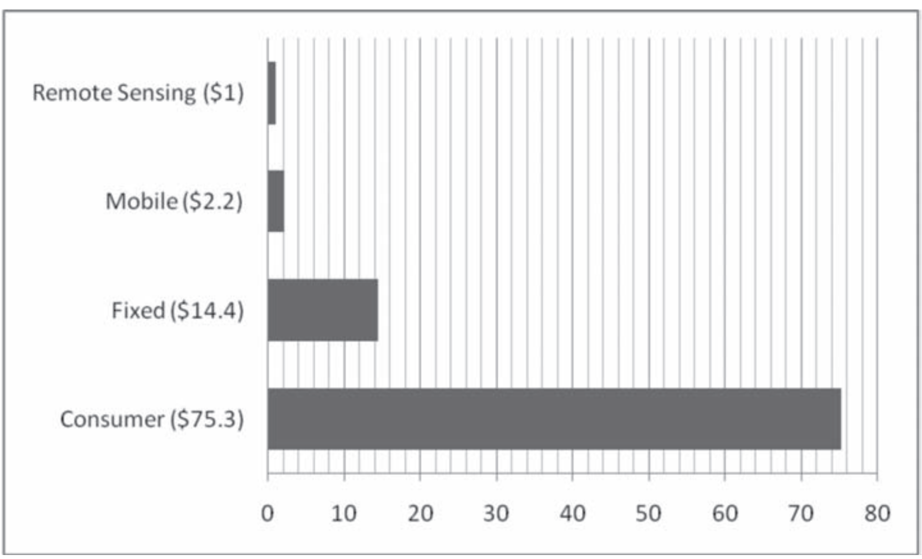
Until a few years ago only a government could gain access to remote sensing imagery; today any individual or organization with access to the Internet can use these services through Google Maps, Google Earth, and Yahoo Maps programs.[59] Currently several companies in Canada, France, Germany, Israel, Russia, and the US 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 US government first promised international civilian use of its planned Global Positioning System (GPS) in 1983, following the downing of Korean Airlines Flight 007 that strayed over Soviet territory, and in 1991 pledged that it would be freely available to the international community beginning in 1993.[60] US GPS civilian signals have dominated the commercial market, but new competition may emerge from the EU's Galileo system, which is specifically designed for civilian and commercial use, and Russia's GLONASS.[61] China's regional Beidou system will also be available for commercial use.[62] (For further information on satellite navigations 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.[63] The core of revenues to the commercial satellite positioning industry is sales of ground-based equipment. Sales to commercial users first outpaced those to military buyers in the mid-1990s.[64] 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.[65]

Figure 5.3: 2009 worldwide satellite services revenue (in $B)[66]



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 early December 2004 the US Congress passed into law 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 US, allowing it to issue permits to private spacecraft operators to send customers into space.[67] In 2006 the European Space Agency (ESA) announced the "Survey of European Privately-funded Vehicles for Commercial Human Spaceflight" to support the emergence of a European commercial space transportation industry.[68]

The market for commercial space transportation remains small but has attracted a great deal of interest. By the end of 2009 seven private citizens had purchased and flown on orbital spaceflights through Space Adventures, which sells seats on the Russian Soyuz.[69] 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.[70] Canadian Guy Laliberté is the latest private citizen to fly in space through Space Adventures. In June 2004 SpaceShipOne, developed by US Scaled Composites, became the first private manned spacecraft, but only conducted suborbital flights.[71] It was followed by SpaceShipTwo, unveiled in December 2009 and expected to carry passengers on suborbital flights starting in 2011. Still, the number of space tourists will be limited until prohibitively high costs are lowered. While the industry continues to face challenges — including a lack of international legal safety standards, high launch costs, and export regulations[72] — important liability standards are beginning to emerge. In 2006 the FAA released final rules governing private human spaceflight requirements for crew and participants.[73] Final rules were also issued for FAA launch vehicle safety approvals.[74]

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.[75] 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.[76]

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.[77] The approximate premium for launch vehicles (as a percentage of launch costs) has recently been in the range of: Ariane-5, 6.5 percent; Atlas-5, 6.6 percent; Sea Launch, 7.5 percent; Chinese Long March, 7.9 percent; and Proton, 10.3 percent.[78] Terms have also become more restricted. Insurers do not generally quote premiums more than 12 months prior to a scheduled launch and in-orbit rates are usually limited to one-year terms and often do not cover events such as terrorism or "Acts of God."[79] 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.[80]

With the advent of space tourism, the space insurance industry may expand to cover human spaceflight. In the US, 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.[81]

2009 Development

Private human access to space slowly continues

The year 2009 saw another visit to the ISS by a private citizen. The latest spaceflight participant was Cirque du Soleil founder, Guy Laliberté.[82] The former clown used his visit to space as a platform to raise awareness about One Drop, an organization dedicated to freshwater access for all humankind.[83]

Private access to space took a front seat in the Augustine report. Norman Augustine and a panel of top-notch experts examined options available to support safe, affordable, and innovative human spaceflight, presenting their findings to the White House after three days of public hearings held in states housing NASA's major space centers — Texas, Alabama, and Florida.[84] The report, which came out in September, recommended extending the life of the ISS until 2020, but found overly optimistic the timetable for alternative transportation from earth to the station (Orion and Ares), which had been NASA's focus. Instead, the Augustine panel advocated reliance upon private sector transport for cargo and possibly crew.[85] (For further details on the Augustine Commission see Chapter 3.)

Those private sector alternatives continued development. Virgin Galactic successfully completed the first phase of tests of the rocket motor for its SpaceShip Two.[86] In August, Sir Richard Branson took his first flight in VMS Eve, the Virgin mothership that will launch the spaceships.[87] On 7 December 2009, SpaceShip Two made its debut at the Mojave Desert spaceport during a spectacular demonstration.[88] And SpaceX founder Elon Musk announced his company's interest in providing manned spaceflight to Mars — a far more ambitious goal than LEO missions.[89]

2009 Development

Investment in commercial space on rise

Perhaps partially in response to the Augustine report's recommendations regarding the private sector's future role in space transport, investment in commercial spaceflight is on the rise.[90] The Tauri Group, a Virginia consulting firm, and the Commercial Spaceflight Federation surveyed 22 companies involved in commercial human spaceflight and discovered that the total investment in that sector had risen by 20 percent last year to a collective total of $1.46-billion.[91]

Aabar Investments PJSC stepped up and bought a third of Virgin Galactic for $280-million.[92] Aabar is a company 71.23 percent owned by the International Petroleum Investment Co., which is itself fully owned by the government of Abu Dhabi. The transaction is subject to regulatory clearances in the US and is slated to utilize Abu Dhabi's proposed spaceport, to be built by Aabar, with funds committed to small satellite launch capability.

2009 Development

Commercial operators expand availability of imagery and satellite services

US President Obama approved a new electro-optical satellite imaging plan; the US National Geospatial-Intelligence Agency (NGA) intends to buy commercial imaging with ground resolution as fine as a quarter meter under the contracting vehicle EnhancedView, part of a larger satellite imagery strategy intended to service both the military and intelligence communities.[93] Obama's plan contemplates procurement of two imaging satellites and increased use of commercially available imagery.[94] Imagery provided by Germany's TerraSAR-X presently meets NGA's advertised specifications.[95]

Google Inc. and NASA cooperated to offer a new add-on to Google Earth — the "Live from Mars" update for Google Mars 3-D. The update incorporates features such as "watching orbital tracks of spacecraft in real-time, peeling back historical globe maps of Mars and taking a guided fly-around tour of the red planet."[96] Users can also go to the locations of some of NASA's landers and rovers. The imagery available is rapidly improving. Currently, GeoEye-1 is able to take pictures with a resolution of 50 centimeters; the company is developing GeoEye-2, capable of 25-centimeter resolution.[97] An Italian earth observation company, e-Geos, was formed to leverage the country's Cosmo-SkyMed radar satellite constellation into a viable commercial business.[98] E-Geos is funded by public and private investors.

Figure: 5.4: Commercial remote sensing satellites

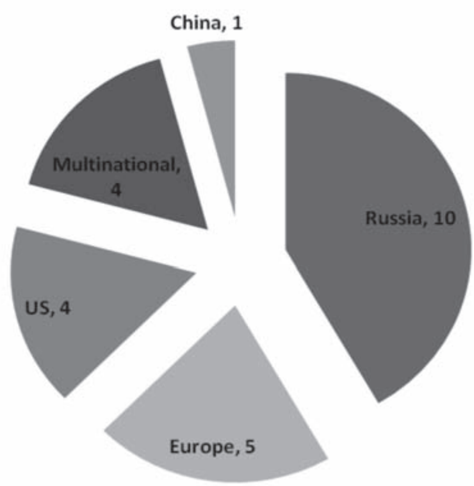
System	Operator	Current Satellites	Type	Highest Resolution (meters)
EROS	ImageSat International	EROS A	Optical	1.5
		EROS B	Optical	0.7
		EROS C	Optical	0.7
IKONOS	GeoEye	IKONOS-2	Optical	0.8
OrbView	GeoEye	OrbView-2	Optical	1,000
GeoEye	GeoEye	GeoEye-1	Optical	0.41
QuickBird	DigitalGlobe	EarlyBird	Optical	3
		QuickBird-1	Optical	1
		QuickBird	Optical	0.6
Radarsat	MDA	Radarsat-1	Radar	8
		Radarsat-2	Radar	3
SPOT	Spot Image	SPOT 2	Optical	10
		SPOT 4	Optical	10
		SPOT 5	Optical	2.5
WorldView	DigitalGlobe	WorldView-1	Optical	0.5
Disaster Monitoring Constellation	DMC International Imaging	AISAT-1 (Algeria)	Optical	32
		NigeriaSAT-1 (Nigeria)	Optical	32
		UK-DMC (United Kingdom)	Optical	32
		Beijing-1 (China)	Optical	4
TerraSar		TerraSar-X	Radar	1
RapidEye	RapidEye	RapidEye-1	Optical	6
		RapidEye-2	Optical	6
		RapidEye-3	Optical	6
		RapidEye-4	Optical	6
		RapidEye-5	Optical	6

2009 Development

New launchers with increased capacity under development

Ares, NASA's heavy lift launcher, had its first unmanned flight on 28 October 2009.[99] Despite this, the Obama administration ditched plans for the Ares series, instead committing $1-billion to develop another heavy lift launcher.[100] France, too, plans to support Arianespace for the development of a next-generation heavy lift rocket to replace Ariane 5. [101] Also on the drawing board in Europe is the Vega, a vehicle intended to service low-Earth orbit science and observation missions.

Figure 5.5: Commercial orbital launches by country in 2009[102]



On 13 July Space-X successfully launched to orbit a Malaysian earth observation satellite, its first commercial launch, onboard its Falcon-1 rocket.[103] Space-X will use Falcon-9 to launch its Dragon craft, hoping to transport cargo to and from the ISS. Masten Space Systems of Mojave, California, has developed a small, low-cost vertical-takeoff-and-landing (VTOL) launch vehicle, the Zombie. Although the number of companies and countries able to launch continues to increase, space insurers are concerned that the new entrants will also spur a rise in the number of in-orbit failures.[104]

2009 Space Security Impact

Increased access to space has both positive and negative impacts on space security. As more entities, both government and private, are able to reach space, the benefits of the resource spread, ideally in an equitable manner. However, increased access to space also translates into a more congested environment, thus further straining an already complex domain that lacks effective mechanisms for the allocation of scarce resources. Private access to space, although still at an embryonic stage, may yield a positive impact on space security as private citizens, many previously oblivious to the security challenges facing outer space, will expand the number of stakeholders with a vested interest in space security beyond governments and commercial operators. Such access may also challenge both the sustainability of the space environment as well as the applicability of international laws to the largely uncharted realm of space tourism.

Trend 5.3: Government dependency on the commercial space sector means that subsidies and national security concerns remain important

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. On the other hand, due to the security concerns associated with commercial space technologies, governments also 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 the success of the US commercial launch industry is viewed as "beneficial to national interests."[105] Indeed, the US Space Launch Cost Reduction Act of 1998 established a low-interest loan program to support the development of reusable vehicles.[106] In 2002 the US Air Force requested $1-billion in subsidies for development of Lockheed Martin's Atlas-5 and Boeing's Delta-4 vehicles as part of the Evolved Expendable Launch Vehicle (EELV) program.[107] To maintain the financial feasibility of the program, the 2005 Space Transportation Policy requires the Department of Defense (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 forcing price-driven competition.[108] Similarly, the US Commercial Remote Sensing Space Policy directs the US 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."[109]

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.[110] The program explicitly recognizes a competitive European launch industry as a strategic asset and is designed to ensure sustained government funding for launcher design and development, infrastructure maintenance, and upkeep.[111] 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."[112]

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.[113] China's space industry is indistinguishable from its government, with public and private institutions closely intertwined.[114] 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 US NGA's NextView program subsidizes commercial remote sensing to meet military needs for high-resolution images, which are then for sale commercially at a lower resolution.[115] Similarly, the commercial Radarsat-2 satellite was largely paid for by the Canadian Space Agency (CSA), by pre-purchasing $445-million in data, which is also sold commercially[116] in an arrangement similar to that for Germany's TerrSar-X remote sensing satellite.[117] Remote sensing is not the only instance of such partnering. The UK's Skynet-5 secure military communications satellite is operated by a private company, which sells its excess capacity.[118] 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 US firm to protect national interests.[119]

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 (MTCR), 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.[120] However, export practices differ among members. For example, although the US "Iran Nonproliferation Act" of 2000 limited the transfer of ballistic missile technology to Iran, Russia is still willing to provide such technology under its Federal Law on Export Control.[121] 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.[122]

From the late 1980s to late 1990s, the US had agreements with China, Russia, and Ukraine to enable the launch from foreign sites of US satellites and satellites carrying American components. However, in 1998 a US investigation into several successive Chinese launch failures led to allegations about the transfer of sensitive US 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 US Munitions List (USML) in 1999.[123] The new legislation treated satellite sales as weapons sales, making international collaboration more heavily regulated, expensive, and time consuming.

Exports of USML items are licensed under the ITAR regime, which adds several additional reporting and licensing requirements for US 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."[124] Industries are therefore maneuvering around ITAR restrictions by purchasing ITAR-free satellites and launch services. China was able to launch the Chinasat 6B telecommunications satellite, built by Thales Alenia Space, in its Long March launcher because the satellite was built without US components. Thales Alenia Space is the only western company that has developed a product line deliberately designed to avoid US trade restrictions on its satellite components.[125]

Finally, because certain commercial satellite imagery can serve military purposes, a number of states have implemented regulations on the sector. The 2003 US Commercial Remote Sensing Policy sets up a two-tiered licensing regime that limits the sale of sensitive imagery.[126] In 2001 the French Ministry of Defense prohibited open sales of commercial Spot Image satellite imagery of Afghanistan.[127] Indian laws require the 'scrubbing' of commercial satellite images of sensitive Indian sites.[128] Canada has recently passed a regulatory regime that will give the Canadian government "shutter control" over the collection and dissemination of commercial satellite imagery due to national security or foreign policy concerns, and priority access in response to possible future major security crises.[129] Analysts note that competition among increasing numbers of commercial satellite imagery providers may eventually make shutter control prohibitively expensive.[130]

Commercial space systems as critical infrastructure

Space systems, including commercial systems, are increasingly considered to be critical national infrastructure and strategic assets. During the overcapacity of the 1990s, the US military began employing commercial satellite systems for non-sensitive communications and imagery applications. During Operation Enduring Freedom in Afghanistan in 2001 the US military used 700 megabytes per second of bandwidth, 75 percent of which was from commercial systems.[131]

The US DOD is the largest customer for the satellite industry, although it accounts for less than 10 percent of most large satellite operators' revenues.[132] By November 2003 it was estimated that the US military was spending more than $400-million each year on commercial satellite services.[133] By 2006 this figure had jumped to more than $1-billion a year for commercial broadband satellite services alone.[134] For instance, after the first three years of Operation Iraqi Freedom, it was reported that more than 80 percent of satellite bandwidth utilized by DOD was provided by commercial broadband satellite operators.[135] DOD is studying different acquisition methods to facilitate satellite service procurement.[136] To this end, a US Government Accountability Office report recommended that the US military be more strategic in planning for and acquiring bandwidth by, among other things, consolidating bandwidth needs among military actors to capitalize on bulk purchases.[137]

European states also view the space sector as a strategic asset "contributing to the independence, security, and prosperity of Europe."[138] Similarly, China's 2006 White Paper on Space Activities identifies the development of an independent space industry as a key component to its goals for outer space.[139]

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 of this volume, 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.[140] The importance of the private sector in space safety and governance issues has also been highlighted by the US government. Under a program called the Commercial and Foreign Entities (CFE) program, the US DOD is attempting to align government and industry resources to address growing space security challenges and to increase space situational awareness.[141] The program is intended to enhance safety, reduce risk, and contribute to the sustainable use of key orbits.[142] The draft EU Code of Conduct for Outer Space Activities[143], specifically addresses issues of harmful interference with space assets. However, it is not legally binding and the level of international support it receives when it opens for signatures in the latter half of 2010 remains to be seen.

2009 Development

Military dependence on the commercial sector continues to expand

Commercial satellite operators are investigating ways to create a more seamless interdependence between the public and private sectors for hosted payloads.[144] Noting the disparity in timeline from inception to actual launch between a completely private project and a government project, operators are working with manufacturers to develop in satellites a plug-and-play feature that would allow government customers to design hosted payloads to a standard interface, thereby allowing them to contract for space on an as-available basis.

Spacehab Inc. changed its name to Astrotech Corp. and is shifting its focus from offering payload processing services to commercial customers to offering similar services to the military.[145] Astrotech also plans to expand past its focus on prelaunch services, instead offering end-to-end mission assurance as part of a new venture called Astrotech-Syncomm. The new endeavor is in partnership with Space Florida, a public-private partnership driving economic development in Florida's space industry.

In the UK, Paradigm Secure Communications was established to provide satellite communication services to the Ministry of Defence with the operation of the Skynet 4 and 5 satellite fleets, supplying X-band, UHF, and other services to military users.[146] Now expanding to the US, Intelsat General was selected as the preferred distributor of those communication services on satellites operated by Paradigm to the US DOD.

2009 Development

Public-private partnerships on the rise

The interdependence between public and private space sectors continued to grow in 2009. Globalstar received credit backing from the French government, a development which prompted its competitors to claim that it was really a "disguised subsidy."[147] New Canadian regulations require better monitoring by firms that construct, mine, or work with industrial explosives in any way. Compliance with the new laws is creating new opportunities for satellite-based services in surveillance by the Iridium satellite network.[148] EADS Astrium formed a partnership with Kazakhstan Gharysh Sapary, a company connected to the Kazakh space agency.[149] The deal requires Astrium to build two Earth observation satellites and set up a satellite integration center in Astana, Kazakhstan, which will be operated as a joint venture and will market the images commercially. Aabar, Virgin Galactic's new partner, is a public-private partnership.[150]

Faced with budgetary cutbacks, NASA is ever more prone to work in tandem with private industry.[151] The Augustine panel recommended more reliance upon private sector transport going forward. Boeing has expressed its desire to research and develop commercially viable space transportation in partnership with NASA.[152] NASA and the US Air Force are developing a "technology roadmap" for a commercial reusable launch vehicle (RLV) industry, hoping to trigger progress toward low-cost, frequent, and reliable access to LEO.[153] Members of Congress representing Central Florida, home to the state's space industry, have introduced a bipartisan bill designed to minimize the negative impact anticipated by the space shuttle's impending retirement.[154] The bill establishes a competitive research and development "Centers of Excellence" program within NASA and creates university-based public-private partnerships to support commercial spaceflight research.

2009 Development

Revision of export controls considered in the US

In response to an often-voiced need for export-control reform, in June 2009 the US House of Representatives passed the Foreign Relations Authorization Act of 2010-11.[155] Now before the Senate Foreign Relations Committee, the bill grants authority to Presidents of the US to remove satellites and related components from the USML.[156] (For further details see Chapter 3.)

SES and Intelsat, with full support from Space Systems/Loral, asked Washington lawmakers to consider lifting the ban on the launch of US commercial satellites from China and India. Without Sea Launch as a viable launch option, the three companies would be forced to rely on either Ariane 5 or the Russian Proton.

2009 Space Security Impact

As the relationship between the public and private sectors becomes more collaborative and cooperative, the polarity between them decreases. This interdependence has a positive impact for space security as conceptions about what constitutes space security will merge and take into consideration the needs of the commercial sector as well as the security of states. As this mutual dependence deepens, multiple-use spacecraft built by commercial operators could become military targets, resulting in an overall decrease in security. On the other hand, the proliferation of dual-use or multi-use assets in space could make a military attack less useful and, therefore, less likely. The range of peaceful space applications could potentially decrease as the commercial industry, lured by profitable government contracts, might divert much of its research and developments efforts to military applications.

Space Support for Terrestrial Military Operations

CHAPTER SIX

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 US 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.[1]

Extensive military space systems were developed by the US 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 US President John F. Kennedy to realize that fears of a missile gap between the US 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 US 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 (GPS), the US 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 US currently leads in the deployment of dedicated space systems to support military operations, accounting for over half of all dedicated military satellites.[2] 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 space actors, although several countries are increasingly pursuing space-based military capabilities. The US and USSR/Russia have launched more than 3,000 military satellites, while the rest of the world has launched under 100. By mid-2010 there were 164 operational dedicated military satellites worldwide, with the US operating approximately 81, Russia 38, and China 12.[3]

Given the overwhelming superiority of US and Russian space-based military capabilities, this chapter identifies developments related to these countries as a distinct space security trend. In addition, it examines the efforts of a growing number of other states that have begun to develop national space systems to support military operations, primarily in the areas of imagery intelligence and communications. Many of these systems are dual-use, meaning that they also support civilian applications. This section does not examine military programs pertaining to space systems protection or negation, or space-based strike capabilities, which are described in separate chapters.

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.

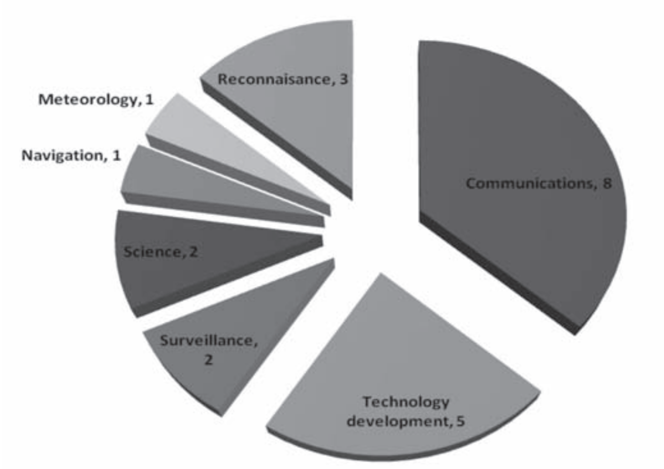
Space assets play an important strategic role in the terrestrial military operations of certain states. In most cases, space systems have augmented the military capabilities of advanced states by enhancing battlefield awareness, including, as mentioned above, precise navigation and targeting support, 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 more incentive to protect them by developing space system protection and negation capabilities, which may 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, but state practice over the past 40 years has generally accepted these applications as peaceful insofar as they are not hostile in space (see Space Laws, Policies, and Doctrines 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.

Figure 6.1: Dedicated military spacecraft launched globally in 2009, by application[4]



Trend 6.1: The US and Russia continue to lead in deploying military space systems

During the Cold War, the US 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 US expanded its military space capabilities. There has been a general decrease in the number of military launches by both states in recent years. However, US 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 integrated with the military. Commercial systems are also playing a rapidly growing military support role. Figures 6.4 and 6.5 provide an overview of US and Russian military satellite launches since 1957.

United States

The US 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 US currently outspends all other states combined on military space applications. The US Department of Defense (DOD) Budget for FY2009 provided $10.7-billion to strengthen space-based capabilities is categories such as Space-Based Infrared Systems, communications satellites, GPS satellites, environmental satellites, Advanced Extremely High Frequency satellites, and launch vehicles.[5] This allocation, which does not include money for the National Reconnaissance Office, National Geo-Spatial Agency, or Missile Defense Agency, constituted an increase of $1.6-billion over the previous fiscal year.[6] US military and intelligence space-based capabilities continue to outpace those of the rest of the world and, by all indications, the US is the nation most dependent on its space systems. While the US is currently upgrading almost all of its major military space systems, they remain robust[7] and technically advanced.

Satellite Communications

Satellite communications have been described by one expert as "the single most important military space capability."[8] The Military Satellite Communication System (Milstar) is currently one of the most important of these systems, providing protected communications for the US Army, Navy, and Air Force through five satellites in Geostationary Orbit (GEO). Replacement of Milstar satellites with Advanced Extremely High Frequency (AEHF) satellites is under way in cooperation with Canada, the UK, and the Netherlands. The US DOD budgeted $2.3-billion for the AEHF program in 2010, up more than 300 percent from $552-million in 2009.[9]

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 (see related development below). The program, whose procurement – if fully developed – had been estimated to cost between $14-billion and $25-billion by 2016,[10] was disrupted by repeated delays and the first launch had been postponed several times.[11]

Figure 6.2: US dedicated military satellites launched in 2009[12]

Satellite	Operator	Function	Orbit	Launch Date	Contractor
Orion/Mentor 4 (Advanced Orion 4, NRO L-26, USA 202)	National Reconnaissance Office (NRO)	Surveillance	GEO	1/18/2009	National Reconnaissance Laboratory
Wideband Global Satcom 2 (WGS-2, USA 204)	Military Satellite Communications - US Air Force	Communications	GEO	4/4/2009	Boeing Satellite Systems
STSS ATRR (Space Tracking and Surveillance System Advanced Technology Risk Reduction Satellite, USA 205)	Missile Defense Agency (MDA)	Technology Development	LEO	5/5/2009	Northrop Grumman
Tacsat 3	Air Force Research Laboratory	Reconnaissance	LEO	5/19/2009	Air Force Research Laboratory/Raytheon
Atmospheric Neutral Density Experiment (ANDE) Castor Sphere	Naval Research Laboratory	Scientific Research	LEO	7/15/2009	Naval Research Laboratory
Atmospheric Neutral Density Experiment (ANDE) Pollux Sphere	Naval Research Laboratory	Scientific Research	LEO	7/15/2009	Naval Research Laboratory
PAN-1 (Palladium at Night, P360, USA 207)	Unknown US agency	Communications	GEO	9/8/2009	Lockheed Martin
STSS Demo-1 (Space Tracking and Surveillance System Demonstrator)	Missile Defense Agency (MDA)	Technology Development	LEO	9/25/2009	Northrop Grumman
STSS Demo-2 (Space Tracking and Surveillance System Demonstrator)	Missile Defense Agency (MDA)	Technology Development	LEO	9/25/2009	Northrop Grumman
DMSP 5D-3 F18 (Defense Meteorological Satellites Program, USA 210)	DOD/NOAA	Meteorology	LEO	10/18/2009	Lockheed Martin Missiles and Space

The Defense Satellite Communications System (DSCS) – the workhorse of the US 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. A planned follow-on to this system, the Wideband Global Satellite System or Wideband Global SATCOM (WGS), is expected to significantly increase available bandwidth. The 2010 budget requested for WGS, intended to transmit data at gigabit speeds, was $335-million, to be used mainly for on-orbit testing of the second and third satellites of the constellation.[13]

In addition to dedicated systems, space-based military communications use commercial operators such as Globalstar, Iridium, Intelsat, Inmarsat, and Telstar. Increased use of unmanned aerial vehicles (UAV) is straining both military and commercial capacity in places such as the Middle East; secure, high-speed, high-volume data transmission is critical to meet current and future demand.[14] The US DOD will likely remain dependent on these services in the future, even with the deployment of new systems.

Early Warning

Space-based early warning systems provide the US with critical missile warning and tracking capabilities. The first such system, the US Missile Defense Alarm System, was first deployed in a polar orbit in 1960. The current US Defense Support Program (DSP) early warning satellites were first launched in the early 1970s and the final one in 2007, providing enhanced coverage of Russia while reducing the number of necessary satellites to four.[15]

The US plans to replace the DSP system with the Space Based Infrared System (SBIRS) to provide advanced surveillance capabilities for missile warning and missile defense. However, by the end of 2009 the SBIRS was more than eight years behind schedule[16] and significantly over budget, with an estimated final cost of more than $10-billion.[17] 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, the Third Generation Infrared Surveillance (3GIRS).[18] The US Space Tracking and Surveillance System (STSS), discussed below, will work with SBIRS to support missile defense responses.

Intelligence

The first US optical Corona satellites for imagery intelligence were launched as early as 1959, with the Soviets following suit by 1962. These early remote sensing satellites had lifetimes of only days and were equipped with film-based cameras. 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 was improved from about 10 m to less than one meter. As early as 1976 the US 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.[19] Open source information suggests that the US 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 today's remote sensing satellites remains classified, the Improved Crystal satellites are believed to have a resolution of up to 6 inches.[20] The US operates between 18 and 27 signals intelligence satellites in four separate systems – the Naval Ocean Surveillance System, Trumpet, Mentor, and Vortex. [21]

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."[22] The Misty Stealth Reconnaissance Imaging program was also cancelled due to costs, schedule delays, and poor performance.[23] An additional setback was caused by the failure of USA-193 in orbit in 2006. These events leave US military reconnaissance capabilities largely based on outdated systems. While there is not a gap in coverage, "the constellation is fragile."[24] In addition, the US military also uses commercial imagery services from DigitalGlobe and GeoEye.

Navigation

In 1964 the first navigation system was deployed for military applications by the US 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 widely, 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). Despite being available commercially, the GPS system provides greater accuracy for military users than for publicly available receivers.

Launch

In 2007 the US 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.[25] 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 US TacSat microsatellite series falls under the 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."[26] The satellites are controlled directly by deployed US commanders.[27] In 2009, two of the TacSat program's satellites were successfully launched, as discussed in the related development below.

The Evolved Expendable Launch Vehicle (EELV) program is a $31.8-billion USAF effort that began in 1994, with the objective of reducing launch costs by at least 25 percent by partnering with industry to develop capabilities that could be used for both commercial and government purposes.[28] To meet future government requirements, both Lockheed Martin and the Boeing Company 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 after the US. Its early warning, imaging intelligence, communications, and navigation systems were developed during the Cold War, and between 70 and 80 percent of spacecraft have exceeded their designed lifespan, making the current operational status of these programs uncertain.[29] Forced to prioritize upgrades, Russia focused first on its early warning systems, and continues to move toward completion of the GLONASS navigation system, which in 2009 was allocated approximately $1-billion.[30] Since 2004 Russia has focused on "maintaining and protecting" its fleet of satellites and developing satellites with post-Soviet technology.[31] 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.[32] 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; the total number of spacecraft placed in orbit during this period exceeded 600.[33] 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 in 2009 (see Figure 6.3 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).[34] Satellites in the civilian Gonets LEO system have been reported to relay information to the Russian military, in addition to other government agencies and private organizations.[35]As recently as 2008, three satellites were successfully added to the Gonets system.[36] The Molniya-1 and -3 communications satellites, which are in Highly Elliptical Orbits (HEO), serve as data relay satellites for both military and civilian use and are to be replaced by the Meridian series of communications satellites.[37] Meridian 1 and Meridian 2 were launched in 2006 and 2009.[38]

Figure 6.3: Russian dedicated military satellites launched in 2009[39]

Satellite	Operator	Function	Orbit	Launch Date	Contractor
Raduga 1-M1 (Cosmos 2450)	Ministry of Defense	Communications	GEO	2/28/2009	Applied Mechanics (NPO)
Rodnik-5 (Cosmos 2451)	Ministry of Defense	Communications	LEO	7/6/2009	OAO ISS
Rodnik-6 (Cosmos 2452)	Ministry of Defense	Communications	LEO	7/6/2009	OAO ISS
Rodnik-7 (Cosmos 2453)	Ministry of Defense	Communications	LEO	7/6/2009	OAO ISS
Parus-98 (Cosmos 2454)	Ministry of Defense	Navigation	LEO	7/21/2009	Information Satellite Systems (formerly NPO-PM)
Lotos-S (Cosmos 2455)	Ministry of Defense	Reconnaissance	LEO	11/20/2009	TsSKB-Progress Samara Space Center and KB Arsenal

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 US 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 US land-based ballistic missiles. The Oko system provides coverage of US 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.[40] 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.[41] At least three satellites that were launched in 2009 have been reported to be part of the OKO network.[42]

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.[43]

Intelligence

The USSR began using film-based optical imagery satellites in 1962 and by the 1980s was able to electronically transmit images while still maintaining a film-based system.[44] 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.[45] 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 was the Tsyklon system deployed in 1968. Tsyklon was followed by the Parus military navigation system, deployed in 1974 and still operating, with an accuracy of about 100 m.[46] Currently, however, 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.[47] The inadequacies of the GLONASS system are also becoming more apparent. Not only has it been inaccurate, providing at best positional accuracy of 10-17 m, but it is also unstable, sometimes providing no reading at all.[48] Despite setbacks, funding for GLONASS continues, as discussed below.

2009 Development

Despite some setbacks in satellite capabilities, the US continues to upgrade its systems

Intelligence

In 2008 critics argued against some US plans for "homemade" satellite imagery, pointing out that commercial operators are already providing similar capabilities.[49] One year later, a central part of the Obama administration's satellite imaging plan calls for buying more commercial space imagery in the short term from such US companies as DigitalGlobe and GeoEye.[50] Specifically, the US National Geospatial-Intelligence Agency (NGA) intends to buy commercial imagery with ground resolution as fine as a quarter-meter and hopes to have contracts with commercial providers in place by spring 2010.[51] (For further details see Chapter 5.) Following this commercial approach, the US Air Force is seeking input from industry on possible commercial options for obtaining space weather data after the Defense Meteorological Satellite Program (DMSP) ends in 2015.[52]

The most recent USAF DMSP satellite, F18, was successfully launched in October to replace F16, which will remain in service as a secondary craft.[53] The US military maintains a constellation of two primary DMSP satellites along with older backups, as long as they remain viable. The satellites provide global environmental information to the Defense Department and other government agencies.[54]

Satellite Communications

Upgrades to US military communications infrastructure remained a significant focus in 2009. In particular, the overall satellite communications roadmap has been streamlined, with over-budget and behind-schedule programs being cut entirely. While the $26-billion Transformational Satellite Communications System (TSAT) had been cancelled in 2008, with a view to launching a restructured, "slimmed-down" version in 2019,[55] in April the Defense Department announced that it was cancelling all funding for even a "slimmed-down" TSAT and would instead procure two additional Advanced Extremely High Frequency (AEHF) communications satellites.[56] It is estimated that this will save up to $2.5-billion by 2015.[57]

Nevertheless, AEHF has problems of its own. While it represents a less ambitious satellite communications system than TSAT, it too is over budget (technical problems caused $259-million in cost growth in 2009)[58], behind schedule, and suffering from technical problems. The US Government Accountability Office (GAO) announced this past spring that "the Defense Department faces a potential gap in protected military communications caused by delays in the AEHF program."[59] The first AEHF satellite is scheduled to be launched in 2010 (rescheduled from 2008 and then 2009[60]), with the second to be launched in 2011.[61] The completed system will consist of three satellites in geosynchronous earth orbit (GEO), providing up to 100 times the capacity of the present Milstar communications satellite system and servicing up to 4,000 networks and 6,000 terminals.[62] The Defense Department budgeted $2.3-billion for the AEHF program in 2010, up 318 percent from $552-million in 2009.[63]

The Wideband Global SATCOM (WGS) system, part of the US military's communications constellation, will provide high capacity X- and Ka-band communications and is designed to gradually replace the communications capabilities of the existing Defense Satellite Communications System (DSCS) constellation.[64] WGS was seen as a positive development in the US military's campaign to upgrade its aging communications satellites, with the second and third WGS satellites being launched in 2009.[65] WGS will ultimately be a constellation of five satellites that will supply service for military leaders to command and control their tactical forces.[66]

Early Warning

With the DSP racing towards degradation,[67] news that the next-generation SBIRS for missile warning and missile defense faces a further delay of twelve to eighteen months comes at a bad time for the US military's space-based early warning systems.[68] The latest plan is for Lockheed Martin to deliver the first geosynchronous satellite by the fourth quarter of 2010, one year later than the previous planned delivery date.[69] While two of the hosted SBIRS payloads are now in orbit on classified satellites,[70] the dedicated geosynchronous satellites are more than eight years behind schedule and the SBIRS program has exceeded its original $3.5 billion budget by nearly $8 billion.[71] Additional funding, $143 million of it, for a 2010 follow-on program called the Third Generation Infrared Surveillance system, was recently approved by the US Senate.[72]

The experimental STSS, comprised of two long delayed satellites designed to track missiles through all stages of flight,[73] was launched in September.[74] The satellites fly in tandem 730 nautical miles above the Earth and provide a "stereo" view of missiles that are being tracked, allowing the system to differentiate actual warheads from decoys.[75] If the system performs as expected, the satellites will be able to detect missile launches and track them through the boost, midcourse, and terminal phases of flight – something that no other sensor system can presently do.[76]

Launch

The experimental TacSat satellite program, designed to advance operationally responsive space systems, had a relatively successful year. Although TacSat-3's launch was postponed in October 2008,[77] it was successfully launched in May 2009.[78] One of TacSat-3's sensors, the Raytheon hyper-spectral sensor known as ARTEMIS,[79] consists of a telescope, an imaging spectrometer, and a computer. ARTEMIS will enable the US military to spot vehicles hidden under foliage, detect recently buried roadside bombs, and find enemy troops despite camouflage.[80] Further, in early December, the US Navy announced that TacSat-4, TacSat-3's successor, had completed environmental and performance testing, and was ready for its scheduled launch in August 2010.[81] The TacSat program is a key part of the Defense Department's Operationally Responsive Space Office (ORS), a program designed to quickly accommodate the urgent space needs of the US military.[82]

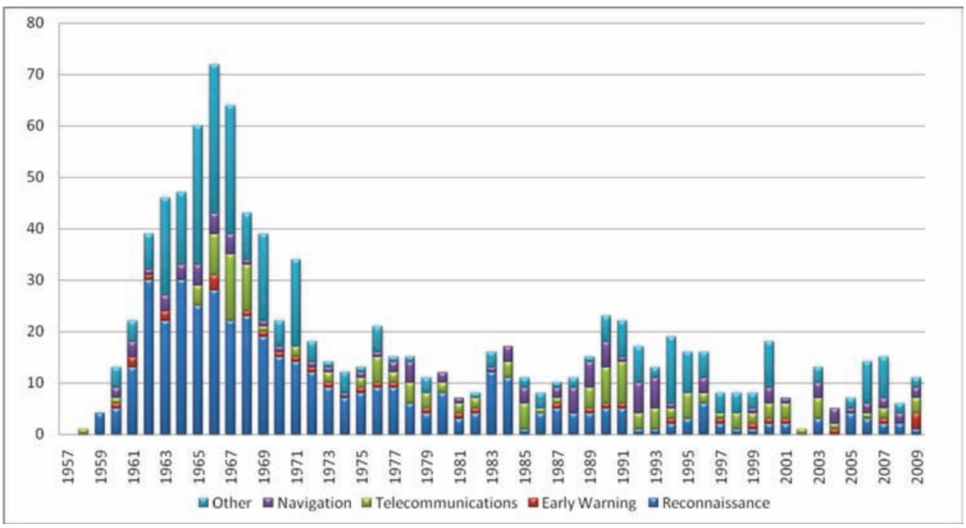
The ORS has been successful this year as the Pentagon seems to be embracing the concept of smaller, faster, cheaper satellites as opposed to "one-size-fits-all" approaches.[83] In addition to its success with the TacSat program, the ORS is moving forward with modular approaches to imaging,[84] examining options for a lower-cost solution to early missile warning systems,[85] and starting work on ORS-2, a lightweight imaging radar satellite, while ORS-1, a reconnaissance satellite, has a scheduled launch date for early 2010.[86]

Despite apparent ORS successes and a recent statement by US Strategic Command chief Gen. Kevin Chilton that he would give up new, state-of-the-art space systems to swell the number of small satellites the military could launch as needs arise, the US Air Force removed nearly $102-million of the more than $215-million required to fund the ORS from their 2010 budget request, exposing a potential conflict within the Air Force about future satellite plans.[87] Defense contractors seem to also be in agreement with the short-order satellite plan, with executives from Raytheon, Lockheed Martin, and Northrop Grumman seeing ORS as key to their bottom lines.[88] However, the industry's outlook has not been entirely rosy; some officials criticize the small-satellite plan because defense companies do not have solid information on the requirements or vision of ORS, which seem to be a constantly moving target.[89]

Navigation / GPS

In the spring, the GAO warned that there are serious concerns with respect to the GPS and its service reliability in the coming years, noting that "it is uncertain whether the Air Force will be able to acquire new satellites in time to maintain current GPS service without interruption."[90] The GAO said that, starting in 2010, the probability of maintaining a constellation of at least 24 operational satellites will fall below 95 percent, and between 2010 and 2014, could fall to as low as 80 percent.[91] Nevertheless, days later the Air Force disputed that report: "The issue is not whether GPS will stop working. There's only a small risk we will not continue to exceed our performance standard."[92] Meanwhile, the Pentagon has stated that there are 31 satellites currently active (24 are required for full coverage) and the military has multiple backups in storage.[93]

Figure 6.4: US military spacecraft launched by application: 1957 – 2009



2009 Development

Russia moves forward with GLONASS and maintains aggressive satellite launch schedule

Navigation / GLONASS

As in 2008, Russia continues to struggle with its *Global'naya Navigatsionnaya Sputnikovaya Sistema* (GLONASS) satellite navigation system. While the Russian government pledged not to cut funding for GLONASS despite the economic crisis,[94] the building of the satellite constellation experienced several setbacks and delays in 2009. Although Russia had planned to launch six GLONASS satellites over two launches in 2009,[95] only one launch was carried out in the year.[96] The successful launch, which took place in early December, placed three

GLONASS satellites into orbit, bringing the constellation to 19 satellites, with 16 in use, two under regular maintenance, and one with an expired service life. GLONASS requires 18 operational satellites for continuous navigation services inside the territory of Russia,[97] while worldwide navigation requires 24.[98]

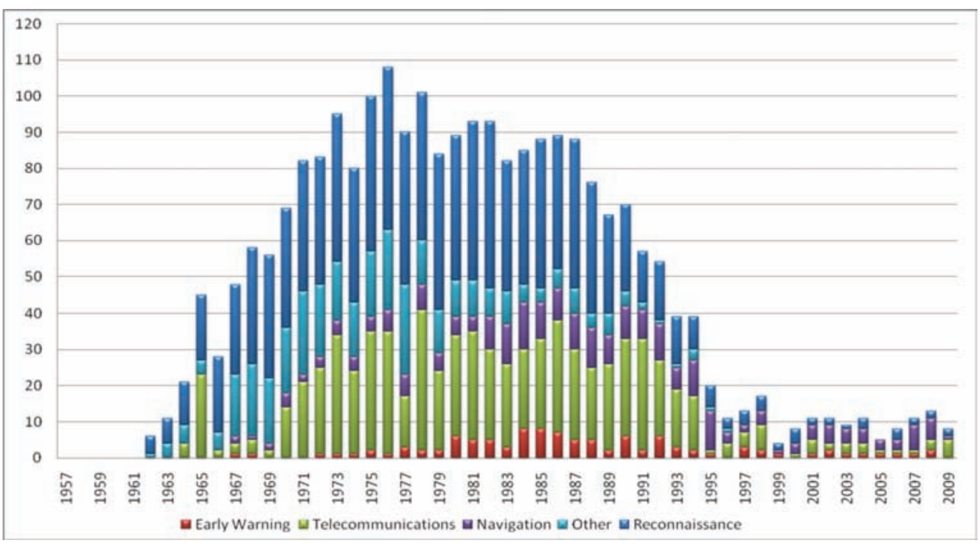
Communications and Intelligence

Despite its difficulties with GLONASS, Russia maintained an aggressive launch schedule of communications, intelligence, and other satellites in 2009. Russia launched military communications satellites,[99] a new surveillance Kobalt-class imaging satellite,[100] three Cosmos-series military satellites that are believed to be part of Russia's Oko (Eye) orbital missile early warning network,[101] along with a satellite launch in November that some experts believe could also be part of Russia's Oko network,[102] among others. At present, Russia reportedly operates a network of 60–70 reconnaissance satellites.[103]

Launch

Russia announced plans in 2008 to build a new launch facility for heavy payloads at the Plesetsk Cosmodrome to help reduce Russia's reliance on Kazakhstan's Baikanur Cosmodrome,[104] but the schedule associated with those plans has been pushed back due to budgetary issues. It was announced in November that there was a serious delay in construction of the heavy payload launch facilities due to a shortage in financing from the Defense Ministry.[105] As a result, tests of the new Angara carrier rocket, designed to replace the existing line of Rockot and Proton launch vehicles, have been postponed to 2012.[106]

Figure 6.5: Russian military spacecraft launched by application: 1957 – 2009



2009 Space Security Impact

Given the growing reliance by the US and Russia on military space systems, their assets in space may increasingly be seen as strategic targets by an adversary with the necessary means to interfere with them, thus making these assets more vulnerable. Thus, the continuing development and maintenance of US and Russian military space systems may have a positive impact on space security as the two countries will have a direct interest in advancing a norm of no hostile interference with space assets. On the other hand, the delicate boundary between militarization and weaponization of space risks being crossed as more states embrace the use of space-based military applications.

Trend 6.2: More states are developing military and multi-use space capabilities

During the Cold War, states allied with either the US 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 UK, NATO, and China had joined the US and USSR in launching dedicated military satellites. In 1995 France and Chile both launched military satellites (see Figure 6.7).[107] Historically, military satellites outside the US and Russia have been 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.[108] 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. Such activities contribute to the blurring of the divide between military and civilian and commercial space assets and applications.

Figure 6.5: Minimum resolutions for remote sensing target identification in meters

Target on the Ground	Detection	General Identification	Precise Identification	Technical Analysis
Vehicles	1.5	0.6	0.3	0.045
Aircraft	4.5	1.5	1.0	0.045
Nuclear weapons components	2.5	1.5	0.3	0.015
Rockets and artillery	1.0	0.6	0.15	0.045
Command and control headquarters	3.0	1.5	1.0	0.09
Ports and harbors	30.0	15.0	6.0	0.3

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. European military space spending has been steadily rising and was recently estimated at $1.35-billion annually.[111] While individual nations have pursued independent space capabilities for military support, many of these capabilities -in particular communications and imagery intelligence- are also shared among several European Union 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.[112] France's Helios-1 observation satellite in LEO was included under this agreement[113] and was subsequently replaced by the Helios-2B second-generation defense and security observation system, which was launched by France in 2004 in conjunction with Belgium and Spain.[114] They are joined by 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, which are expected to be integrated with France's Pleiades dual-use optical remote sensing satellites.[115] Austria, Belgium, France, Italy, Spain, and Sweden cooperate on the dual-use ORFEO satellite network.[116] 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;[117] the new optical component of MUSIS is expected to replace the French Helios-2 optical satellite by 2015.[118] However, recent developments suggest that MUSIS has been stalled by disagreements among the partners and the project could collapse.[119]

There are also several dedicated and dual-use satellite communications systems in Europe. In 2006 France completed the Syracuse-3 next-generation communications system, described as "the cornerstone in a European military Satcom system."[120] France also maintains the dual-use Telecomm-2 communications satellite and the military Syracuse-2 system.[121] The UK operates a constellation of dual-use Skynet-4 UHF and Super High Frequency (SHF) communications satellites[122] as well as a next-generation Skynet-5 system, intended to provide British forces with a secure, high-bandwidth capability though 2022.[123] The latest Skynet 5satellite was launched in June 2008 and another launch is expected for 2013, making the £3.6-billion (approximately $5.6-billion) project the single biggest UK space project.[124] 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.[125] Italy's Sicral military satellite provides secure UHF, SHF, and EHF communications.[126]

Other military space capabilities in Europe include France's constellation of four signals intelligence satellites know as Essaim, launched in 2004. France launched two Spirale early warning satellites in early 2009 for a probative research and technology demonstration[127] and, at a cost of $142.3-million each, has commissioned from EADS Astrium four Elisa microsatellites, which will gather signals intelligence data and identify civil and military radars for the French intelligence community.[128] Other European states have thus far refused to participate or invest in a pan-European missile-warning system.[129]

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.[130] The joint EU/European Space Agency (ESA) Global Monitoring for Environment and Security (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.[131] 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.[132] Similarly, the Galileo satellite navigation program initiated in 1999 and jointly funded by the EU and the ESA will provide location, navigation, and timing capabilities for both civilian and military users.[133] 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.

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,[134] but as with 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.[135] 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."[136]

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.[137] It successfully launched 15 recoverable film-based satellites, the last of which was reportedly decommissioned in 1996.[138] Today China maintains two ZY-2 series transmitting-type optical imagery satellites in LEO that could support tactical reconnaissance and surveillance.[139] In 2005 China launched the Beijing-1 (Tsingshua-1) microsatellite, which is a civil Earth observation spacecraft that combines a multispectral camera with a high-resolution panchromatic imager and could also support the military.[140] More recently, China has launched a series of six Yaogan satellites for "scientific experiment, survey of land resources, appraisal of crops and disaster prevention and alleviation."[141] 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.[142]

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 UHF systems.[143]

China also operates the Beidou regional navigation system that is comprised of four satellites in GEO, designed to augment the data received from the US GPS system and enable China to maintain navigational capability if the US were to deny GPS services in times of conflict.[144] Beidou may also improve the accuracy of China's intercontinental ballistic missiles (ICBMs) and cruise missiles.[145] 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. Responsibility for Compass falls to China's defense ministry, but 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."[146] China launched the first Compass-M1 test satellite into MEO in 2007.[147] Concerns have been expressed that Compass will use the same radiofrequencies as Galileo and possibly GPS; however, China maintains that this is still under negotiation. Some analysts have suggested that using the same radiofrequencies would make jamming the Compass system more difficult.[148]

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 are providing signals intelligence, although their official purpose is to measure the space environment.[149]

India

India has one of the oldest and largest space programs in the world, which has developed a range of indigenous dual-use capabilities. Space launch has been the driving force behind the Indian Space Research Organisation (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.

During this time ISRO developed a series of civilian Indian Remote Sensing satellites and, as of July 2010, maintains 10 satellites that provide imagery for the Indian military.[150] 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.[151] 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,"[152] 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 will be able to take 3-m resolution images in all-terrain, all-weather, day/night conditions – a significant dual-use capability.[153] The satellite, built with Israeli assistance and equipped with all-weather vision capabilities, was successfully launched in April 2009.[154]

The Indian National Satellite System[155] 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 US GPS, the country is developing GAGAN, the Indian Satellite-Based Augmentation System, which will be followed by the Indian Regional Navigation Satellite System (IRNSS) to provide an independent satellite navigation capability, which is expected to be made up of seven navigation satellites by 2012.[156] In 2007 India signed an agreement with Russia to jointly use its GLONASS navigation system.[157] Although these are civilian-developed and -controlled technologies, they are used by the Indian military for dual-purpose applications.[158] In 2008 the US-India civilian nuclear cooperation agreement was approved. By ending longstanding sanctions it could allow for greater cooperation between ISRO and the military.[159]

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.[160] Officially called the Information Gathering Satellite 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.[161] 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.[162]

In December 2003 South Korea announced its intentions to increasingly use space for military purposes.[163] 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."[164] It also bought 10 Hawker 800-series satellites from the US and has operated them for signals intelligence since 1999.[165] 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.[166] South Korea also launched the Kompsat-2 high-resolution Remote Sensing Satellite for Earth mapping in 2006.[167] Although a civilian spacecraft, its 1-m resolution could allow it to serve as a reconnaissance asset.[168]

In July 2004 Thailand signed a deal with the European Aeronautic Defence and Space Company (EADS) Astrium to provide its first remote sensing satellite, to be used for intelligence and defense.[169] The THEOS Earth Observation Satellite, which orbits in LEO, was launched on 1 October 2008 for the Thai government.[170] 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.[171]

Middle East

Israel operates the dedicated military Ofeq optical imaging system, which provides both panchromatic and color imagery for intelligence purposes.[172] The newest satellite in the system, the Ofeq-9, launched in June 2010, will be in a constellations with the other two Ofeq satellites currently in orbit (Ofeq-5 and Ofeq-7), and reportedly can identify objects as small as approximately 0.5-m.[173] 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.[174] 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[175] with a resolution of up to 10cm,[176] the TecSAR is reportedly used to spy on Iran.[177]

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.[178] 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.[179] However, its 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.[180]

Egypt's civilian Egyptsat-1 remote sensing microsatellite was launched in 2007. Weighing just 100 km, 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.[181] 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.[182]

Turkey awarded a $250-million contract for its first military optical imaging satellite, the GOKTURK. It is intended to have an 80-cm resolution, and the launch is planned for 2011.[183]

Australia

Until recently the Australian defense forces used X-band facilities on satellites owned by the US and other allies.[184] 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 radiofrequency bands.[185] Australia is also participating in the US Wideband Global SATCOM program.[186]

Canada

Canada uses commercial satellite communications and imaging services to meet its military needs.[187] In June 2005 Canada's 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.[188] 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.[189] 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.[190] It uses synthetic aperture radar to produce images with a resolution of up to 3 m,[191] and will be upgraded in 2010, as discussed below. It also has an experimental Ground Moving Target Indicator capability to detect and track the movement of vehicles and ships.[192] 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 provided by commercial satellites such as Radarsat-2, and also provide space situational awareness data gathered by the US Space Surveillance Network.[193] Canada will have its first access to dedicated military satellite communications capability when the US AEHF satellite system becomes operational.[194]

2009 Development

The Indian Space Research Organisation (ISRO) begins to develop military capabilities

Subsequent to the steps taken in 2008 toward the formation of the Integrated Space Cell – a conduit between the military and ISRO to make better use of India's space assets to increase the technical capability of India's fighting forces[195] – ISRO continued a path toward military capabilities in 2009. This year marked the first time that ISRO had officially used its technology for military purposes when it began providing technical support to the Indian Air force and ground forces in a major offensive against Naxalites in the jungles of Chhattisgarh, Jharkhand, and West Bengal.[196] ISRO is providing the military with images of the ground using the radar-imaging satellite RISAT-2, launched in April 2009.[197]

Military cooperation between Israel and India[198] continued in 2009 with India's use of an Israeli-built radar component on its RISAT-2 satellite.[199] The radar-imaging satellite was rushed into service following the 26 November 2008 terrorist attacks on Mumbai.[200] The 300-kg satellite has all-weather capabilities to take images of Earth and will primarily keep an eye on the country's borders and aid in anti-infiltration and anti-terrorist operations.[201] Along with RISAT-2, the launch put a 40-kg communications test micro-satellite called ANUSAT into orbit.[202]

More cooperation between ISRO and the military is planned; in October India announced that its Navy will have a dedicated geo-stationary communications satellite built by ISRO before 2010.[203] This first dedicated Indian military satellite will be followed by Air Force and Army satellites in 2011 or 2012.[204] The Air Force's dedicated surveillance satellite is scheduled to launch in late 2010 and will have both military and civilian uses.[205]

2009 Development

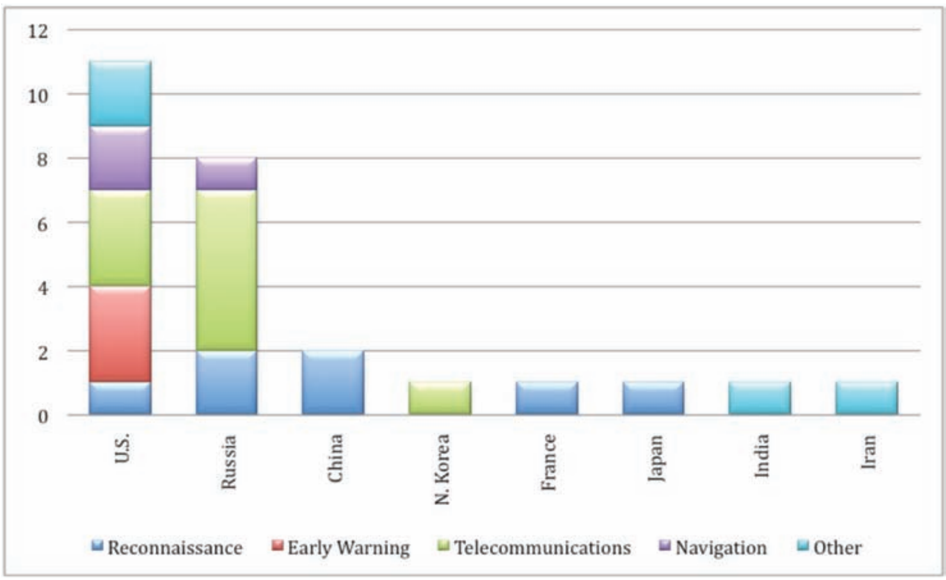
Various countries pursue satellite navigation systems

In addition to the US GPS, Russian GLONASS, and European Galileo satellite navigation systems, other countries are working toward their own domestic systems to decrease foreign dependence for such an essential military service. The second-generation Chinese Beidou

(Compass) satellite navigation system is well on its way to becoming a GPS alternative, making several advances in 2009. Following the first satellite launch in 2007, the second was launched in April and placed into a geostationary orbit.[206] While China's first-generation Beidou satellite navigation constellation provides coverage only over China, this system is expected to provide global coverage by 2015.[207] The system will comprise at least 30 satellites by 2015, with at least 10 new Compass satellites scheduled to be launched in 2010 and 2011.[208]

ISRO is developing a constellation of seven satellites for regional navigation.[209] The Indian Regional Navigational Satellite System (IRNSS) will provide a "position accuracy of more than 20 meters throughout India and within a region extending approximately 2,000 km around it."[210] As well, in a document released in early 2009 entitled *Basic Guidelines for the Development and Use of Outer Space*, Japan noted that it will seek to develop an "independent navigation and positioning capability" in the near future.[211]

Figure 6.6: Military spacecraft launched by country and type: 2009



2009 Development

Canada's multi-use space capabilities continue to be developed

After announcing its intentions in 2008,[212] Canada's Department of National Defence moved forward with Project Polar Epsilon, a satellite-based wide area surveillance and support system.[213] In 2010 the Radarsat-2 satellite will be upgraded in orbit with new software, which will allow the satellite to better conduct maritime surveillance in the Arctic and on the approaches to Canada's east and west coasts.[214] The software upgrade consists of new surveillance beams, including a ship-optimized beam that will cover a 450-km swath at a resolution of 20 m. A multipurpose beam will also be uploaded with a 530-km swath width and a resolution of 50 m. Finally, the upgrade will also include a spotlight mode beam that will allow the satellite to produce imagery using a resolution of 1–3 m for focusing on individual ships.[215] In 2009 the Canadian government also announced the locations of ground stations for Project Polar Epsilon to support the Radarsat-2 satellite: Aldergrove, British Columbia and Masstown, Nova Scotia. Construction has begun on both stations, with an estimated completion date of June 2010.[216]

In addition to the Radarsat-2 upgrade, Canada is also on track to deliver the next evolution of the Radarsat program, the Radarsat Constellation, which will upgrade the current systems features and improve reliability over the next decade.[217] The purpose of the system is not to replace Radarsat-2, but to meet its core demands at a lower cost and to enable future applications. Satellite launches that will enable maritime surveillance, disaster management, and ecosystem monitoring are planned for 2014 and 2015.[218]

2009 Development

Europe moves forward with Galileo navigation system and deepens military cooperation on space projects

After a $4.6-billion plan involving 26 satellites was announced in 2008,[219] the Galileo satellite navigation system inched forward in 2009, despite some significant difficulties. While the first Galileo test satellite, GIOVE-A, successfully completed its tests and was moved to a higher orbit this year to make way for the coming operational navigation satellites, there was little other good news for the program.[220] The ESA announced in October that two launches scheduled for early 2010, which were to put four operational Galileo satellites into orbit, were rescheduled to late 2010 and mid-2011 due to difficulties with the satellites.[221] Further, the European Commission (EC) cut its initial order of 28 satellites (the number required for full operation) down to 22, with the remaining six to be purchased later.[222] The initial open and encrypted signals are planned to be available some time in 2013.[223] While there are explicit plans for military uses of Galileo, the system is funded solely by European governments' budgets for civil space activities.[224] After two years of effort, there continue to be disputes between Europe and China over the frequencies used in their respective satellite navigation systems. While both Europe and China are intent on preserving their respective ability to jam the other's military frequencies, their systems occupy overlapping sections of the radio spectrum, so that neither could jam the other's service without interfering with its own signals.[225]

In addition to the military capabilities of Galileo, which indirectly highlight the ESA's acceptance of security as one of its missions, European states continued to cooperatively develop military space systems in 2009 as the European Defence Agency became increasingly engaged in military space issues.[226] In April, Italy launched the Sicral 1B military telecommunications satellite, which will not only be used by the Italian Defense Ministry, but also by France and the UK as part of a three-nation satellite-telecommunications contract.[227] In October an Ariane-5 rocket launched a Spanish telecommunications satellite and a German military satellite from the ESA's launch site in French Guiana.[228] In December France launched a military spy satellite, the Helios 2B, from French Guiana to provide better imaging and identification of areas of military interest.[229] The intelligence information captured from the satellite will be shared with Italy and Germany according to bilateral agreements between those countries, and the satellite has been developed with some financial support from Belgium, Italy, Greece, and Spain.[230]

While there continue to be no plans for a pan-European missile warning system,[231] France is pushing forward with its SPIRALE missile tracking satellite system. The first two SPIRALE satellites were launched in February and will monitor the Earth with infrared telescopes and alert its operators of missile launches.[232] While these satellites are only part of a demonstration mission, the micro-satellites have acquired more than 300,000 images of the Earth in several infrared bands since their launch.[233] Further, in May the French Armament Procurement

Agency announced that it had accepted the SPIRALE demonstrator early warning system.[234] Meanwhile, although France hopes to have an operational system based on SPIRALE in GEO by 2019, no partners have thus far agreed to sign on.[235]

2009 Development

China rapidly upgrades space-related technologies

After launching the Yaogan-4 and -5 remote sensing satellites in late 2008, China launched Yaogan-6, believed to be a synthetic aperture radar imaging satellite, in April 2009.[236] In December China launched Yaogan-7 and -8, both reportedly classified as Earth monitoring satellites for scientific experiments, land survey, crop yield assessment, and disaster monitoring purposes.[237] However, western space analysts believe that these satellites, like Yaogan-6,[238] are being used for reconnaissance purposes.[239] Specifically, experts believe that Yaogan-7 is likely an electro-optical spy satellite to be operated by the Chinese military; it would be the third Yaogan spacecraft fitted with an optical imager.[240] China also pushed forward in other military-related space domains by launching its second satellite for the next-generation Beidou (Compass) satellite navigation system, with an additional 10 Compass satellite launches scheduled over the next two years.[241]

2009 Development

Japan outlines military space strategy

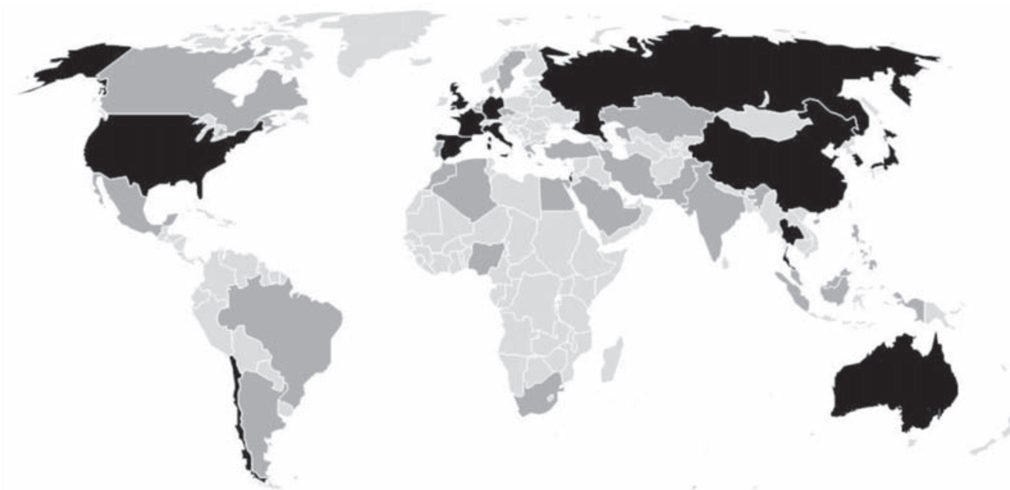
Following the 2008 Basic Space Law, removing the self-imposed Japanese ban on any military use of space,[242] Japan outlined its military space strategy guidelines in early 2009.[243] *Basic Guidelines for the Development and Use of Outer Space,* mandated by 2008's Basic Law for Space Activities, identifies the systems and technologies that Japan is seeking to develop as part of its emerging military space strategy. These include additional imaging satellites, a dedicated military communications satellite, a missile warning system, an independent satellite navigation system, and a signals intelligence satellite, among others.[244] In April Japanese Defense Minister Yasukazu Hamada announced that Japan hopes to develop within five years an infrared early warning satellite to monitor North Korean missile launches.[245] In a related development, in late November Japan launched an advanced spy satellite that became the fifth operational element of Japan's spy satellite fleet.[246] After long relying on the US for intelligence, Japan launched its first two spy satellites in 2003, prompted by concerns over North Korea's missile program.[247] While previous Japanese spy satellites could identify objects 1 m in size or greater, the latest satellite can identify objects as small as 60 cm.[248]

2009 Development

Australia releases defense white paper addressing, inter alia, space situational awareness and access to space-based imagery

In May, the Australian government released a white paper addressing its strategic defense priorities and reform agenda for the next 20 years.[249] In one of the space-related entries, the paper calls for a "capacity for continuous wide area surveillance of our northern approaches."[250] In a related entry, the document states that Australia will improve its intelligence collection capabilities by acquiring a remote-sensing satellite. Further, the white paper notes that, as space assets will play an increasingly important role in military operations, the emergence of counter-space technologies (such as anti-satellite weapons) will make space mission assurance increasingly important.[251] While details on the space-related contents of the white paper are sparse, the paper does show that Australia hopes to become a more important player in space and has aspirations to acquire space-based assets that can assist in terrestrial military operations. The entry in the white paper noting the emergence of counter-space technologies and their military importance is also of interest, though at this point it is difficult to determine the extent to which they will be pursued in Australia.

Figure 6.7: States' first dedicated military satellites and their function



Owns military satellite
Owns satellite

Year	State/Actor	Satellite	Description
1958	US	Project SCORE	Communications and experimental satellite
1960	US	GRAB	Electronic intelligence [some argue that this was truly the first US dedicated military satellite]
1962	USSR	Cosmos-4	Remote sensing (optical)
1969	UK	Skynet-1A	Communications
1970	NATO	NATO-1	Communications
1975	China	FSW-0 No. 1	Remote sensing (optical)
1988	Israel	Ofeq-1	Remote sensing (optical)
1995	France253	Helios-1A	Remote sensing (optical)
1995	Chile	Fasat-Alfa	Communications and remote sensing (optical)
1998	Thailand	TMSAT	Communications
2001	Italy	Sicral	Communications
2003	Australia	Optus and Defence-1	Communications
2003	Japan	IGS-1A and IGS-1B	Remote sensing (optical)
2006	Spain	Spainsat	Communications
2006	Germany	SARLupe-1	Remote sensing (radar)

2009 Space Security Impact

As more states develop the technologies and partnerships required to access space, accessibility to the space environment increases, which can be positive for space security. Further, increased collaboration among states, as in Europe, will allow countries without all the requisite technology or resources to enjoy the benefits of access to space. Nevertheless, the impact of the development of space-based military capabilities by more states can be negative as outer space becomes congested and the number of potential targets increases. At the same time, states will likely have an incentive to develop temporary, reversible offensive capabilities as more actors have a direct stake in this field. Moreover, the investments being made by multiple countries in satellite-based navigation could have a positive impact on space security as more options are presented to users and more redundancy is introduced, in particular with regard to improved space situational awareness and verification capabilities. Finally, Japan's release of its military space strategy and the publication of Australia's defense white paper can be seen as positive for space security as the sharing of their plans increases transparency and reduces uncertainty.

Space Systems Protection

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 (see Chapter 8). 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.

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.[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.

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 (SSA) can help reduce uncertainty when pinpointing the immediate cause behind the malfunction of a space asset.[2] Since SSA can also be used for tracking and targeting foreign satellites, as discussed in Chapter 2, 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 cybernetic 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 much more difficult to develop.

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 weapons, 5) pellet cloud attacks on low-orbit satellites, 6) attacks in space by microsatellites, and 7) high-altitude nuclear detonations (HAND).[3] 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 protection systems. 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 the most 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 US 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.[4] 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,[5] leaving them potentially vulnerable to some of the most basic attacks. Responding to such concerns, the US General Accounting Office — now called Government Accountability Office (GAO) — has recommended that "commercial satellites be identified as critical infrastructure."[6] 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.[7]

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. These 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 radiofrequencies 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.[8]

During the Cold War the US and the USSR led in the development of systems to protect satellite communications links. The US currently appears to be leading in the development of more advanced capabilities. For example, US/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.[9] Through its Global Positioning Experiments project, the US has also demonstrated the ability of GPS airborne pseudo-satellites to relay and amplify GPS signals to counter signal jamming.[10]

The US and several other countries, including Germany and France, are 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.[11] The US is also moving forward with the establishment of a Cyber Command (USCYBERCOMM) responsible for the military's Internet and other computer networks,[12] as discussed below.

In response to several jamming incidents in past years allegedly attributed to the Falun Gong, in 2005 China launched its first anti-jamming satellite, the Apstar-4 communications satellite.[13] China has 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.[14]

2009 Development

Despite uncertainties, development of US Cyber Command moves forward

In June 2009 the US Secretary of Defense ordered the US military to setup a unified command – US Cyber Command (USCYBERCOM) – to act as a central hub for US cyber capabilities, while the Pentagon would continue to develop policies for cyberspace operations. USCYBERCOM was established in October 2009 under the leadership of the director of the National Security Agency (NSA), and is expected to be fully operational by October 2010.[15]

USCYBERCOM comes after the suspension of efforts by the Air Force to implement Air Force Cyber Command (AFCYBER).[16] AFCYBER was scheduled to become operational in October 2008, but all efforts to finalize the project ended in August 2008.[17] The Army and the Navy had similar cyberspace protection capabilities, but the Air Force used a "hard sell" strategy to promote AFCYBER.[18] High-ranking military officials argued for a more unified command, so that instead of one dominating agency there would be a composition of forces to ensure cybersecurity.[19] More precisely, USCYBERCOM will be constituted by several military branches along with assets from the NSA and other government agencies. In addition the Obama administration created a White House office to institute a national cyber policy.[20]

Although USCYBERCOM has been debated in defense circles for more than a year, military and industry are still unsure whether it is a new fighting force, an IT department, or an intelligence agency.[21] A clear definition of what cyber defense means to USCYBERCOM has not been made available. If it is understood to be a new fighting force, the extent of its defensive and offensive activities are unclear. If it is an intelligence agency, there are contentious issues to be addressed regarding practices that may conflict with civil liberties.[22] Since the vast majority of space assets depend on cyber networks, it is important that USCYBERCOM's roles and responsibilities, minimum implementation requirements, and degree of integration with government and military forces be clearly defined.[23]

2009 Development

Development of the Rapid Attack Identification Detection and Reporting System (RAIDRS) continues

In September 2009 the US Air Force allocated $27.7-million to restructuring the Rapid Attack Identification and Reporting System (RAIDRS) Block 10 (B-10) program so that costs could be kept under control.[24] The RAIDRS B-10 has been under development since 2005 and was planned to be deployed in 2007 under a $77.7-million contract. Its original specifications included six fixed RAIDRS installations and three deployable sites,[25] so that it would be possible to detect, locate, identify, and report attacks against ground- and space-based military systems.[26] As a consequence of restructuring the program was scaled down to five deployable sites and its initial deployment date has been shifted to 2010.

In October 2009 Integral Systems announced the continuation of the partnership with the US Air Force to carry on the development of RAIDRS B-10.[27] About 80 percent of Integral Systems' revenue has come from the US government, mainly the Air Force. The continuation of RAIDRS in 2010 is thus expected to have a positive effect on the company's finances, which suffered from several negative events in 2009.[28] After the deployment of

RAIDRS B-10, the Air Force had plans to follow up with RAIDRS B-20, a system that would allow for improved detection of threats. However, the name RAIDRS B-20 has been scrapped and such a system would become part of a larger effort called Joint Space Operation System that would substitute the Space Defense Operations Center (SPADOC).[29]

2009 Space Security Impact

The creation of USCYBERCOM can help the US achieve not only advanced capabilities to combat cyber threats, but also higher levels of security in space missions. Although the implementation of a single cyber command has the benefit of higher levels of integration among different government and military forces, it is still unclear how such integration is to be achieved. Other issues to be solved include the specification of minimum requirements, roles, and responsibilities of the entities involved in its operation. Although RAIDRS B-10 has been scaled down to five deployable sites, its development has continued and deployment is scheduled for 2010. As a result, the US military will be able, in the near future, to detect and identify attacks against their ground and space assets, which would have a positive impact on space security.

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

Although a less likely occurrence 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 (LEO) can be reached in a matter of minutes, while Geostationary Orbit (GEO) takes about a half-day to reach by completing a Hohmann transfer orbit, illustrates the unique protection of dynamics associated with different orbits.[30] 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 one kilometer 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 Medium Earth Orbit (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 US stealth satellite program Misty (cancelled in 2007).[31] 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 maintain 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,[32] but the extra fuel required might represent more than 10–20 percent of the satellite cost.[33]

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.[34]

Dispersing capabilities is a well established practice in terrestrial conflict that can be applied to satellite operations.[35] 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 US 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.[36] 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,[37] which is expected to become operational in 2013 with an on-orbit demonstration of a fractioned space architecture.[38]

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 European Space Agency (ESA) and the EU, Japan, and India are developing satellite navigation systems that will decrease dependency on the US GPS. Constellations of satellites such as the US

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.[39] The 3-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.[40] The US 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.[41] This program, however, was cancelled in the FY2009 budget.[42]

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."[43] 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.[44] 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 US and the USSR during the Cold War were aimed at increasing the survivability of strategically important satellites in the face of nuclear attack. US systems such as the Defense Support Program (DSP) 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.[45] 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 US 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.[46]

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 percent of satellite costs, while hardening against the EMP effects of a nuclear detonation can be up to 10 percent of satellite costs.[47]

The US 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.[48] 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.[49] The US Air Force (USAF) has been developing a coating for critical system components that would offer some kind of protection from directed energy weapons such as lasers.[50] 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.[51] 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.

2009 Development

US Air Force delays launch of pace based surveillance system

To improve its space surveillance capabilities, the US Air Force has been developing advanced systems to monitor and detect spacecraft and other objects in space, including Air Force assets and those of other countries.[52] The larger system is Space Based Space Surveillance (SBSS), while the smaller one is called Autonomous Nanosatellite Guardian for Evaluating Local Space (ANGELS). US space surveillance systems have been based on ground radars – a technology originally conceived during the Cold War. Since the main goal at the time was to detect incoming missiles from the Soviet Union, most stations are able to scan the northern hemisphere only. Even if more stations were to be constructed and added to the system, there would be several blind spots over the oceans. By relying on SBSS and ANGELS, it will become possible for the Air Force to augment and update its catalog of space objects with more accurate information.

The SBSS system was built by Ball Aerospace in partnership with Boeing, and is planned to operate in a polar orbit over a five-year period. Instead of radar, SBSS will rely on a gimbaled telescope, which can remain fixed on a steady position to inspect an object of particular interest, or even focus on several targets as they pass by. As a result, it will become possible to confirm whether a given spacecraft has arrived at the correct orbital slot and determine its precise position. Such capabilities could also be utilized to detect space debris and monitor foreign spacecraft. SBSS was scheduled to launch October 30, 2009 on a Minotaur IV launch vehicle at the Vandenberg Air Force Base, California.[53] It has been delayed indefinitely due to a failure in a Taurus rocket, which experienced a problem with the hardware that supports the third stage of the launch vehicle and employs some subsystems that are also used by the Minotaur IV.[54] The Air Force is expected to proceed with the launch once corrections are implemented.

The ANGELS nanosatellites will be capable of performing proximity operations in geostationary orbit and conducting inspections through a 12-km telescope. It will also carry a sensor to indicate when it is being tracked by radar, which could support the execution of evasive maneuvers. Given this wide range of features, the Air Force has provided funds for a second stage of development that will enhance its ability to detect space- and ground-based threats. A launch date has not been officially set for ANGELS.[55]

2009 Development

More reliable evasive maneuvers for small satellites under development

The National Science Foundation has provided a $100,000 fund to the Aerospace Engineering Laboratory at the University of Florida for the Rapid Retargeting and Precision Pointing project, which is to develop, build, and launch picosatellites with enhanced attitude control. Researchers aim to reduce power consumption of onboard sensors, as well as to distribute the workload among several orbiting picosatellites through a wireless network.[56] The main goal of the project is to utilize multiple picosatellites to achieve the capabilities of their larger counterparts and thus achieve better attitude control. Launching picosatellites might seem easy and inexpensive in comparison to launching their full-sized counterparts. However, the real challenge lies in controlling such small satellites, given their small mass and limited power. And because their ability to execute evasive maneuvers is limited, picosatellites can become easy targets of attackers.

DARPA has been conducting similar research. In a project named Future Fast, Flexible, Fractioned, Free-Flying Spacecraft (System F6),[57] DARPA has been exploring how larger satellites could be partitioned into smaller ones while keeping the same overall spaceborne capabilities as a virtual satellite. Each spaceborne module would be capable of performing one of the following tasks: computation and data handling, communications relay, guidance and navigation, or payload sensing. The planned communications architecture includes integrity, availability, authentication, and non-repudiation. Such a robust approach can guarantee a high level of reliability and security, possibly inhibiting attacks against the system.[58] Phase 1 of the program was accomplished by Boeing, Lockheed Martin Space Systems, Northtop Grumman Space and Mission Systems, and Orbital Sciences.[59] A one-year, $74.6-million contract for Phase 2 was awarded solely to Orbital Sciences, in partnership with IBM, NASA Jet Propulsion Laboratory, Georgia Institute of Technology, SpaceDev, and Aurora Flight Sciences. The second phase of development consists of a critical design review of ground stations and spacecraft modules, demonstrations of key enabling technologies, and a plan and concept of operations.[60] It will include wireless data communications, cluster flight operations, distributed spacecraft computing systems, rapidly re-locatable ground systems, and value-centric design methodologies.[61] A first flight demonstration is scheduled for 2013.[62]

2009 Space Security Impact

Determining the precise positioning of space objects and fine-grained maneuvering of spacecraft can be used in performing evasive operations to avoid collisions, thus contributing to higher security in space. The same capabilities, however, could be used to precisely determine the position of a foreign spacecraft, perform fly-around maneuvers, and attack it. The distribution of information processing among several picosatellites can help reduce the burden of power consumption in an individual spacecraft during onboard processing. Consequently, picosatellites could rely on enhanced attitude control to perform evasive maneuvers, thereby improving security. As well, the use of cryptographic mechanisms in System F6 could increase the overall security of its communications systems to the extent that it would become virtually immune to attackers, thereby achieving high security levels.

Trend 7.3: Efforts underway to develop capacity to rapidly rebuild space systems following direct attacks on satellites, but no operational capabilities

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 US 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 out-gassing before the satellite can enter service.[63] 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.[64] 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.[65]

The US has undertaken significant efforts to develop responsive space capabilities. In 2007 the Department of Defense 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.[66] 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."[67] 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.[68] 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.[69] In September 2008, Falcon 1 reached orbit on its fourth attempt.[70] 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."[71] A full ORS capability could allow the US to replace satellites on short notice,[72] enabling rapid recover from space negation attacks and reducing general space system vulnerabilities.

The concept for a US 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.[73] The first technology demonstrators built were the X-40 (USAF) and the X-37A (NASA/DARPA).[74] A successor to the X-37A, the X-37B unmanned, reusable spacecraft was launched for the first time in April 2010 under significant secrecy, as discussed below. India is reportedly working on a Reusable Launch Vehicle, which is not anticipated before 2015.[75] 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.[76] 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.[77] The US 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.[78] Other efforts include the China Aerospace Science and Technology Corporation plan to launch small payloads released from a modified H-6 bomber.[79]

2009 Development

Research and development of low-cost launch capabilities progress

The X-37B spacecraft – a reusable, unpiloted military space plane being developed for the US Air Force – underwent finals stages of development in 2009 under a shroud of secrecy.[80] Development began in 1999 with a four-year contract between Boeing Phantom Works and NASA. In November 2002 Boeing continued the development of the flight demonstrator via a $301-million contract,[81] but in 2006, under the Bush administration, the US Air Force took control of the program from NASA and has since been mostly silent about the spacecraft's budget and mission.[82] Although its objectives have been officially described as "space experimentation, risk reduction and a concept of operations development for reusable space vehicle technologies,"[83] it has been argued that the X37-B could be utilized as a weapon platform and also as an anti-satellite weapon.[84] These claims, however, are speculative in nature and have not been substantiated. The original plans to deploy the X37-B from the Space Shuttle cargo bay changed after the Space Shuttle Columbia accident in 2003. The Delta rocket had been considered, but plans later changed to utilize an Atlas V EELV launch vehicle.[85] Although the maiden flight of X37-B was originally planned for January 2010[86] the launch was postponed and took place on 22 April 2010.[87] Gary Payton, Air Force deputy undersecretary for space systems, responded to allegations about the use of the spacecraft as a weapon, and was quoted as saying: "I don't know this could be called weaponization of space, it's just an updated version of Space Shuttle type of activities."[88] A second experimental plane has been ordered and is expected to be launched in 2011.[89]

The company AirLaunch LLC was involved in developing a low-cost, rapid-reaction small satellite launcher, which could contribute to the reconstruction of space systems following attacks. However, it discontinued operations in fall 2009 due to a lack of funding from DARPA and the Air Force.[90] AirLaunch LLC had accomplished phase 2 of the launch system, when in 2007 the Air Force did not provide the promised funding for phase 3 flight tests.[91] Although the company still exists, it has been put in "hibernation mode" and all its personnel have been laid off.

Space Exploration Technologies (SpaceX) has been developing the Falcon 1 and Falcon 9 vehicles, which are intended to provide reliable and cost-efficient launches of manned and unmanned spacecraft.[92] The inaugural flight of Falcon 9 should have happened in 2007, but the development of Falcon 9 and Falcon 1 has taken longer than expected.[93] In September 2009 SpaceX announced that the initial flight of Falcon 9 will carry a qualification unit of the Dragon spacecraft,[94] which is part of the company's $238-million agreement with NASA. In November 2009 SpaceX requested 2 February 2010, 11:00 a.m. EST as the new launch date for Falcon 9. However, that date conflicted with the already approved launch of the Atlas 5 of NASA's Solar Dynamic Observatory.[95] Falcon 9 was eventually launched on 4 June 2010.[96]

2009 Space Security Impact

Quick launch with minimum cost can be considered primordial capabilities to allow for fast recovery of space assets following attacks. Although delayed in their schedule, Falcon launch vehicles can help reduce launch cost and time, thereby contributing to higher levels of security for space systems. The progress made with the X-37B is expected to help the further development of technologies for reusable spacecrafts, which could be used for in-orbit repairs. While the X-37B's mission has been broadly described as testing reusable space technologies, there has been some apprehension from nations like China that it could be used as part of a weapon system, which, if true, would have a negative impact on space security by promoting distrust among other spacefaring nations and potentially triggering a weapons race in space.

CHAPTER EIGHT

Space Systems Negation

This chapter assesses trends and developments related to the research, development, testing, and deployment of physical 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 (SSA) 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 US 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 would be more likely to trigger an arms race.

Soviet and US 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 space security, 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: Widespread capabilities to attack ground stations and 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 US leads in developing advanced technologies to temporarily negate space systems by disrupting or denying access to satellite communications. The US Department of Defense (DOD) "Counterspace Systems" budget line item has had steady funding for early-stage research and technology development of offensive programs "to disrupt, deny, degrade or destroy an adversary's space systems, or the information they provide, which may be used for purposes hostile to US national security interests."[6] 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.[7] An upgrade to this system was implemented in 2007 to fully equip two squadrons with seven jamming systems, up from the original two.[8] Next-generation jammers also under development will have "enhanced capabilities for SATCOM denial" using largely commercially available components.[9]

The US "Space Control Technology" program seeks 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 notes 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* calls for development of capabilities to selectively deny, as necessary, Global Positioning System (GPS) and other navigation services.[12]

Although the US 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, an event involving the jamming by Libyan nationals of Thuraya Satellite Telecommunications mobile satellite communications, 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 Ltd.[15] The US CounterCom system is largely based on commercially available components.[16]

Reported incidents of electronically jammed media broadcasts include interruptions to US broadcasts to Iran,[17] Kurdish news broadcasts,[18] and Chinese television.[19] Computer networks linked to communications systems have also been the targets of attack.[20] 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 being transmitted by an older, unidentified commercial satellite.[21] It is often difficult to determine if satellite interference conducted by individual attackers is state-sponsored. In 2009 Iran was accused of jamming the satellite transmission of the Voice of America and the BBC into Iran, as discussed below.

2009 Development

Satellite communications resources remain vulnerable to attack

On 20 March 2009, the transponders of US Navy communications satellite FLTSAT-8 were hijacked by Brazilian amateur hackers.[22] Because older satellites lack appropriate security mechanisms such as encryption and authentication, individuals can illegally use satellite communications channels. To utilize such a military satellite for personal communications a pirate needs a ham radio transmitter with an operating range between 144 and 148 megahertz in conjunction with a frequency doubler and a varactor diode. At a cost of about $100, the result is a radio capable of operating at between 292 and 317 megahertz, which is the FLTSAT uplink frequency range.[23] Following instructions from Anatel (Brazil's FCC) and the US DOD, the Brazilian Federal Police were able to charge 39 suspects in six federal states. If convicted, the suspects can be fined and face up to four years in jail. Since techniques and equipment to tamper with satellite communications are widely available, it will be difficult to prevent more attacks, without proper security mechanisms to protect satellite communications.

In late December 2009 the Iranian government was accused of jamming satellite transmissions of Voice of America and BBC into Iran.[24] The Broadcasting Board of Governors (BBG), the agency that monitors all US government-supported civilian international broadcasts, condemned the incident as censorship of the free flow of news and information to the Iranian population. BBG engineers estimate that Iran has been interfering with a satellite in charge of such transmissions known as Hot Bird since 27 December 2009.[25] Iranian authorities have been queried by BBG and have been called to the UN to explain the incident, but they have not responded to those requests.

2009 Development

Facing growing threat of cyber warfare, Pentagon plans creation of a military command for cyberspace

In May 2009 the US Government Accountability Office (GAO) issued a study that indicated that cyber threats against the federal system and critical infrastructure have been growing in number and evolving in sophistication.[26] According to the GAO, federal computer systems are not sufficiently protected against cyber threats and security deficiencies could put federal assets at risk. Virtually any cyber attack against regular computers could also be ported and launched against spacecraft and their corresponding ground station computers. Consequently, high levels of protection are imperative to appropriately protect space systems from attackers.

2009 Space Security Impact

Attackers have been successful in hijacking transponders linked to older satellites and jamming communications links, thereby drawing attention to the vulnerability of the ground components of space systems. The operations of some space systems can be compromised cheaply and with relative ease by individuals, groups, or governments, consequently reducing the security of space assets. Additionally, the number of highly sophisticated attacks against computer systems has increased. As a result, the US GAO issued a report detailing the lack of appropriate security and the consequences to national space assets; if enhanced security measures are instituted, as recommended, the renewed vigilance may help increase security levels of space systems through improved awareness of the vulnerabilities of ground stations.

Trend 8.2: Ongoing proliferation of ground-based capabilities to attack satellites

As noted in Figure 8.3 a series of US 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).[27] 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.[28]

US Air Force (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."[29] Among the tools for offensive counterspace operations, the document lists direct ascent and co-orbital ASATs, directed energy weapons, and electronic warfare weapons. The US 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 in FY1996 through FY2005.[30] For FY2005 Congress appropriated $14-million the KE-ASAT program through the Missile Defense Agency's (MDA) Ballistic Missile Defense Products budget.[31] The KE-ASAT program was part of the Army Counterspace Technology testbed at Redstone Arsenal.[32] The US 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.[33] EKVs use infrared sensors to detect ballistic missiles in midcourse and maneuver into the trajectory of the missile to ensure a hit to kill.[34] With limited modification, the EKV could be used against satellites in LEO.[35] Japan is the largest international partner with the US 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.[36]

Notably, in 2008 the US reconfigured an anti-missile system to destroy failing satellite USA-193 as it de-orbited. 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 US have stressed that it was a 'one-time event'[37] and 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.[38] 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.[39] Russia has also developed a long-range (350-km) exoatmospheric missile, the Gorgon, for its A-135 anti-ballistic missile system.[40]

China has developed an advanced kinetic anti-satellite capability, demonstrated by the 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.[41] However, China called the event an experiment, not an anti-satellite test.[42] 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.[43] The UK, Israel, and India have also explored techniques for exoatmospheric interceptors. [44]

Nuclear weapons

A nuclear weapon detonated in space generates an electromagnetic pulse that is highly destructive to unprotected satellites, as demonstrated by the US 1962 Starfish Prime test.[45] 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 US 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.[46]

China, the member states of European Space Agency, India, Iran, Israel, Japan, Russia, and the US 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 US, and the UK. North Korea has an ongoing nuclear program and attempted to detonate a nuclear device in 2006.[47] Iran reportedly ended its nuclear weapons program in 2003, but, as of 2010, the International Atomic Energy Agency continues to investigate potentially illegal uranium enrichment activities.[48]

Directed energy weapons

Low-powered lasers, which could be used to "dazzle" unhardened satellites in LEO, have been used to degrade unhardened sensors on satellites in LEO.[49] In 1997 a 30-watt laser used for alignment and tracking of a target satellite for the megawatt US Mid-Infrared Advanced Chemical Laser (MIRACL) was directed at a satellite in a 420-km orbit, damaging the satellite's sensors.[50] This suggests that even a commercially available low-watt laser functioning from the ground could be used to "dazzle" or temporarily disrupt a satellite.[51] 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 is a technology that enables telescopes to rapidly adjust their optical components to compensate for distortions. This technology could be applied 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 industrial countries such as Canada, China, Japan, the US, Russia, and India have engaged in such research.[52] Nations that are developing laser satellite communications systems, such as France, Germany, and Japan, also inherently have 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 US have developed prototypes of laser systems that are capable of destroying artillery shells and rockets at short ranges. The potential of high-energy lasers to be used against satellites has been extensively explored by the US, the USSR/Russia, and China. The MIRACL laser system is able to dazzle and blind sensors in geostationary orbit (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 in New Mexico has undertaken laser experiments under the Advanced Weapons Technology program that have been characterized as "experiments for applications including anti-satellite weapons" and called for a demonstration of "fully compensated beam propagation to Low-Earth orbit satellites" in the FY2007 budget request.[53] Funding was only authorized after the USAF denied any intent to test Starfire against a satellite.[54]

The Boeing YAL-1 Airborne Laser Testbed (ALTB) system – formerly known as Airborne Laser (ABL) – of the US Air Force is central to plans for Boost Phase Ballistic Missile Defense.[55] This technology is believed by some experts to have potential ASAT capabilities despite the significant technical and cost challenges it has faced.[56] The program was initiated in 1996 and took 12 years to reach first light, at a cost of $5-billion.[57] The first ballistic missile interception was planned for late 2009[58] and finally occurred in February 2010 when the ALTB system successfully shot down a test ballistic missile.[59]

China operated a high-power laser program as early as 1986 and is believed to have since acquired multiple hundred-megawatt lasers.[60] The Chinese government has also devoted resources to high-power solid state laser research[61] and 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.[62] In 2006 China reportedly used a ground-based laser to illuminate an American reconnaissance satellite flying over Chinese territory.[63] However, using public sources to verify the nature of the laser beam, the physical effects on the spacecraft, or the intent behind the illumination is difficult.[64] South Korea is also interested in developing laser systems for use against North Korean missiles and artillery shells, and has expressed hopes of deploying such a system in 2010.[65] Indian defense scientists have also reportedly experimented with "high-power laser weapons."[66]

A summary of the technologies that are required to support the development of ground-based capabilities to attack satellites is provided in Figure 8.1.

2009 Development

Direct energy weapons continue to be developed and tested

A recent series of tests performed by the US Air Force Research Laboratory demonstrated that even relatively low power lasers can seriously compromise aircraft.[67] The experiments, which were carried out at the Naval Air Warfare Center, utilized the Boeing-developed Mobile Active Targeting Resource for Integrated Experiments (MATRIX). Five unmanned aircraft were shot down by MATRIX using 2.5-km-class lasers. While the laser may have caused damage to the aircraft control system or burned holes into its fuselage, officials have not yet clarified how such a laser was capable of taking down the drones.

At a media briefing organized by the American Association for the Advancement of Science (AAAS) that took place on 27 August 2009, the decreased performance of American satellites when flying over China[68] in 2006 was discussed. It was believed that the Chinese military had tried to degrade the performance of foreign spacecraft with the use of laser beams. In this briefing, though, some military affairs experts argued that the Chinese may have been attempting to determine orbital paths of spy satellites, and even detect their own lasers reflected back by those spacecrafts,[69] employing low power lasers that would not permanently damage a satellite.

2009 Development

Development of indigenous launch capabilities in Iran and North Korea raises concerns about peaceful intentions of their space programs

Coinciding with the celebrations of the 30th anniversary of the Islamic revolution, in February 2009 Iran launched its first domestically produced, two-staged satellite, Omid.[70] As reported by the Iranian official news agency IRNA, the Safir-2 rocket was used as a launch vehicle and the satellite successfully achieved LEO. This accomplishment represents a step forward in a national effort to create an Iranian space industry. Omid is part of a data processing satellite project that has been under development since March 2005. Western countries and Israel expressed concerns about such a development since theoretically Iran could use the launch vehicle to develop long-range missiles to carry nuclear warheads. Iran has affirmed, however, that it is not pursuing military goals with its satellite program.[71] US officials have declared that the launch vehicle is unsophisticated and relied on 50-year-old technology, and doubt that the satellite will stay in orbit for very long.[72] Iran plans a March 2011 launch of a communications satellite, which has been named Mesbah-2.[73] Israel claims that Mesbah-2 is a spy satellite designed to provide reconnaissance of Israeli territory and guide future ballistic missiles.[74] Given the refusal of Russia and Italy to launch its new satellite, Iran has decided to go ahead with the launch on its own using domestic technology. In December 2009 Iran also launched its Sejil-2 intercontinental missile.[75] Sejil-2 has enough range to reach Israel and US military bases in the Middle East. The US said that such missile launches undermine Iran's claim of peaceful intentions, whereas Iran continues to reiterate the peaceful intentions of its space program.[76]

North Korea also attempted to put its own satellite in orbit in April 2009 by utilizing a two-staged Taepodong-2 missile. After the launch, Korean officials announced that the satellite had reached orbit and was transmitting data. However, according to US military officials the satellite landed in the Pacific Ocean.[77] The United States, the European Union, Japan, and South Korea condemned the launch, arguing that it was a cover for a long-range missile launch test.[78] In spite of its failure, the launch represents an advance over the 2006 launch, when the missile disintegrated less than one minute into flight.[79] In July 2009 North Korea launched seven missiles that appear to have travelled 400 km before falling on the country's east coast.[80] Once again, the missile launches were immediately condemned by the international community.

Figure 8.1: Technologies required for the development of ground-based capabilities to attack satellite

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

2009 Development

Development of ASAT capabilities discussed in some countries

When asked in March 2009 about recent US and Chinese anti-satellite tests, Deputy Defense Minister Gen. Vladimir Popovkin said that Russia "can't sit and watch others do it. I can only say similar works are done in Russia too," adding that it is crucial to develop anti-satellite weapons in case "somebody puts weapons into space."[81] He said Russia already possesses some "basic, key elements" of the necessary technology, although he added that Moscow hopes to avoid an arms race in outer space.[82] Furthermore, Russian Air Force commander Gen. Alexander Zelin has been quoted as saying that Russia has started developing S-500 surface-to-air missiles with tracking capabilities and a 3,500-km range.[83] Zelin predicts that the US and other nations could have space-based strike systems that could reach any target in Russia by 2030.[84]

Citing the Chinese downing of the FY-1C satellite in 2007, Bruce MacDonald, a consultant to the Council on Foreign Relations, told the US Armed Services Committee in March 2009 that the US should consider the development of weapons capable of disabling space-based threats as a strategy to protect its own space assets, given the country's reliance on its space infrastructure.[85] However, MacDonald warned that the US Defense Department should pursue these capabilities "in a manner that other nations see as unthreatening as possible" so that the development of US offensive space systems does not lead to an arms race in outer space. He stated, "If there are no feasible alternatives, then we should develop a limited offensive capability, in a deterrence context."[86] Furthermore, he added that a US ASAT should be designed to temporarily disable, rather than destroy, an enemy satellite.

Of further concern, in the fall, Chinese Air Force commander Xu Qiliang stated that it was imperative for the People's Liberation Army Air Force to develop offensive and defensive operations in outer space, as a space arms race has become a "historical inevitability and cannot be undone."[87] In response, Gen. Kevin Chilton, head of the Pentagon's Strategic Command, noted that the US military is keen to investigate "why they might want to go in that direction and what grounds might exist to accommodate a different direction."[88] Just days later, however, Chinese President Hu Jintao aimed to dispel any concerns that his Air Force commander's comments may have raised by reiterating that China has not abandoned its longstanding opposition to the weaponization of space. Specifically, Hu noted that "China will unswervingly uphold a national defense policy that is defensive in nature and will never seek military expansion and an arms race."[89]

The Iranian launch of Omid has renewed Israel's intentions to protect its assets in space and negate space-based intelligence of enemy countries. The head of the Space Research Center of Israel's Fisher Institute for Air and Space Strategic Studies, Tal Inbar, said that Israel should address ASAT issues in the technological and political spheres, since ASAT operations may be deployed in the future.[90] Retired Maj. Gen. Yitzhik Ben-Israel, chairman of the Israel Space Agency, reported that the Arrow-3 interceptor could be adapted for ASAT roles.[91] The Arrow-3 is a hit-to-kill, exo-atmospheric interceptor being developed by Israel Aerospace Industries (IAI). Yari Ramati, IAI's vice-president for marketing, outlined engineering challenges such as the necessity of launching the interceptor before the target comes into line of sight, the determination of impact points for debris minimization, and the necessity of intercepting sensors to detect approaching satellites. [92]

A senior official of the India Defence Research & Development Organisation (DRDO), V.K. Saraswat, claimed that India planned to start a comprehensive test of its missile defense system in 2009. Such a system would employ radar technology for tracking and fire control, and appears to have been developed by DRDO in partnership with Israel and France.[93] However, in March 2009 the Indian Prime Minister's Special Envoy, Shyam Saran, stated that India is also willing to work with the US to achieve a multilateral agreement in the area of anti-satellite weapons that will secure nuclear stability and international security. This statement is in accord with recent announcements of US President Barack Obama, who intends to prevent military conflict in space and prohibit testing of anti-satellite weapons.[94]

Figure 8.2: History of ground-based anti-satellite demonstrations[9]

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 kilometers of the 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 kilometer
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 in satellite's path
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.

2009 Space Security Impact

In experiments in the US Air Force Research Laboratory, low-power lasers have successfully compromised small aircraft. Although not tested against satellites, low-power lasers could potentially temporarily or permanently damage non-hardened components of spacecraft. Although US satellites experienced only decreased performance when purportedly illuminated by Chinese laser beams in 2006, such an incident could have led to reciprocal actions and therefore have contributed negatively to security in space. Another factor potentially affecting space security is the sustained testing of launch vehicles by Iran and North Korea. Since those launch vehicles could also be employed for non-peaceful objectives, the conduct of these countries has been scrutinized. The development of ASAT weapons remains highly contentious. The actual hostile use of a weapon against a space asset could result in a weapons race in space, thus considerably reducing space security.

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, or non-negation military programs. A summary of the existing capabilities of key space actors that are considered enabling technologies for the development of space-based ASATs is provided in Figure 8.3.

Space-based weapons targeting satellites with conventional explosives, referred to as "space mines," could employ microsatellites to maneuver near a satellite and explode within close range. Microsatellites are relatively inexpensive to develop and launch, and have a long lifespan; their intended purpose is difficult to determine until detonation. Moreover, due to its small size, a space-mine microsatellite can be hard to detect.

Microsatellite technology has become widespread, involving an array of civil, military, commercial, and academic actors. In 2000 the partnership between China and Surrey Satellite Technology Ltd. of the UK saw the launch of the Tsinghua-1 microsatellite and companion Surrey Nanosatellite Application Platform to test on-orbit rendezvous capabilities.[96]

A variety of ongoing US programs are developing 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) employs 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 is linked to the Advanced Weapons Technology element of the budget suggests that it could potentially evolve into an ASAT program.[97]

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,[98] prompting the kill vehicle to be replaced with a laser communications payload. In 2006 the US 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 the Defense Advanced Research Projects Agency (DARPA), the USAF, and the US Navy. A major goal of the MiTEx demonstrations is to assess the potential of small satellites in GEO for defense applications.[99] In January 2009 the Pentagon confirmed that the two MiTEx microsatellites had maneuvered in close proximity to a failing satellite in GEO.[100] This incident, described below, raised concerns that the ability to get in such close proximity to another satellite could potentially be used for hostile actions.[101]

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.[102] 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.[103]

Other US 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.[104] 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 is "designed to allow interaction with geostationary orbit (GEO)-based military and commercial spacecraft, extending their service lives and permitting satellite repositioning or retirement."[105]

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.[106] As well, DARPA's Tiny Independent Coordinated Spacecraft (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 potentially be used against non-cooperative satellites. However, this program was cancelled in the FY2009 budget.[107] Although these developing technologies could potentially support space-based anti-satellite systems, many of them also enable space-based means for protecting satellites and are thus covered in Chapter 7.

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."[108] Sweden has developed the automated rendezvous and proximity operation PRISMA satellites, which were successfully launched in June 2010 from Yasni, Russia.[109] The PRISMA satellite project will demonstrate technologies for autonomous formation flying, approach, rendezvous, and proximity operations.[110] There is no evidence to suggest that these programs are intended to support space systems negation, but the technologies could conceivably be modified for such an application.

2009 Development

US updates military doctrine on space operations and advances its rendezvous capabilities

In a January 2009 report the US Joint Chiefs of Staff updated the US Armed Forces doctrine for planning, executing, and assessing joint space operations.[111] The report includes a section on Rendezvous and Proximity Operations, which determines that such maneuvers should ensure space flight safety to avoid collisions, and prevent the creation of space debris. Another section on Offensive Space Control mentions the utilization of space systems to negate capabilities of adversaries through denial, deception, disruption, degradation, or destruction.[112] Undoubtedly such a report explicitly reflects US preparedness for negation actions in space.

In January 2009 the Pentagon used two DARPA-developed MiTEx microsatellites orbiting at GEO to inspect the failing DSP-23 satellite.[113] The use of the microsatellites, whose tasks included the localization of missile launches and nuclear tests, has raised concerns that "if such satellites can get so close to a target, they could probably attack it."[114] The secrecy surrounding this operation has generated questions about potential future use of the microsatellites, particularly in anti-satellite missions.

Figure 8.3: Enabling capabilities of key actors for space-based kinetic-energy ASATs*

Capability	China	EU/ESA	France	UK	India	Israel	Japan	Russia	Ukraine	US
Space launch vehicles										
Land – Fixed[115]	X	X	X		X	X	X	X	X	X
Land – Mobile[116]	L		L	L	L	L		X	L	X[117]
Sea	L[118]							X[119,120]	X[121]	X[122]
Air								D[123]		X[124]
Space tracking (uncooperative)										
Optical (passive)	X[125]	X	X[126]	X[127]			X[128]	X[129]		X[130]
Radar	X[131]		X[132]	X[133]			X[134]	X[135]		X[136]
Laser[137]	X	X	X	X		X	X	X	X	X
Autonomous rendezvous										
Cooperative		D[138]						X[139]		D[140]
Uncooperative		D[141]						F[142]		D
Proximity operations										
Cooperative		D[143]								X[144]
Uncooperative		D[145]								X[146]
High-g, large-△V upper stages	X	X	X	L	D		X	X	X	X
Microsatellite construction	X	X	X	X	X	X	X	X	X	X

Key:
X = Existing capability
F = Flight-tested capability
D = Under development
L = Latent capability
*This figure highlights enabling technologies for space-based kinetic-kill negation capabilities. It does not imply that these actors have such negation systems or even programs to develop them, merely that they have prerequisite technologies that would make acquisition of such a system a shorter-term possibility.

2009 Space Security Impact

The inclusion of sections on rendezvous and proximity operations and offensive space control in the US doctrine for planning, executing, and assessing joint space operations can have serious implications for space security. Those capabilities can be employed not only to increase the security of US space assets by allowing for evasive maneuvers, but also to rendezvous with and compromise foreign spacecrafts. Enhanced rendezvous operations have already been demonstrated by the DARPA MiTEx microsatellites when inspecting the non-operational DSP-23 satellite. Several foreign nations can interpret such developments as potential threats to their space assets. A consequence of such a development could be the acceleration of investments in enhanced negation capabilities worldwide, thereby negatively impacting space security.

CHAPTER NINE

Space-Based Strike Capabilities

This chapter assesses trends related to the research, development, testing, and deployment of capabilities that could support space-based strike systems. Space-based strike systems operate from Earth orbit with the capability to damage or destroy either terrestrial targets (land, sea, or air) or terrestrially launched objects passing through space (e.g., ballistic missiles), via the projection of mass or energy. Earth-to-space and space-to-space strike capabilities, often referred to as anti-satellite (ASAT) weapons, are addressed in Chapter 8, Space Systems Negation. Space systems that support Earth-based strike capabilities, such as reconnaissance satellites, are addressed in Chapter 6, Space Support for Terrestrial Military Operations.

Mass-to-target strike systems collide with a target, damaging it through the combined mass and velocity impact of the weapon, or hit a target with inert or explosive devices. One mass-to-target concept is the US missile defense Space-Based Interceptor (SBI), which is designed to accelerate toward and collide with a ballistic missile in its boost phase. Another mass-to-target concept is the hypervelocity rod bundle – an orbital uranium or tungsten rod that would be decelerated from orbit and reenter the Earth's atmosphere at high velocity to attack ground targets.

Energy-to-target strike systems, often called directed energy weapons, transfer energy through a beam designed to generate sufficient heat or shock to disable or destroy a target. This beam could be generated using lasers, microwaves, or neutral particle beams. An example is the US Space-Based Laser (SBL) concept for missile defense. An SBL would attempt to use a satellite to direct an intense laser beam at a missile during its launch phase, heating it to the explosion point. An SBL satellite would require an energy source to power the laser, optical systems to generate the laser, and precise attitude control to point the laser beam accurately at the target for a relatively sustained period of time. The US Missile Defense Agency (MDA) closed the SBL program in 2000, thus cancelling the anticipated 2012 test of the system, although some reports have suggested that classified work on the concept may be ongoing.[1]

While no space-based strike weapons (SBSW) have yet been tested or deployed, the US and USSR devoted considerable resources to developing them during the Cold War. The US continues to research supporting technologies within the context of its missile defense program and a vocal minority continues to argue for deployment of such systems. In addition to assessing the status of these dedicated space-based strike programs, this chapter also assesses efforts of space actors to develop key technologies required for space-based strike capabilities, even if they are not being pursued for that purpose. While it is generally accepted that only the most advanced spacefaring states could overcome the technical hurdles to deploy space-based strike systems in the foreseeable future, the actual effectiveness of such systems remains unclear.[2]

Space Security Impact

Space-based strike systems can have a direct impact on several aspects of space security. An actor with a space-based strike capability, such as an SBI, could use such a system to deny or restrict another actor's ability to access space by attacking its space launch vehicles. Moreover, since some space-based strike systems may also be capable of attacking satellites, they could be used to restrict or deny the use of space assets. In addition, such an attack could generate additional space debris or electromagnetic interference.

The deployment of a space-based strike system would enable an actor to threaten and even attack targets on Earth with very little warning, which would constitute a departure from current practice regarding the military use of space. Such a scenario would raise questions regarding the interpretation of the "use of outer space for peaceful purposes" as enshrined in the preamble of the Outer Space Treaty, which remains a point of contention in space law.[3] It would directly threaten space security since actors would no longer enjoy freedom from space-based threats.

Because actors may seek to offset space-based threats, the deployment of space-based strike systems would most likely encourage the development of anti-satellite weapons and legitimize attacks on space assets in self-defense, thereby undermining certain normative restrictions and moratoria concerning such attacks. To ensure a rapid response, strike systems would have to be placed in low earth orbit, making them vulnerable to attack.[4] Further, the testing and deployment of ASAT systems in response to the development of space-based strike capabilities could generate space debris, further compromising the sustainable use of space for all space actors.

It has been argued that space-based strike capabilities may be necessary to protect space systems from attack.[5] The protection of satellites and the missile defense potential of space-based strike systems are two of the most commonly cited justifications for their development. As noted in Chapter 8, these systems could be used to protect the security of space assets against space negation attacks that might inflict long-term and disproportionate damage to the space environment or otherwise deny access to space.

Trend 9.1: Funding cuts in US mark move away from development of missile defense space-based interceptor

No known integrated space-based strike systems have been tested or deployed. The most advanced space-based strike effort during the Cold War focused primarily on the development of mass-to-target weapons. In the 1960s the USSR developed the Fractional Orbital Bombardment System (FOBS) to deliver a nuclear weapon by launching it into a low Earth orbit (LEO) at an altitude of 135-150 km; it would de-orbit after flying only a fraction of one orbit, destroying Earth-based targets.[6] The FOBS was not a space-based strike system, although it demonstrated capabilities that could be used in the development of an orbital bombardment system. A total of 24 launches – 17 successful – were undertaken between 1965 and 1972 to develop and test FOBS.[7] It was phased out in January 1983 to comply with the Strategic Arms Limitation Treaty II, under which deployment of FOBS was prohibited. It is not publicly known whether nuclear weapons were orbited through the FOBS efforts.

The US and USSR both pursued the development of energy-to-target space-based strike systems in the 1980s, although today these programs have largely been halted. In 1985 the US held underground tests of a nuclear-pumped X-ray laser for the SBL under the Strategic Defense Initiative, although the effort proved unsuccessful and was abandoned. In 1990 the US also performed a Relay Mirror Experiment, which tested ground-based laser re-directing and pointing capabilities for the SBL.[8] In 1987 the USSR's heavy-lift Energiya rocket launched a 100-ton payload named Polyus, which by some reports included a neutral particle beam weapon and a laser. Due to a failure of the attitude control system, the payload did not enter orbit.[9] The USSR's neutral particle beam experiments were reportedly halted in 1985.

The US SBL program was cancelled in 2000 and the SBL office closed in 2002.[10] Although indirect research and development continue through the US MDA, the technology for the

SBL does not exist.[11] Approximately $50-million was allocated to both the Department of Defense (DOD) Directed Energy Technology and High Energy Laser Research programs in FY2007; however, Congress cut funding for Laser Space Technology development.[12] Other larger classified budgetary programs are suspected to be continuing work on space-based directed energy technologies.[13]

The SBI concept was developed to contribute to missile defense by providing a capability to intercept missiles as they pass through space. One of the first key tests of US SBI-enabling technologies was the 1994 Clementine lunar mission to test lightweight spacecraft designs "at realistic closing velocities using celestial bodies as targets."[14] The US Near-Field Infrared Experiment (NFIRE) is designed to include many of the key capabilities required for an SBI, including appropriate sensors, propulsion, and guidance units.[15] However, the US Congress denied the NFIRE system the ability to launch an independent "kill vehicle" to intercept a missile.[16] The US has also completed a phase-one study for the Microsatellite Propulsion Experiment (MPX), which would include two two-stage, anti-missile propulsion units – a key requirement for an SBI capability.[17]

Longer-term US plans for the potential deployment of an SBI testbed[18] have faced repeated delays and funding cuts in recent years. This is generally perceived to be a positive development as deployment of the testbed would constitute the first of a space-based strike system (although there are questions about its operational utility). Since its first appearance on the budget request in FY2004 under the Ballistic Missile Defense Interceptor Program, plans for the Space Test Bed have been scaled back financially and the timeline has been extended. The budget request in FY2004 was $14-million, with initial tests scheduled for 2008. By FY2005 initial experiments had been pushed back to 2010–2011. The amount of funding requested dropped sharply, from $1.5-billion for FY2003–2007 to $290-million for FY2007–FY2013. The FY2007 authorization bill prohibited the DOD from using funds for the "testing or deployment of space-based interceptors" until 90 days after submitting to Congress a detailed report on the project, including, inter alia, "a projection of the foreign policy and national security implications of a space-based interceptor program, including the probable response of United States adversaries and United States allies."[19] More recently, for FY2010 the US House Budget Committee resolved not to allocate any funding for the research and development of space-based interceptors, as explained in the related development below.

While the development of an integrated space-based strike vehicle may be possible within years rather than decades, building a militarily effective strike system with global coverage remains a significant technical challenge. A truly global system would require hundreds or even thousands of vehicles in orbit, and thus a launch capacity about five to 10 times greater than the current US launch capacity.[20] An examination of the technical feasibility of such a system for missile defense, conducted by the American Physical Society, estimated that launch costs alone for a system covering latitudes that include Iran, Iraq, and North Korea would likely exceed $44-billion.[21] The US Congressional Budget Office estimated the full cost of a system with a similar coverage of the globe, but with the capability to intercept only liquid-fueled ballistic missiles with longer launch timelines, at between $27-billion and $40-billion. Such a system presumed considerable advances in kill vehicle components. Without these advances, coverage would cost between $56-billion and $78-billion.[22]

In sum, no SBSW have been tested or deployed to date, although Cold War-era programs did support considerable development and testing of key technologies. Moreover, while it is hard to determine whether the trend is long-term, at present there seems to be a move *away* from the development of SBI systems.

2009 Developments

Space-based missile interceptor technologies face funding cuts in the US

Following the funding cuts for the US Space Test Bed in 2008,[23] other space-based weapons projects continued to lose funding or be cancelled in 2009. In the Defense Budget Recommendation Statement, released in April, the US Department of Defense announced that the second Airborne Laser (ABL) prototype aircraft, designed to create an air-based weapons platform that could hit ballistic missiles in their launch phase, would be cancelled.[24] The first ABL aircraft, already in existence, will be kept but will be shifted to an R&D effort. Further, the Multiple Kill Vehicle (MKV), whose building contract was awarded to Raytheon in November 2009 with an intended completion date of 2011,[25] will also be terminated due to its "significant technical challenges."[26] In October, these decisions were finalized in the 2010 Defense Authorization bill. The Kinetic Energy Interceptor (KEI), a project designed to create an interceptor capable of destroying incoming missiles while their booster rockets are still burning,[27] was also terminated.[28] In total, the MDA program was reduced by $1.4-billion.[29] Finally, the US House Budget Committee for FY2010 resolved in section 502 that "ballistic missile defense technologies that are not proven to work through adequate testing and that are not operationally viable should not be deployed, and that *no funding should be provided for the research or development of space-based interceptors*" [emphasis added].[30]

2009 Development

US reiterates policy of not actively developing space weapons

The Pentagon reiterated in early 2009 that the United States is not developing space weapons and that, even if it wanted to, it could not afford to do so.[31] While early in President Obama's term the Whitehouse pledged to seek a worldwide ban on space weapons,[32] the US policy against signing a legally binding treaty that would ban space-based weapons has not changed since the 1970s.[33] (For further details see Chapter 3.)

2009 Development

Development of Space Tracking Surveillance System moves forward while related Space Based Space Surveillance project remains stalled

While SBI technology projects continued to be scaled back and cancelled in 2009, the US pressed forward with the Space Tracking Surveillance System (STSS), which represents a significant development in the capability to detect an intercontinental ballistic missile from space. In May, the STSS Risk Reduction satellite was launched as a research and development project that will test new space-based sensors and their ability to track ballistic missiles.[34] In September, two additional STSS experimental satellites were launched from the Cape Canaveral Air Force Station in Florida.[35] The satellites were designed to demonstrate the ability to track ballistic missiles in every stage of their flight, something that current US space technology cannot do.[36] Tests are planned to verify the satellites' performance using dedicated missile launches in the near future. The US Congress has yet to approve funding for an operational version of the STSS, but funding may be pursued by the military in 2011 or later if the demonstration satellites prove to be effective.[37]

Meanwhile, the related Space Based Space Surveillance (SBSS) project remains stalled. The project, originally planned in 2001, is intended to track space objects from space to provide the US military with space situational awareness.[38] While the first SBSS satellite launch was originally planned for late 2008,[39] it was later rescheduled for spring 2009, then October 2009,[40] and has now been delayed indefinitely due to concerns with the Minotaur 4 launch vehicle.[41]

2009 Space Security Impact

The absence of functioning space-based strike systems undoubtedly has a positive impact on space security. The US government seems to be voluntarily backing away from the pursuit of SBI technology by cutting R&D funding for these programs. The Pentagon's reiteration of its policy to not actively develop space weapons also has a positive impact for space security. The fact that the country with the most advanced space capabilities chooses not to actively pursue space-based weapons serves to delegitimize these weapons among other spacefaring states. Although the development of the STSS continued to move forward in 2009, this technology is not necessarily applicable to space-based strike systems; the direction this system takes when operational will indicate its overall impact on space security.

Trend 9.2: Continued development of advanced technologies that could be used for space-based strike-enabling capabilities

Due to the potentially significant effects of space-based strike systems on space security dynamics, it is important to assess research into advanced enabling technologies that could support the development of space-based strike capabilities. Of concern here are purely technological capabilities, not the intentions of actors. The enabling technologies described below are multi-purpose. None are related to dedicated space-based strike programs, but are part of other civil, commercial, or military space programs. However, they do bring actors technologically closer to developing such a capability.

The advanced enabling technologies listed in Figure 9.2 are those required for space-based strike capabilities, which differ from and are more advanced than basic space access and use capabilities such as orbital launch capability, satellite manufacturing, satellite telemetry, tracking and control, mission management, and Earth imaging. This analysis is based on the characteristics of these weapons systems as described in open source literature.[42]

A precision **position maneuverability capability** to ensure that an object can be moved to a specific location with an accuracy of less than 10 m has been demonstrated by only a few actors. Both the US and Russia have performed a large number of space dockings that require such capability. The European Space Agency has completed the development of this capability for its Automated Transfer Vehicle, which docked at the International Space Station in 2008. The Chinese manned spacecraft, the Shenzhou series, is also equipped with a docking mechanism.[43]

The US has worked on the development of **high-G thrusters** that would provide the large acceleration required for the final stages of missile homing for an SBI system, should one be eventually developed. As well, a large delta (Δ)-V thruster, which would enable the change in velocity required to maneuver in orbit or to de-orbit to reach the target, is fundamental for several space-based strike capabilities. The latter is a relatively common capability that has been demonstrated by space actors with rocket technology, including the states that have demonstrated orbital or suborbital space access.

Figure 9.1 provides an overview of the space-based strike enabling technologies reported to be possessed or under development by key space actors. Included are only those spacefaring nations that have developed orbital space access, a prerequisite for all space-based strike systems.

Figure 9.1: Space-based strike enabling capabilities of key space actors[4]

Advanced capabilities	China	EU/ESA	France	UK	India	Israel	Japan	Russia	Ukraine	US
Precision position maneuverability	■	■					■		■	■
High-G thrusters										□
Large Δ-V thrusters	■	■	■	■	■	■	■	■	■	■
Accurate global positioning	□	□			□	□	□	□	□	■
Anti-missile homing sensors			■	■	□	■	■	■		■
Global missile tracking							■		■	■
Global missile early warning			□				■		■	■
Launch on demand							□		□	□
Microsatellite construction	■	■	■	■	■	■	■	■	■	■
High-power laser systems	■								■	■
High-power generation							(■)		□	□
Large deployable optics	■	■	■		□	□	□	■		■
Precision attitude control	■	■	■		□	■	■	■		■
Precision reentry technology	■	□	■	■	□			■		■
Nuclear power	■		■	■	■	■	■	■	■	■
Space-based laser									(□)	(□)
Space-based interceptors									(□)	□
Hypervelocity rod bundle										
SB munitions delivery (conventional)										
Neutral particle beam									(□)	(□)

Key
■ = Some capability[46]
□ = Capability under development
(■) = Past development
(□) = Past capability

Accurate **global positioning** capabilities required for all space-based strike concepts are possessed primarily by the US (GPS) and Russia (GLONASS). Other actors with space access have some involvement in the development of navigation systems – for example, the EU Galileo system, the Chinese Beidou constellation, and the Japanese Quazi-Zenith Satellite System (see Chapter 4, Civil Space Programs and Global Utilities). It is also noteworthy that many actors could make use of the global positioning afforded by the US and Russian systems.

Missile homing sensors, which provide real-time directional information during the missile homing phase and would be required for an SBI system, are a capability common to most advanced military powers, including the US, Russia, and Israel, which have developed such systems for their ground-based missile defense capabilities.

Relatively extensive **global missile warning and missile tracking** capabilities, required for SBI and SBL, were developed by the US and USSR during the Cold War. Early warning of missile launches has been provided by the US Defense Support Program satellites and the Russian Oko and Prognoz satellites; both states are working on upgrades and/or replacements for these systems. The US Space Based Infrared System (SBIRS) and Space Tracking and Surveillance System (STSS) are expected to be significantly more accurate. While the STSS – designed to track missiles through all stages of flight[47] – was launched in September 2009, the launch of the first geosynchronous satellite for the SBIRS system has been delayed until late 2010 or early 2011.[48] Finally, the first two satellites of France's early warning SPIRALE system were placed in orbit in February 2009.[49]

Launch vehicles with an operational readiness of less than one week are necessary to provide the launch-on-demand capabilities to maintain an effective global space-based strike system. Russia has traditionally had the shortest average period between launches, but no state yet possesses a launch-on-demand capability. The US is developing a responsive launch capability through its Falcon program.[50] Some commercial actors, in particular Space-X, aim to provide more responsive and less expensive space launches[51] with vehicles like Falcon 9.

Microsatellite construction, which allows for reduced weight and increased responsiveness of space-based interceptors, is also a key enabling capability for an effective SBI system. China, ESA, France, Israel, Russia, the UK, the US, Canada, and India have developed microsatellites.

The **high-power laser systems** envisioned for an SBL have been developed to some extent by the US, initially through its SBL effort and more recently through its Airborne Laser, MIRACL, Joint High Power Solid-State Laser (JHPSSL), and Starfire programs (see Chapter 8). China has also operated a high-power laser program since 1986 and has reportedly developed multiple hundred-megawatt lasers.[52] The development of a technology to build a high-power SBL has not been documented.[53]

High-power generation systems for space, necessary to power an SBL concept and for high thrust propellants for kinetic strike capabilities, have been developed and deployed both by the US and former USSR, particularly with the use of nuclear power. The US System for Nuclear Auxiliary Power-10A mission launched in 1965 had a 45-kw thermonuclear reactor. NASA is working on several nuclear projects under Project Prometheus.[54] Between 1967 and 1988 the USSR launched 31 low-powered reactors in Radar Ocean Reconnaissance Satellites.[55] While no other states have developed such capabilities for space, all states with a launch capability also have nuclear power programs.

Large deployable optics and precision attitude control – both needed for an SBL concept, and the latter applicable for all space-based strike concepts – have been developed by actors that include China, ESA, France, Japan, Russia, and the US for military reconnaissance or civil astronomical telescope missions.[56]

Precision reentry technology, needed to prevent burn-up and lateral lift when reentering the atmosphere, for kinetic space-to-Earth strike concepts, has been developed by those states with a human spaceflight capability: China, Russia, and the US. As well, the Japan Aerospace Exploration Agency has some experimental reentry vehicle programs.[57] While states with nuclear weapons may have developed precision reentry technologies for their nuclear warhead reentry vehicles, the capabilities needed for a rapid strike from space are more complex, due to the higher speed at which reentry would occur.[58]

Figure 9.2: Advanced space-based strike enabling capabilities*

Capability	Conventional			Nuclear	Directed energy	
	Interceptor	Hypervelocity rod bundle	Munitions delivery	Munitions delivery	Laser	Neutral particle beams
Precision position maneuverability	■	■	■	■		
High-G thrusters	■					
Large Δ-V thrusters	■	■	■	■		
Global positioning	■	■	■	■	■	■
Missile homing sensors	■				■	
Global missile tracking	▲				▲	▲
Global missile early warning	▲				▲	▲
Launch on demand	■	■	■	■	■	■
Microsatellite construction	■					
High-power laser systems					■	
High-power generation					■	■
Large aperture deployable optics					■	
Precision attitude control					■	■
Precision reentry technology		■	■	■		
Nuclear weapons				■		

Key
■ = Required
▲ = Needed but not necessarily on the primary Space-Based Strike Weapon

* This figure highlights technologies for space-based strike. It does not imply that all of these actors have such strike capabilities or programs to develop them, merely that they have prerequisite technologies that would make acquisition of such a system a real possibility.

2009 Development

Boeing conducts successful test of air-based laser weapon for US Air Force

In June Boeing and the US Air Force successfully fired a high-powered laser from the Advanced Tactical Laser (ATL) aircraft while in flight.[59] The successful test demonstrates that an airborne system can fire a high-power laser while in flight and deliver laser beam energy to a ground target. In August the ATL achieved another milestone when it destroyed a ground target, demonstrating the first air-to-ground high-power laser engagement of a tactically representative target.[60] Following that test, the system struck a moving target for the first time in a test in October.[61] While these tests do not represent *space*-based weaponry, they are technological steps toward the capability of defeating ground-based military targets from space. In a somewhat related development, the US Air Force and Boeing announced this year that they will be ready to test the X-37B, an unpiloted military space plane, in early 2010.[62] This project is seen by many as a potential space-based weapons platform. The Director of the United Nations Institute for Disarmament Research noted that the X-37B could be seen as a Global Strike platform, to which competitors might see anti-satellite weapons as a leveler, potentially leading to a space-based arms race.[63]

2009 Development

Space-based strike enabling capabilities continue to be developed

Following the 2007 call for the US Department of Defense to establish a Prompt Global Strike (PGS) program,64 Air Force Gen. Kevin Chilton, head of US Strategic Command, noted in 2009 that deploying the first prompt global strike weapon within the next five to six years would be a "reasonable" objective, and he is pushing for a debut by 2015.[65] Further, the PGS could receive another push forward; in June the Pentagon modified a defense contract that will allow Lockheed Martin's FALCON Hypersonic Test Vehicle (HTV) project to become a component of the PGS program, giving the PGS a possibility of a future hypersonic speed component.[66]

Nevertheless, the first Air Force-sponsored test of a PGS system, the Conventional Strike Missile (CSM), has been postponed to 2012 due to 2009 funding cuts.[67] PGS and other 2009 advances, including the successful tests of air-to-ground laser weapons and the moving forward of a potential global-strike space-based weapons platform based on the X-37B military space plane, do not necessarily represent dedicated space-based strike programs, but do bring the United States closer to being able to develop a space-based strike capability.

2009 Space Security Impact

Space-based weapons designed to strike terrestrial targets will require sophisticated technological developments that, at present, few spacefaring states seem able or willing to attempt. Although there is no evidence to definitively suggest that states are developing the abovementioned technologies for space-based strike purposes, the potential for space-to-Earth strike systems will continue to challenge the international community. The technology behind the air-based laser weapons developed by Boeing, for example, would have a negative impact for space security should it be conceived as a steppingstone toward a space-based weapon. Similarly, the push for a debut of the Prompt Global Strike program by 2015 could also represent a negative for space security; this program can be seen as another step toward the development of space-based strike capabilities, even if the current program has another goal. Nevertheless, restraint in adopting these technologies is being observed. Continued restraint bodes well for space security.

Space Security Working Group Meeting

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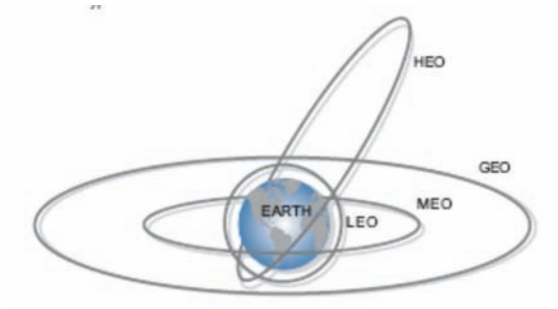
ANNEX 2: Types of Earth Orbits

Types of Earth Orbits*



Low Earth Orbit (LEO) is commonly accepted as below 2000 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.

ANNEX 3: Worldwide Launch Vehicles

Worldwide launch vehicles[1]

Vehicle	First Launch	Reliability*	Active Sites	LEO kg	GTO kg
Europe					
Ariane 5 (G, G+, GS, ECS)	1996	49/51	Kourou	16,000-21,000	6,200-10,500
China					
Long March 2C (SD, CTS,SMA)	1975	33/33	Jiuquan, Taiyuan, Xichang	3,200	1,000
Long March 2D	1992	11/11	Jiuquan	3,500	1,250
Long March 2F	1999	7/7	Jiuquan	?	?
Long March 3A	1994	16/16	Taiyuan, Xichang	6,000	2,600
Long March 3B	1996	11/12	Xichang	13,562	4,491
Long March 3C	2008	2/2	Xichang	3,700	N/A
Long March 4B	1999	11/11	Taiyuan	2,800	N/A
Long March 4C	2007	3/3	Taiyuan	4,200	1,500
India					
PSLV	1993	14/15	Satish Dhawan	3,700	800
GSLV	2001	4/5	Satish Dhawan	5,000	2,500
Japan					
H-2A H-2B	2001 2009	17/17 1/1	Tanegashima Tanegashima	11,730 19,000	5,800 8,000
Israel					
Shavit 1	1988	5/7	Palmachim	225	N/A
US					
Atlas 5	2002	19/19	CCAFS, VAFB	12,500 (402) 20,520 (552)	4,950 (400) 8,670 (500)
Delta 2	1990	75/76	CCAFS	6,100	2,170
Delta 4	2002	11/11	CCAFS, VAFB	9,150 (M) 13,360 (M+) 22,560 (H)	4,300 (M) 8,670 (M+) 12,980 (H)
Falcon-1	2008	2/5	Omelek Island	470	N/A
Minotaur	2000	9/9	VAFB, MARS	640	N/A
Pegasus XL	1994	28/30	CCAFS, Kwajalein, MARS, VAFB	443 (XL) 500 (HAPS)	N/A
Taurus XL	1994	6/9	VAFB	1,275	445
Russia					
Dnepr	1999	12/13	Baikonur, Dombarovskiy	3,700	N/A
Kosmos 3M	1967	422/445	Plesetsk	1,350	N/A
Molniya	1960	331/342	Baikonur, Plesetsk	1,800	N/A
Proton K	1967	316/342	Baikonur	19,760	4,430
Proton M	2000	37/39	Baikonur	21,000	5,500
Rockot	1994	12/14	Baikonur, Plesetsk	1,850	N/A
Soyuz	1958	1325/1377	Baikonur, Plesetsk	6,708	1,350
Soyuz 2	2004	7/7	Baikonur, Plesetsk	7,800	1,700
Tsiklon 2/3 (retired in January 2009)	1965	242/259	Baikonur	3,000	N/A

[1] Space Foundation, The Space Report 2008 (Colorado Springs: Space Foundation 2008), at 53-57; FAA, "Year in Review 2009;" Gunter de Krebs, Gunter's Space Page, http://www.skyrocket.de/space/.

Vehicle	First Launch	Reliability*	Active Sites	LEO kg	GTO kg
Russia (cont'd.)					
Zenit 2/2M	1985	31/37	Baikonur	12,030	N/A
Iran					
Safir	2008	1/2	Iran Space Center	?	?
South Korea					
KSLV-I	2009	0/1	Naro	100	N/A
North Korea					
Taepodong 2	2009	0/1	Tonghae	100?	N/A
Sea Launch					
Zenit 3SL	1999	31/33	Pacific Ocean	N/A	6,100
Land Launch					
Zenit 3SLB	2008	2/2	Baikonur	N/A	3,750

* As of December 2009.

ANNEX 4: Spacecraft Launched in 2009

Spacecraft Launched in 2009

COSPAR	Launch Date	Satellite Name	Actor Type	Primary Function	Owning State	Launch Vehicle	Orbit
2009-001A	1/18/2009	Orion/Mentor 4 (Advanced Orion 4, NRO L-26, USA 202)	Military	Surveillance	USA	Delta 4	GEO
2009-002A	1/23/2009	Greenhouse Gases Observing Satellite (Ibuki, GoSAT)	Civil	Earth Science	Japan	H2A	LEO
2009-002B	1/23/2009	Prism (Pico-satellite for Remote-sensing and Innovative Space Missions, Hitomi)	Civil	Earth Observation	Japan	H2A	LEO
2009-002E	1/23/2009	SOHLA 1 (Space Oriented Higashiosaka Leading Association, Maido 1)	Civil	Technology Development	Japan	H2A	LEO
2009-002C	1/23/2009	SDS-1 (Small Demonstration Satellite)	Government	Technology Development	Japan	H2A	LEO
2009-003A	1/30/2009	Koronas-Foton (Complex Orbital Observations Near Earth of Activity of the Sun)	Government	Solar Physics	Russia	Tsyklon-B	LEO
2009-005A	2/6/2009	NOAA-19 (NOAA-N Prime, COSPAS-SARSAT)	Government	Meteorology	USA	Delta 2	LEO
2009-007A	2/11/2009	Express-AM44	Commercial	Communications	Russia	Proton M	GEO
2009-007B	2/11/2009	Express-MD1	Commercial	Communications	Russia	Proton M	GEO
2009-008B	2/11/2009	Hot Bird 10	Commercial	Communications	Multinational	Ariane 5 ECA	GEO
2009-008A	2/11/2009	NSS-9	Commercial	Communications	Netherlands	Ariane 5 ECA	GEO
2009-008C	2/11/2009	SPIRALE-A (Système Préparatoire Infra-Rouge pour l'Alerte)	Military	Technology Development	France	Ariane 5 ECA	Elliptical
2009-008D	2/11/2009	SPIRALE-B (Système Préparatoire Infra-Rouge pour l'Alerte)	Military	Technology Development	France	Ariane 5 ECA	Elliptical
2009-009A	2/26/2009	Telstar 11N	Commercial	Communications	Canada	Zenit 3SLB	GEO
2009-010A	2/28/2009	Raduga 1-M1 (Cosmos 2450)	Military	Communications	Russia	Proton K	GEO
2009-013A	3/17/2009	GOCE (Gravity Field and Steady-State Ocean Circulation Explorer)	Government	Earth Science	ESA	Rokot	LEO
2009-014A	3/24/2009	Navstar GPS 49 (Navstar SVN 49, GPS IIR-20, USA 203)	Military/ Commercial	Navigation/ Global Positioning	USA	Delta 2	MEO
2009-016A	4/3/2009	Eutelsat W-2A	Commecial	Communications	Multinational	Proton M	GEO
2009-017A	4/4/2009	Wideband Global Satcom 2 (WGS-2, USA 204)	Military	Communications	USA	Atlas 5	GEO
2009-019B	4/20/2009	Anusat (Anna University Satellite)	Civil/ Government	Communications	India	PSLV C12	LEO
2009-019A	4/20/2009	RISAT-2 (Radar Imaging Satellite 2)	Military	Surveillance	India	PSLV C12	LEO
2009-020A	4/20/2009	Sicral 1B	Military/ Commercial	Communications	Italy	Zenit 3SL	GEO

COSPAR	Launch Date	Satellite Name	Actor Type	Primary Function	Owning State	Launch Vehicle	Orbit
2009-021A	4/22/2009	Yaogan 6 (Remote Sensing Satellite 6, Jian Bing 7-A)	Government	Remote Sensing	China (PR)	Long March 2C	LEO
2009-023A	5/5/2009	STSS ATRR (Space Tracking and Surveillance System Advanced Technology Risk Reduction Satellite, USA 205)	Military	Technology Development	USA	Delta 2	LEO
2009-027A	5/16/2009	Protostar 2	Commercial	Communications	Netherlands	Breeze M	GEO
2009-028C	5/19/2009	Hawksat-1	Civil	Technology Development	USA	Minotaur 1	LEO
2009-028E	5/19/2009	Aerocube-3	Commercial	Technology Development	USA	Minotaur 1	LEO
2009-028B	5/19/2009	Pharmasat	Government	Space Science	USA	Minotaur 1	LEO
2009-028A	5/19/2009	Tacsat 3	Military	Reconnaissance	USA	Minotaur 1	LEO
2009-029A	5/20/2009	Meridian-2	Government	Communications	Russia	Soyuz-Fregat (Soyuz 2)	Elliptical
2009-032A	6/21/2009	Measat 3A (Malaysia East Asia Sat 3A)	Commercial	Communications	Malaysia	Zenit 3SLB	GEO
2009-033A	6/27/2009	GOES 14 (Geostationary Operational Environmental Satellite, GOES-O)	Government	Earth Science/ Meteorology	USA	Delta 4	GEO
2009-034A	6/30/2009	Sirius FM-5	Commercial	Communications	USA	Proton M	GEO
2009-035A	7/1/2009	TerraStar 1	Commercial	Communications	USA	Ariane 5 ECA	GEO
2009-036A	7/6/2009	Rodnik-5 (Cosmos 2451)	Military	Communications	Russia	Rokot	LEO
2009-036B	7/6/2009	Rodnik-6 (Cosmos 2452)	Military	Communications	Russia	Rokot	LEO
2009-036C	7/6/2009	Rodnik-7 (Cosmos 2453)	Military	Communications	Russia	Rokot	LEO
2009-037A	7/14/2009	RazakSat (MACSat)	Government	Remote Sensing	Malaysia	Falcon 1	LEO
2009-038F	7/15/2009	Atmospheric Neutral Density Experiment (ANDE) Castor Sphere	Military	Scientific Research	USA	Space Shuttle (STS 127)	LEO
2009-038E	7/15/2009	Atmospheric Neutral Density Experiment (ANDE) Pollux Sphere	Military	Scientific Research	USA	Space Shuttle (STS 127)	LEO
2009-039B	7/21/2009	Sterkh-1 (KOSPAS-11, COSPAS-11)	Government	Rescue	Russia	Kosmos 3M	LEO
2009-039A	7/21/2009	Parus-98 (Cosmos 2454)	Military	Navigation	Russia	Kosmos 3M	LEO
2009-041F	7/29/2009	AprizeSat 3	Commercial	Communications	USA/ Argentina	Dnepr	LEO
2009-041D	7/29/2009	AprizeSat 4	Commercial	Communications	USA/ Argentina	Dnepr	LEO
2009-041A	7/29/2009	Deimos 1	Government	Earth Observation	Spain	Dnepr	LEO
2009-041B	7/29/2009	DubaiSat-1	Government	Earth Observation	UAE	Dnepr	LEO
2009-041E	7/29/2009	Nanosat-1B	Government	Communication/ Technology Development	Spain	Dnepr	LEO
2009-041C	7/29/2009	UK-DMC-2 (BNSCSat-2, British National Science Center Satellite 2)	Government	Earth Observation	United Kingdom	Dnepr	LEO

COSPAR	Launch Date	Satellite Name	Actor Type	Primary Function	Owning State	Launch Vehicle	Orbit
2009-042A	8/11/2009	AsiaSat 5	Commercial	Communications	China (PR)	Breeze M	GEO
2009-043A	8/17/2009	Navstar GPS 50 (Navstar SVN 50, GPS IIR-21M, USA 206)	Military/ Commercial	Navigation/ Global Positioning	USA	Delta 2	MEO
2009-044A	8/21/2009	JCSat RA (JCSat 12, Japan Communications Satellite 12)	Commercial	Communications	Japan	Ariane 5	GEO
2009-044B	8/21/2009	Optus D3	Commercial	Communications	Australia	Ariane 5	GEO
2009-046A	8/31/2009	Palapa D1	Commercial	Communications	Indonesia	Long March 3B	GEO
2009-047A	9/8/2009	PAN-1 (Palladium at Night, P360, USA 207)	Military	Communications	USA	Atlas 5	GEO
2009-049D	9/17/2009	Tatiana-2 (Universitetskij 2)	Civil	Earth Observation	Russia	Soyuz 2-1b	LEO
2009-049E	9/17/2009	UGATUSAT (Ufa State Aviation Technical University (UGATU) Satellite)	Civil	Technology Development/ Earth Observation	Russia	Soyuz 2-1b	LEO
2009-050A	9/17/2009	Nimiq 5	Commercial	Communications	Canada	Breeze M	GEO
2009-049A	9/17/2009	Meteor-M (Meteor-M1)	Government	Meteorology	Russia	Soyuz 2-1b	LEO
2009-049B	9/17/2009	Sterkh-2 (KOSPAS-12, COSPAS-12)	Government	Rescue	Russia	Soyuz 2-1b	LEO
2009-049F	9/17/2009	SumbandilaSat (ZASat-002)	Government/ Civil	Remote Sensing	South Africa	Soyuz 2-1b	LEO
2009-051C	9/23/2009	BeeSat (Berlin Experimental and Educational Satellite)	Civil	Technology Development	Germany	PSLV	LEO
2009-051D	9/23/2009	ITU-pSAT1 (Istanbul Technical University Picosat-1)	Civil	Technology Development	Turkey	PSLV	LEO
2009-051E	9/23/2009	SwissCube	Civil	Technology Development	Switzerland	PSLV	LEO
2009-051A	9/23/2009	Oceansat-2	Government	Remote Sensing	India	PSLV	LEO
2009-052A	9/25/2009	STSS Demo-1 (Space Tracking and Surveillance System Demonstrator)	Military	Technology Development	USA	Delta 2	LEO
2009-052B	9/25/2009	STSS Demo-2 (Space Tracking and Surveillance System Demonstrator)	Military	Technology Development	USA	Delta 2	LEO
2009-054A	10/1/2009	Amazonas-2	Commercial	Communications	Spain	Ariane 5	GEO
2009-054B	10/1/2009	COMSATBw-1 (COmmunications SATellite für BundesWehr)	Military	Communications	Germany	Ariane 5	GEO
2009-055A	10/8/2009	Worldview 2	Military/ Commercial	Earth Observation	USA	Delta 2	LEO
2009-057A	10/18/2009	DMSP 5D-3 F18 (Defense Meteorological Satellites Program, USA 210)	Military	Earth Science/ Meteorology	USA	Atlas 5	LEO
2009-058A	10/29/2009	NSS-12	Commercial	Communications	Netherlands	Ariane 5	GEO
2009-058B	10/29/2009	Thor-6	Commercial	Communications	Norway	Ariane 5	GEO
2009-059B	11/2/2009	Proba 2 (Project for On-Board Autonomy)	Government	Technology Demonstration	ESA	Breeze KM	LEO

COSPAR	Launch Date	Satellite Name	Actor Type	Primary Function	Owning State	Launch Vehicle	Orbit
2009-059A	11/2/2009	SMOS (Soil Moisture and Ocean Salinity satellite)	Government	Earth Observation	ESA	Breeze KM	LEO
2009-061A	11/12/2009	Shijian 11-01 (SJ-11-01)	Government	Space Physics	China (PR)	Long March 2C	LEO
2009-063A	11/20/2009	Lotos-S (Cosmos 2455)	Military	Reconnaissance	Russia	Soyuz U	LEO
2009-064A	11/23/2009	Intelsat 14 (IS-14)	Commercial	Communications	USA	Atlas	GEO
2009-065A	11/24/2009	Eutelsat W-7	Commercial	Communications	Multinational	Breeze M	GEO
2009-066A	11/28/2009	IGS-5A (Information Gathering Satellite 5A, IGS Optical 3)	Government	Reconnaissance	Japan	H2A	LEO
2009-067A	11/30/2009	Intelsat 15 (IS-15)	Commercial	Communications	USA	Zenit 3SLB	GEO
2009-068A	12/6/2009	Wideband Global Satcom 3 (WGS-3, USA 211)	Military	Communications	USA	Delta 4	GEO
2009-069A	12/9/2009	Yaogan 7 (Remote Sensing Satellite 7)	Government	Remote Sensing	China (PR)	Long March 2D	LEO
2009-071A	12/14/2009	WISE (Wide Field Infrared Survey Explorer)	Government	Astrophysics	USA	Delta 2	LEO
2009-070A	12/14/2009	Glonass 730 (Glonass 41-1, Cosmos 2456)	Military/ Commercial	Navigation/ Global Positioning	Russia	Proton M	MEO
2009-070B	12/14/2009	Glonass 733 (Glonass 41-2, Cosmos 2457)	Military/ Commercial	Navigation/ Global Positioning	Russia	Proton M	MEO
2009-070C	12/14/2009	Glonass 734 (Glonass 41-3, Cosmos 2458)	Military/ Commercial	Navigation/ Global Positioning	Russia	Proton M	MEO
2009-072B	12/15/2009	XW-1 (Hope Oscar 68, HO-68, Xi Wang 1, Hope-1, CAS-1)	Civil	Communications	China (PR)	Long March 4C	LEO
2009-072A	12/15/2009	Yaogan 8 (Remote Sensing Satellite 8)	Government	Remote Sensing	China (PR)	Long March 4C	LEO
2009-073A	12/18/2009	Helios 2B	Military	Reconnaissance	France/Italy/ Belgium/ Spain/Greece	Ariane 5	LEO
2009-075A	12/29/2009	DirecTV-12	Commercial	Communications	USA	Breeze M	GEO

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44 The SBSW section of the table implies neither the existence of a program for integrating these into an actual SBSW system nor the capability to deploy that SBSW, but only the existence of some capability for each of the necessary prerequisite technologies for that particular SBSW system. This clarification is important since integration of these technologies into a working system, including testing, can take many years. Nevertheless, with the prerequisite technologies in hand, the SBSW systems are considerably closer to the reach of that actor. It is clear that the US and Russia currently have all the prerequisite technologies for SBSW systems.

45 The Galileo navigation system is an initiative of the European Commission of the EU in partnership with the European Space Agency, which is responsible for the technical aspects of the project. All EU members will have access to it, as well as Norway and Switzerland, who are ESA member states. Additional international partners include Israel, Ukraine, India, Morocco, Saudi Arabia, South Korea, the US, and Russia. China will not have access to the encrypted service. See Civil Space and Global Utilities Trend 3.4.

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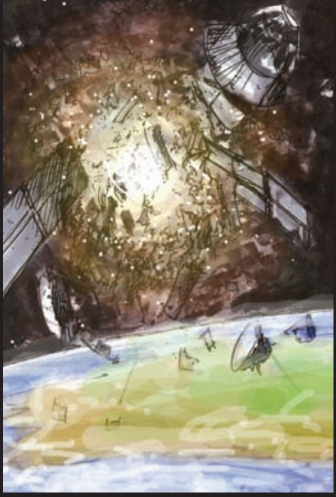

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