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Governance Group

Advisory Board

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ACRONYMS

3GIRS	Third Generation Infrared Surveillance Program (formerly AIRSS)
ABM	Anti-Ballistic Missile
ABL	Airborne Laser
AEHF	Advanced Extremely High Frequency system
AIRSS	Alternative Infrared Satellite System
ANGELS	Autonomous Nanosatellite Guardian for Evaluating Local Space
ASEAN	Association of Southeast Asian Nations
ASAT	Anti-Satellite Weapon
ASI	Italian Space Agency
AWS	Advanced Wideband System
BOC	Besoin Operationnel Commun
BMD	Ballistic Missile Defense
BNSC	British National Space Centre
CASC	China Aerospace Corporation
CAV	Common Aero Vehicle
CD	Conference on Disarmament
CFSP	Common Security and Foreign Policy (Europe)
CNES	Centre National d'Études Spatiales
CNSA	Chinese National Space Administration
COPUOS	United Nations Committee on the Peaceful Uses of Outer Space
COSPAS-SARSAT	Committee On Space Research – Search and Rescue Satellite-Aided Tracking
COSTIND	Commission of Science, Technology, and Industry for National Defense (China)
COTS	Commercial Orbital Transportation System
CSA	Canadian Space Agency
DARPA	Defense Advanced Research Projects Agency
DART	Demonstration of Autonomous Rendezvous Technology
DBS	Direct Broadcasting by Satellite
DGA	Délégation Générale pour l'Armement
DISCOS	Database and Information System Characterising Objects in Space
DLR	German Aerospace Center
DOD	Department of Defense (US)
DRDC	Defence Research and Development Canada
DRDO	Defence Research and Development Organization (India)
DSCS	Defense Satellite Communications System
DSP	Defense Support Program
EADS	European Aeronautics Defence and Space Company
EC	European Commission
EELV	Evolved Expendable Launch Vehicle

EHF	Extremely High Frequency
EKV	Exoatmospheric Kill Vehicle
ELINT	Electronic Intelligence
EMP	Electromagnetic pulse
ESA	European Space Agency
ESDP	European Security and Defence Policy
EUMETSAT	European Organization for the Exploitation of Meteorological Satellites
FAA	Federal Aviation Administration (US)
FCC	Federal Communications Commission (US)
FMCT	Fissile Material Cut-off Treaty
FIA	Future Imagery Architecture
FOBS	Fractional Orbital Bombardment System
FSS	Fixed Satellite Service
GAGAN	GPS and GEO Augmented Navigation (India)
GEO	Geostationary Orbit
GEOSS	Global Earth Observation System of Systems
GLONASS	Global Navigation Satellite System (Russia)
GMES	Global Monitoring for Environment and Security
GMTI	Ground Moving Target Identification
GNSS	Global Navigator Satellite System
GPS	Global Positioning System
GRAVES	Grande Réseau Adapté à la Veille Spatiale
GSLV	Geostationary Satellite Launch Vehicle
HAND	High Altitude Nuclear Detonation
HAPS	Hydrazine Auxiliary Propulsion System
HEO	Highly Elliptical Orbit
IADC	Inter-Agency Space Debris Coordinating Committee
IAI	Israeli Aerospace Industries
IASF	Israeli Air and Space Force
ICBM	Intercontinental Ballistic Missile
IGS	Information Gathering Satellites
IIRS	Indian Institute of Remote Sensing
ILS	International Launch Services
Inmarsat	International Maritime Satellite Organization
Intelsat	International Telecommunications Satellite Consortium
IRNSS	Indian Regional Navigation Satellite System
ISI	ImageSat International
ISR	Intelligence, Surveillance, Reconnaissance
ISRO	Indian Space Research Organization
ISS	International Space Station
ITAR	International Traffic in Arms Regulation

ITU	International Telecommunications Union
JAXA	Japan Aerospace Exploration Agency
JHPSSL	Joint High-Power Solid-State Laser
JSpOC	Joint Space Operations Center (US)
JSSP	Joint Space Support Project (Canada)
KARI	Korean Aerospace Research Institute
KEI	Kinetic Energy Interceptor
KSLV	Korean Space Launch Vehicle
LAD-C	Large Area Debris Collector
LOAC	Laws of Armed Conflict
LEO	Low Earth Orbit
MAWS	Missile Attack Warning System (Russia)
MDA	Missile Defense Agency (US)
MEO	Medium Earth Orbit
Milstar	Military Satellite Communications System
MIRACL	Mid-Infrared Advanced Chemical Laser
MiTEX	Micro-satellite Technology Experiment
MKV	Miniature Kill Vehicle
MOST	Microvariability and Oscillations of Stars
MPX	Micro-satellite Propulsion Experiment
MSS	Mobile Satellite Service
MTCR	Missile Technology Control Regime
NATO	North Atlantic Treaty Organization
NASA	National Aeronautics and Space Administration (US)
NEO	Near-Earth Object
NEOSSat	Near Earth Object Surveillance Satellite
NFIRE	Near-Field Infrared Experiment
NGA	National Geospatial-Intelligence Agency (US)
NGO	Nongovernment Organization
NOAA	National Oceanic and Atmospheric Administration (US)
NORAD	North American Aerospace Defense Command
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NRO	National Reconnaissance Office (US)
NSSO	National Security Space Office (NSSO)
NTM	National Technical Means
ORS	Operationally Responsive Spacelift
OST	Outer Space Treaty
PAROS	Prevention of an Arms Race in Outer Space
PLA	People's Liberation Army (China)
PPWT	Treaty on the Prevention of the Placement of Weapons in Outer Space, the Threat or Use of Force against Outer Space Objects

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
RFTWARS	Radio Frequency, Threat Warning, and Attack Reporting
ROEM	Renseignement d'Origine ElectroMagnétique
Roscosmos	Russian Federal Space Agency
SALT	Strategic Arms Limitations Talks
SAR	Synthetic Aperture Radar
SBI	Space-Based Interceptors
SBIRS	Space Based Infrared System
SBL	Space Based Laser
SBSS	Space Based Surveillance System
SDI	Strategic Defense Initiative
SHF	Super High Frequency
SIGINT	Signals Intelligence
SM-3	Standard Missile 3
SMV	Space Maneuver Vehicle
SSA	Space Situational Awareness
SSN	Space Surveillance Network (US)
SSS	Space Surveillance System (Russia)
STSS	Space Tracking and Surveillance System
TCBM	Transparency and Confidence-Building Measure
TICS	Tiny Independent Coordinating Spacecraft
TSAT	Transformational Satellite Communications system
TT&C	Tracking, telemetry, and command
UHF	Ultra High Frequency
UAV	Unmanned Aerial Vehicle
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
USSPACECOM	US Space Command
USSTRATCOM	US Strategic Command
WGS	Wideband Global SATCOM
XSS	Experimental Spacecraft System

INTRODUCTION

Space Security 2008 is the fifth annual report on trends and developments in space, covering the period January to December 2007. It is part of a wider Space Security Index (SSI) project that facilitates dialog among space experts on space security challenges.

In keeping with the intent expressed in the 1967 Outer Space Treaty that space is a global commons to be used for peaceful purposes, the definition of space security guiding this report is:

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

The primary consideration is not the interests or the security of specific actors operating in space, but the security of space as an environment that can be sustained for use by all actors.

The Space Security Index 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 ensure secure space access for all nations. This is critical because outer space is an environment distinctly different from the terrestrial environment, but intimately connected. Human activities such as debris creation require special caution and attention because their impact on space and on Earth can be extreme and far-reaching. Military security on Earth has become intertwined with the security of space assets. Conflicts in space between states can reflect but also aggravate existing tensions. While space activities are a strategic focus for national security, the pervasive dual military and civilian uses of space assets also contribute to global human security by, for example, tracking weather patterns to support agriculture, assisting responses to natural calamities, and interdicting criminal activities and human rights violations. And yet technologies that better enable the use of space for some purposes and actors may deny the secure use of space for other legitimate purposes and actors as technological developments outstrip the existing governance framework for outer space.

Space security is assessed here according to the following eight indicators:

- The space environment
- Space laws, policies and doctrines
- Civil space programs and global utilities
- Commercial space
- Space support for terrestrial military operations
- Space systems protection
- Space systems negation
- Space-based strike systems

Each chapter provides a description of a specific indicator and its impact on space security. A discussion of the prevailing trends associated with each 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. Longer-term changes can also be observed and noted. For example, a prolonged decline in the annual production of new space debris, described in Trend 1.1 under the Space Environment, has reversed and rates are once again increasing.

Several developments in 2007, captured under different indicators in this volume highlight the contradictions and complexities intrinsic to outer space activity. As described under the space environment indicator in chapter 1, the year 2007 marked the greatest annual increase in space debris, largely attributed to the intercept and destruction of a redundant weather satellite in low Earth orbit by China and the explosion of a failed Russian Briz-M rocket body. Yet 2007 also witnessed the adoption of debris mitigation guidelines by the United Nations, described in chapter 2 on laws, policies and doctrines. Chapter 7 on space support for terrestrial military operations describes the use of missile and anti-missile technologies to threaten space assets and collective security in outer space. Such use sparked renewed efforts to regulate deployments and activities in outer space, as indicated in chapter 2. Despite what may be viewed as growing military tensions in space, 2007 also marked the creation of a "Global Exploration Strategy," described in chapter 3 on civil space programs — a vision produced by the 14 largest national civil space agencies to coordinate future space exploration activities.

Space Security 2008 does not seek to provide an absolutely positive or negative assessment of all outer space activities conducted in 2007. The contradictions and complexities do not allow it. Instead, this volume aims to assess the range of implications that developments could have on the security of space across the various indicators. Such an assessment reflects the real-life challenge faced by policymakers in determining the multiple effects of their potential and actual decisions across the range of indicators.

Expert participation in the Space Security Index is a key component of the project. The primary research is reviewed prior to publication through three processes. The annual Space Security E-Consultation is done online, with comments provided by participants representing all sectors (commercial, military, civil, etc.). This consultation provides invaluable insights into the perceptions, concerns, and priorities of space stakeholders around the world, as well as critical feedback on the research. The Space Security Working Group consultation is held each spring for 2 days and the text is reviewed chapter by chapter for corrections and gaps. The participants are listed in Annex 1. The Working Group meeting also provides an important forum for dialog. Finally, the Advisory Group to the Space Security Index provides its comments in the penultimate step before publication.

Space Security 2008 is based solely on open source information. 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, particularly when reporting on proposed research or future activities. It should be noted, however, that space assets and activities by their very nature are generally in plain view to those with the technology to observe them. Such technology is increasingly available at low cost.

For further information about the Space Security Index, its methodology, project partners, and sponsors, please visit the website **www.spacesecurity.org**. Comments and suggestions to improve the publication are welcome.

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The content of *Space Security 2008* does not necessarily reflect the views of the Spacesecurity.org partners — the McGill University Institute of Air and Space Law, Project Ploughshares, the Secure World Foundation, the Simons Centre for Disarmament and Non-Proliferation Research, the Space Generation Foundation — or The Department of Foreign Affairs and International Trade Canada or The Govenment of Canada.

While we as members of the Governance Group for the Space Security Index have benefited greatly from the input of many experts in the development of *Space Security 2008*, responsibility for any errors or omissions in this volume rests with us.

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The Space Environment

Trend 1.1: Growing debris threats to spacecraft as rate of debris production increases — Traveling at speeds of up to 7.8 kilometers per second, space debris poses a significant threat to spacecraft. 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 17,300 objects approximately 10 cm or larger. It is estimated that there are over 300,000 objects measuring between 1 and 10 cm in diameter, and billions smaller. The annual growth rate of tracked debris began to decrease in the 1990s, largely due to national debris mitigation efforts, but has been growing again since 2004.

2007 Developments

- Chinese kinetic satellite intercept creates largest manmade debris field in history
- Trackable space debris population increases by 20.12 percent

Space security impact

The deliberate destruction of a satellite and creation of such a massive debris field at a relatively high altitude in a crowded orbit has a negative impact on space security, increasing the threat of debris collision for operational satellites in low Earth orbit and those launched in the future. Additional unintentional breakups demonstrate that even normal launch activity can further degrade the space environment, even if best practices are applied. Efforts must be made by all space actors to mitigate the threat to space security posed by debris.

Trend 1.2: Increasing awareness of space debris threats and continued efforts to develop guidelines for debris mitigation — Significant on-orbit collisions such as the collision of the French military satellite Cerise with a portion of an Ariane rocket in 1996, and improved tracking abilities have encouraged the cognition of space debris as a growing threat. Since the mid-1990s, many spacefaring states, including China, Japan, Russia, and the US, and the European Space Agency have developed debris mitigation standards.

2007 Developments

- International debris mitigation guidelines adopted
- Better implementation of mitigation guidelines by commercial actors

Space security impact

The approval of voluntary debris mitigation guidelines is a positive step for ensuring the sustainability of the space environment, but the number of breakup events in 2007 (see Trend 1.1) demonstrated that the challenge of space debris will require solutions on multiple fronts. If implemented by all space actors, the debris mitigation guidelines will reduce the chances that future space launches and missions will create additional debris but will not reduce the debris creation from objects already on orbit. The record of implementation was mixed in 2007, with China worsening the problem of debris but commercial operators better managing end-of-life procedures for satellites in GEO. Solutions that help prevent collisions between operational satellites and other objects are still needed, as well as research into potential methods of removing debris from orbit.

Trend 1.3: Space surveillance capabilities to support collision avoidance slowly improving — Efforts to create an international space surveillance system to support collision avoidance and debris re-entry have been unsuccessful, but several states have pursued national systems. The US Space Surveillance Network uses 30 sensors worldwide to monitor over 17,000 space objects in all orbits, but has moderated access to its data since 2004 out of concern for national security. Russia maintains a Space Surveillance System using its early-warning radars and monitors some 5,000 objects (mostly in LEO), but does not widely disseminate data. The EU, Canada, China, France, Germany, and Japan are all developing independent space surveillance capabilities.

2007 Developments

- US focus on improving space situational awareness capabilities continues, but actions are modest
- Worldwide actors continue to develop independent space surveillance capabilities

Space security impact

The international improvement of space surveillance and space situational awareness capabilities in 2007 may have a positive effect on space security by providing improved and redundant tracking of space objects for collision avoidance, as well as greater transparency of space activities. However, the trend toward secretive development of space situational awareness and the continued drive for *independent* space tracking systems indicate a broader mistrust that could reduce space security, particularly as many aspects of these capabilities are enablers for space system negation. In this context, greater transparency may not make actors feel more secure in space, as the growing focus on the space protection/negation elements of space situational awareness demonstrated (see Space Systems Negation Trend 7.1).

Trend 1.4: Growing demand for radio frequency spectrum and orbital slots

— Expanding satellite applications are driving demand for limited resources in space, including 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. Satellite operators spend about five percent of their 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 growth in military bandwidth consumption has also been dramatic: the US military used some 700 megabytes per second of bandwidth during Operation Enduring Freedom in 2003, compared to 99 megabytes per second during Operation Desert Storm in 1991. There are more than 800 operational satellites in orbit today: Increased competition for orbital slot assignments, particularly in GEO where most communications satellites operate, has caused occasional disputes between satellite operators. The International Telecommunication Union has been pursuing reforms to address slot allocation backlogs and related financial challenges.

2007 Developments

- Cooperation and conflict over satellite navigation signals
- US efforts to increase military communications bandwidth
- Global efforts to solve spectrum demand issues
- Unintentional radio frequency interference continues

Space security impact

Radio frequency competition, coordination, and interference posed a challenge to space security in 2007, particularly for strategic uses. While international institutions such as the ITU continue to manage competition for space resources, the fact that military operators are outside this arrangement complicates the process, which will only become more difficult as demand from all users increases in the future. Nonetheless, recognition of the issue and progress toward solutions demonstrate the willingness of all space actors to work together on this issue.

Trend 1.5: Increased recognition of the threat from NEO collisions with Earth 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 started to identify the types of objects that pose threats to Earth and potential mitigation strategies. Mitigation is a difficult challenge due to the extreme mass, velocity, and distance of any impacting NEO, and depends on the amount of warning time. Types of kinetic mitigation methods may include ramming the NEO with a series of kinetic projectiles, and some have advocated the use of nearby explosions of nuclear weapons, which could create additional threats to the environment and stability of outer space.

2007 Developments

- Ongoing debate on mitigation strategies for NEOs

Space security impact

Efforts to address potential threats from NEOs are positive insofar as they make the link between space and the security of Earth. However, some options to mitigate threats, such as the use of nuclear weapons, may have negative repercussions for space security by contributing to environmental hazards and instability. There is a need to further explore this issue with the aim of balancing protection of the Earth from space-based threats with long-term sustainability of the space environment.

Space Laws, Policies, and Doctrines

Trend 2.1: 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. The OST prohibits the stationing of nuclear weapons or any other weapons of mass destruction anywhere in space. The termination of the Anti-Ballistic Missile Treaty in 2002 eliminated a longstanding US/USSR-Russia prohibition on space-based conventional weapons, stimulating renewed concerns about the potential for space weaponization.

Since 1981 the UN General Assembly (UNGA) has each year adopted a resolution requesting that states refrain from actions contrary to the peaceful use of outer space and calling for negotiations within the Conference on Disarmament (CD) on a multilateral agreement on the Prevention of an Arms Race in Outer Space (PAROS). Voting patterns have demonstrated near-unanimous support for the PAROS resolution; however, the US and Israel cast the first negative votes in 2005.

2007 Developments

- Chinese satellite destruction raises concerns about the peaceful uses of outer space
- Divisions remain on key space security Resolutions at the UN General Assembly
- Some governments and civil society call for regulatory approaches to space security

Space security impact

Although the Chinese satellite intercept and destruction raised concerns about the peaceful uses of outer space, including secure and sustainable access, it also focused the attention of the international community on the gaps in the current space security legal and regulatory framework. High-level support from government, military, and commercial officials for the increased use of regulatory approaches such as guidelines, rules of the road, and codes of conduct suggest that this might be a viable avenue to enhance the security of outer space in the future. Although significant political divisions remain, efforts in this direction are already being implemented with the adoption of space debris mitigation guidelines in 2007 (see trend 2.2). However, these alternative approaches rely on good-will implementation by states. Moreover, the division on implementation of UN-SPIDER demonstrates that secure and sustainable access to, and use of, space for all requires significant technical and financial support in addition to an enabling legal framework. Overall, developments in 2007 indicate the fragility of space security. Although international commitment to ensure space security now seems stronger, obstacles to meaningful action remain.

Trend 2.2: Progress in COPUOS but the Conference on Disarmament has been unable to agree on an agenda since 1998 — A range of international institutions, such as the UNGA, COPUOS, ITU, and the CD, have been mandated to address issues related to space security. The CD has been deadlocked without an agreed plan of work since 1998, however, and there has been no progress on space issues in 30 years despite efforts to move forward on the PAROS mandate to develop an instrument relating to space security and the weaponization of space.

2007 Developments

- COPUOS addresses the Registration Convention and Space Debris Mitigation Guidelines and charts future role and activities aimed at peaceful uses and sustainability
- Renewed efforts toward resumption of substantive work in the CD

Space security impact

Developments in 2007 demonstrated both the expediency and flexibility of technical, regulatory guidelines to address key threats to the security of outer space, as well as the potential weakness of such an approach to enforce behavior. Moreover, events in COPUOS and the CD suggest that a growing division between states that advocate such technical tools and states that insist on a treaty-based approach to space security could result in blocked progress on all fronts. More generally, however, indications of greater cooperation and support for discussions on space security issues were a positive development for 2007.

Trend 2.3: Spacefaring states' national space policies consistently emphasize international cooperation and the peaceful uses of outer space — All spacefaring states emphasize the importance of cooperation and the peaceful uses of space, but with caveats based on national security concerns. The US has recently announced plans for peaceful space exploration of the Moon and Mars, while there is growing interest in manned space programs. The national space policies of many developing countries, such as Brazil and India, tend to focus on the utility of space cooperation for social and economic development.

2007 Developments

- European Space Policy highlights European independence and civil-military synergies within a context of peaceful uses of outer space
- China's five-year Space Development Plan reaffirms the importance of commercial development and national strength within a context of peaceful uses of outer space

- 14 national space agencies jointly develop framework for coordination of outer space exploration efforts

Space security impact

States continued to express commitment to international cooperation and the peaceful use of outer space in their civil space policies in 2007, demonstrated most strongly by the Global Exploration Strategy. Yet independence in space is also emphasized. The peaceful use of space is increasingly viewed as strategic, which could limit opportunities for cooperation. The impact on space security will depend on whether or not states pursue independent or collective measures to achieve the strategic goals set out in their space policies.

Trend 2.4: Growing focus within national military doctrines on the security uses of outer space — Fueled by the technological revolution in military affairs, the military doctrine of a growing number of actors (led by China, Russia, the US, and key European states) increasingly emphasizes the use of space systems to support national security. Dependence on these systems has led several states to view space assets as critical national security infrastructure. US military space doctrine has focused on the need to ensure US freedom of action in space, through the use, when necessary, of "counterspace operations" that prevent adversaries from accessing space to threaten US interests.

2007 Developments

- Japan considers new space law to permit military use of space
- India continues to consider an Aerospace Command and greater military use of space
- Greater use of space for security purposes considered in Europe

Space security impact

In 2007 states continued to emphasize the use of space for national security purposes through military doctrines and some new programs. A positive impact of this development is an increase in transparency, allowing states to better predict the behavior of others in space, although this is limited to broad goals and objectives. On the other hand, these policies and doctrines also demonstrate a growing concern for the need to protect space assets and capabilities, which may have a positive or negative impact on space security, depending on whether such protection is pursued through passive or aggressive means, collectively or independently.

Civil Space Programs and Global Utilities

Trend 3.1: Growth in the number of actors gaining access to space — The rate at which new states gain access to space increased dramatically in the 1990s. By 2007 10 actors had demonstrated independent orbital launch capacity and 47 states had launched civil satellites, 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.

2007 Developments

- Global efforts to increase access to and use of space through development of launch capabilities and institutions
- Microsatellites contribute to increased accessibility of space

Space security impact

Although no new space civil space actors emerged in 2007, nations expanded their civil space capabilities, particularly regarding launch and microsatellite technologies. This is an indicator that space remains accessible for use and exploitation for peaceful purposes. On the other hand, the proliferation of civil space technologies such as launch capabilities also provides more actors with abilities that could potentially be used to threaten access to and use of space by other states. The growing number and diversity of space actors also place increased demand on available space resources and on efforts to coordinate space traffic and implement international legal obligations. In the long term, an increased number of satellites launched into outer space will also add pressure to the problem of space debris.

Trend 3.2: Changing priorities and funding levels within civil space programs — Civil expenditures on space have continued to increase in India and China in recent years, while past decreases in the US, the EU countries, and Russia have begun to rebound. Increasingly, civil space programs include security and development applications. Algeria, Brazil, Chile, Egypt, India, Malaysia, Nigeria, South Africa, and Thailand are all placing a priority on satellites to support social and economic development. Dual-use applications such as satellite navigation and Earth observation are a growing focus of US, European, and Chinese civil space programs.

2007 Developments

- Space budgets grow in India and Russia as focus shifts to large-scale projects
- Use of remote sensing to support sustainable development
- Strong interest in Europe, Russia, US, and India with respect to developing human spacecraft, but efforts progress slowly
- Space agencies continue to focus on the Moon, Mars

Space security impact

Activities in 2007 demonstrated the continuation of a recently renewed interest in large-scale space projects, particularly lunar exploration and human spaceflight. Although developments in 2007 indicate some cooperation on these projects, competition may increase if such capabilities become strategic in the future, as indicated by historical trends. Nonetheless, it remains to be seen if these large-scale projects will gain the necessary investment to come to fruition; only in India, Russia, and possibly China are resources growing significantly. Outer space continues to be dominated by a few states. Delays in construction of new human spacecraft in the US, may adversely influence space security in the future by limiting human access to space, in particular the International Space Station (ISS). Finally, the growing use of remote sensing satellites for sustainable development is drawing more stakeholders into space, and strengthening the relationship between security in space and security on Earth. However, what is essentially the proliferation of dual-use spacecraft may contribute to the expression of regional tensions in space (see Space Support for Terrestrial Military Operations Trend 5.2).

Trend 3.3: Steady growth in international cooperation in civil space programs — International civil space cooperation efforts over the past decades have included the US-USSR Apollo-Soyuz docking of manned modules, Soviet flights to the MIR space station with foreign representatives, the Hubble Space Telescope, and such joint NASA-ESA projects as Skylab. The most prominent example of international cooperation is the ISS, involving 16 states, 56 launches, and an estimated cost of over $100-billion to date. International civil space cooperation has played a key role in the proliferation of technical capabilities for states to access space.

2007 Developments

- International cooperation emerging for Moon/Mars exploration

- International cooperation on the ISS, space science, and launch technology
- US-Chinese cooperation falters

Space security impact

Growing cooperation and collaboration between major and less developed space powers enhance space security by providing partner countries with greater access to space through shared resources and technology. Larger networks of cooperation such as the "Global Exploration Strategy" could also result in greater transparency of space activities, mitigating uncertainties or mistrust that may arise as more countries gain access to space. There is a risk, however, that sensitive military technologies may proliferate. Moreover, as regional cooperation becomes stronger there may be negative geopolitical tensions and rivalries in space — as the tensions between China and the US demonstrate, civil space cooperation is often influenced by strategic concerns. Yet cooperation efforts on the Moon and Mars in 2007 suggest that what is often characterized as a new space race may not in fact become a reality.

Trend 3.4: Continued growth in global utilities as states seek to expand applications and accessibility — The use of space-based global utilities, including navigation, weather, and search-and-rescue systems, has grown substantially over the last decade. These systems have spawned space applications that are 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, and India are developing satellite-based navigation capabilities. The strategic value of satellite navigation was underscored by the conflict over frequencies for Galileo and GPS, resolved in 2004.

2007 Developments

- A difficult year for space navigation utilities
- Civil space applications for global monitoring focus on climate change

Space security impact

On the one hand, the growth in global utilities, particularly navigation systems, should have a positive impact on space security by providing redundancy of capabilities and increasing access to space through collaborative efforts, particularly if they are interoperable. Yet ongoing disputes over the use of signals and the development of *independent* capabilities indicate that cooperation is difficult and that this utility remains an important military application subject to potential interference. The growing use of civil space capabilities for climate change monitoring could enhance international commitments to maintain space security by further linking the security of Earth to the security of space.

Commercial Space

Trend 4.1: Continued overall growth in the global commercial space industry — Growth in the commercial space industry is dominated by satellite services, which have tripled in size since 1996, generating revenues estimated between $62.6-billion and $111.14-billion in 2006, or up to 60 percent of the commercial satellite sector's total. Individual consumers are a growing source of demand for these services. Key commercial satellite telecommunications companies include Intelsat, SES Global, Eutelsat, and Telesat Canada. In recent years Russia has dominated the space launch industry with respect to the number of commercial launches, while US companies have led in the satellite manufacturing sector.

2007 Developments

- Commercial space industry continues to grow, with individual users becoming more important stakeholders
- India and China influence the commercial space industry

Space security impact

Continued growth in the commercial space sector is reflected largely by higher revenues and not necessarily an increase in space activity. However, individual users are becoming more important stakeholders in space as they demand not only more communication services, but also satellite navigation/positioning and remote sensing products. Ongoing growth of the industry suggests that there is overall confidence in the security of space and the ability of both companies and consumers to continue to rely on space resources. Growing competition in the commercial launch market may also contribute to space security by providing greater access to outer space, although tensions may arise if future demand for space resources exceeds supply.

Trend 4.2: Commercial sector supporting increased access to space — Commercial space launches have contributed to cheaper space access. The costs to launch a satellite into GEO have declined from an average of about $40,000/kilogram in 1990 to $26,000/kilogram in 2000, with prices beginning to consolidate. In 2000 payloads could be placed in LEO for as little as $5,000/kilogram. In recent years European and Russian space agencies have been the most active space launch providers. Today's commercial launch providers include Arianespace in Europe, Energiya in Russia, Lockheed Martin in the US, and two international consortia — Sea Launch and International Launch Service. Virgin Galactic and Space Adventures provide private, suborbital human spaceflight.

2007 Developments

- Launch costs remain high in a tight market following launch failures
- Lower insurance rates and new entrants to the launch market may reduce cost of access to space
- Private human suborbital spaceflight expanding, but capabilities limited
- Commercial spaceflight aims for the Moon
- Greater commercial access to high-resolution space imagery

Space security impact

Sustained competition in commercial space launch may slightly reduce the cost of access to space in the near future, but in the absence of revolutionized technologies, there is not likely to be a significant impact on space access. Although the commercial human space flight industry continues to develop, it has yet to deliver sustainable, low-cost launchers. Moreover, while some regulatory efforts are being made to support the prospect of private human access to space, this may cause potential challenges to space security, both in terms of the sustainability of the space environment as well as the applicability of international laws, such as the Outer Space Treaty, which have yet to be revisited by the international community. Finally, while the space industry is facilitating greater use of space applications, in particular remote sensing, there are legitimate fears about the implications for security on Earth (see Trend 4.3 below).

Trend 4.3: Governments both support and regulate the commercial space sector as subsidies and national security concerns continue to play an important role — The commercial space sector is significantly shaped by national governments and security concerns. The 1998 US Space Launch Cost Reduction Act and the

2003 European Guaranteed Access to Space program provide for significant government subsidization of the space launch and manufacturing markets. The US and European space industry also receive important space contracts from government programs. 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 the way US companies participate in international collaborative satellite launch and manufacturing ventures.

2007 Developments

- Governments and militaries partner with the commercial industry for satellite imaging, communications, and launch services
- Galileo demonstrates the limits to public-private partnerships
- Ongoing efforts to regulate access to commercial satellite imagery
- Private industry joins government in space safety efforts
- Export controls try to balance commercial interests with security concerns

Space security impact

The strong relationship between military and commercial uses of space and the security dimensions of many commercial services has a complex impact on space security. On the one hand, multiple-use spacecraft could become military targets in the future, resulting in an overall decrease in security. Alternatively, the proliferation of dual-use assets in space could make a military attack less useful and, therefore, less likely. Arguably, this could increase overall space security. There are also pros and cons for government users of commercial systems, including greater flexibility and options for using space, but fewer security features to protect this use. The failure of the Galileo partnership, however, demonstrates that the costs and risks of space access and use remain high, and governments must play a key role in ensuring that access. Efforts to regulate access to both commercial space technology and data in 2007 reflected ongoing attempts to balance the benefits of secure access to and use of space against the potential threats it may pose to space security. This balance was better addressed regarding access to commercial imagery in 2007, but striking a balance between these two components of space security will become more complicated if commercial capabilities continue to increase. Finally, the growing interest in the commercial space industry to advance and participate in space governance initiatives is a positive development for space security, since all actors share the same interest in the secure and sustainable access to space.

Space Support for Terrestrial Military Operations

Trend 5.1: US and Russia continue to lead in deploying military space systems — By the end of the Cold War, the US and USSR had developed extensive military space systems designed to provide military attack warning, communications, reconnaissance, surveillance, and intelligence, as well as navigation and weapons guidance applications. By the end of 2007 the US and USSR/Russia had launched more than 3,000 military satellites, while the rest of the world had launched under 100.

The US has dominated the military space arena since the end of the Cold War and currently spends close to $28-billion on military space programs and has approximately 136 operational dedicated military satellites — over half of all military satellites in orbit. Russia is believed to have some 67 dedicated military satellites in orbit. The US is, by all major indicators, the actor most dependent on its space capabilities. As early as 2001 the *Report of the Commission to Assess United States National Security Space Management and Organization* warned that US dependence on space systems made it uniquely vulnerable to a "space Pearl Harbor" and recommended that the US develop enhanced space control (protection and negation) capabilities.

2007 Developments

- US focus on major upgrades to critical systems, but some progress more than others
- US continues to face setbacks on remote sensing programs
- Russia continues to invest in military programs to maintain its space-based capabilities, with focus on revitalizing GLONASS

Space security impact

The US is slowly progressing with modernization of its space systems. The focus is on meeting the bandwidth and secure communications needs of today's military and preventing gaps in next-generation capabilities, both of which are elements of secure and sustainable use of space. Troubles faced by the National Reconnaissance Office, however, demonstrate weaknesses in its abilities to manage complex projects, research and development, and acquisitions, which may continue to hinder major system upgrades. Continued dependence on space assets increases US vulnerability in space, and it is not yet clear if efforts to protect those assets in the future will contribute to or detract from the security of outer space. The Russian focus on revitalizing GLONASS and its aging satellite fleet could also be positive for space security by providing redundancy for the US GPS, more reliable and secure early warning capabilities, and more secure satellite communications.

Trend 5.2: More actors developing military space capabilities — Regional tensions are a significant driver of military space acquisitions. Declining costs for space access and the proliferation of space technology are enabling more states to develop and deploy their own military satellites via the launch capabilities and manufacturing services of others, including the commercial sector.

China provides military communications through its DFH series satellite, and has deployed a pair of Beidou navigation satellites to ensure access to navigational capability. China also maintains three ZY series satellites in LEO for tactical reconnaissance and surveillance functions, has deployed three military reconnaissance satellites, and is believed to be purchasing additional commercial satellite imagery from Russia to meet its intelligence needs.

EU states have developed a range of military space systems. France, Germany, Italy, Spain, Belgium, and Greece jointly use the Helios-1 military optical observation satellite system in LEO, which provides images with a one-meter resolution. France, Germany, and Spain have also developed a range of radar reconnaissance and communications capabilities and France is developing a missile early-warning system. The UK maintains a constellation of three dual-use Skynet 4 communications satellites in GEO. The joint EU-European Space Agency Galileo satellite navigation program, initiated in 1999, is intended to operate for civil and commercial purposes, but will have an inherent dual-use capability.

Israel operates a dual-use Eros A imagery system as well as the military reconnaissance and surveillance Ofeq-5 system. India's civil space agency maintains its Technology Experimental Satellite for remote sensing, but it also provides military reconnaissance capabilities. Japan operates the commercial Superbird satellite for military communications and has four "information gathering" remote sensing satellites — two optical and two radar. Thailand operates a military communications satellite and is developing its first intelligence and defense satellite.

2007 Developments

- Europe developing a range of integrated military capabilities, both dedicated and dual-use
- China investing to achieve self-reliance in space
- Focus on remote sensing capabilities in the Middle East and Asia
- Canada to use dual-use satellite to monitor the Arctic, develop military support capabilities
- Potential use of space for military purposes in Nigeria

Space security impact

The continued drive for more states to develop and deploy both dedicated military and dual-use space systems was reflected in 2007 along with a growing emergence of strategic partnerships. While an increase in the use of space for military purposes demonstrates the continued accessibility of the space environment and greater access to space technologies, states continue to operate and develop their space programs with considerable secrecy, reducing transparency of space operations. There are indications that these developments are affecting perceptions of security on Earth; how this in turns affects the security of space will depend on how states react to perceived threats from and in space. As more states become dependent on space systems for military operations and national security, mutual vulnerability may provide incentives to enhance the security of outer space or to develop capabilities to quickly negate space systems. The growing diversity of space systems for global navigation and positioning and communications may enhance the security of space operations by providing redundancy, particularly if they are interoperational.

Space Systems Protection

Trend 6.1: US and Russia lead in general capability to detect rocket launches, while US leads in the development of advanced technologies to detect direct attacks on satellites — The ability to distinguish space negation attacks from technical failures or environmental disruptions is critical to maintaining international stability in space. Early warning also enables defensive responses, but the type of protection available may be limited. Only the US and Russia can reliably detect rocket launches. US Defense Support Program satellites provide early warning of conventional and nuclear ballistic missile attacks; Russia began rebuilding its aging system in 2001 by upgrading its Oko series satellites. France is developing two missile-launch early-warning satellites — Spirale-1 and -2. Most actors 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. It is very difficult to obtain advance warning of directed energy attacks that move at the speed of light.

2007 Developments

- Russia upgrades its early-warning systems, but results are limited
- US early-warning upgrade efforts continue to face challenges, but also some success
- US focus on space situational awareness
- Global development of space surveillance capabilities

Space security impact

As space actors seek to improve their launch detection and space surveillance capabilities, space security could be enhanced through greater transparency of space activities, more accurate threat detection, and greater redundancy, which can support protective responses and overall confidence. The benefits of space surveillance could be increased with data sharing among different actors. Yet the continued drive for independent space tracking systems indicate broader mistrust that could reduce space security, particularly as many aspects of these capabilities are enablers for space system negation. In this context, as demonstrated by the US focus on the space protection/negation elements of space situational awareness, greater transparency may not make actors feel more secure in space.

Trend 6.2: The protection of satellite ground stations is a concern, while the protection of satellite communications links is poor but improving — Many space systems lack protection from attacks on ground stations and communications links. The vast majority of commercial space systems have only one operations center and one ground station, leaving them 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 unique to military systems and the capabilities of more technically advanced states. China and the US have been aggressively pursuing a variety of anti-jamming capabilities.

2007 Developments

- Slow but steady progress on laser satellite communication links but technological challenges remain
- US RADIRS Unit becomes operational
- Renewed focus on protecting commercial satellites

Space security impact

Developments in 2007 had a mixed impact on space security. While some progress has been made toward securing ground to satellites communications through the use of laser links, progress remains slow due to major technological challenges and communication links remain vulnerable. In the meantime, a greater ability by the US to identify and respond to sources of interference might enhance the security of some systems, but efforts to better protect commercial satellites will only be effective if market incentives are in place.

Trend 6.3 Protection of satellites against some direct threats is improving but remains limited — The primary source of protection for satellites comes from the difficulties associated with launching an attack into space. Satellite protection measures also include system redundancy and interoperability, which has 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, if an actor has the ability to overcome these natural defenses, there are few options available for physically protecting a satellite against a direct attack. Consequently, initiatives to prevent the proliferation and use of negation capabilities covered in the chapters on Laws, Policies and Doctrines and Commercial Space are also critical for protection, as is the achievement of collective space security as defined by the Space Security Index.

2007 Developments

- US continues to pursue space-based satellite protection

Space security impact

The development of autonomous on-orbit servicing satellites and nanosatellites for local space surveillance has the potential to improve space security for the actors employing those technologies by providing better on-orbit threat identification and response options to protect the space-based components of satellite systems. However, the basic technologies involved are also applicable for spacecraft negation and raise questions about the implications of more active space-based protection systems for the security of other actors in space. The overall impact on space security will depend greatly on how the relevant technologies are used and how transparent the usage is. Moreover, space-based protection capabilities themselves could be defeated by a determined attacker.

Trend 6.4: US leads in developing of capabilities to rapidly rebuild space systems following direct attacks on satellites — The ability to rapidly rebuild space systems after an attack could reduce vulnerabilities in space and increase the ability to recover from an attack. Although the US and Russia are developing various elements of responsive space systems, no state currently has this capability. The key US responsive launch initiative is the Falcon program, which seeks to develop a rocket capable of placing 100-1,000 kilograms into LEO within 24 hours. It includes the AirLaunch LLC QuickReach air-launch rocket and the SpaceX Falcon-1.

2007 Developments

- US increases efforts for Operationally Responsive Space (ORS)
- Canada considers responsive space
- Small and nanosatellite research may contribute to passive protection

Space security impact

Whether efforts on more responsive space launch and flexible deployment of microsatellites will enhance the secure use of space systems remains unclear. The formal definition of the US ORS concept and the continued development of small satellites and launch vehicles are steps toward a rapid replacement capability, but an operational ORS capacity remains fairly distant. Further studies are also needed to determine the survivability of small satellites against potential threats. Nonetheless, the use of small and relatively low-cost satellites for a greater range of applications potentially allows actors to replace outdated, malfunctioned, or attacked satellites more often and quickly. Constellations of smaller satellites can also provide enhanced protection through redundancy, but because they are difficult to detect and track, transparency of and confidence in space activities could be reduced.

Space Systems Negation

Trend 7.1 Proliferation of capabilities to attack ground stations and communications links — Ground segments and communications links remain the most vulnerable components of space systems, susceptible to attack by conventional military means, computer hacking, and electronic jamming. A number of incidents of intentional jamming of communications satellites have been reported in recent years. Iraq’s acquisition of GPS-jamming equipment for use against US GPS-guided munitions during Operation Iraqi Freedom in 2003 suggested that jamming capabilities are proliferating. 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.

2007 Developments

- Tamil Tigers illegally broadcast radio and television on Intelsat signals
- Mysterious jamming incidents demonstrate continued ease of jamming satellite communications
- Intrusion of secure computer networks in China, UK, Germany, France, and the US
- US and China upgrade capabilities for cyber attacks, jamming

Space security impact

Incidents of both deliberate and unintentional satellite interference in 2007 demonstrate the vulnerability of satellite communications and computer networks to external attacks.

Moreover, the significant security and financial costs that result from interference show the debilitating effect that relatively low-cost, low-technology threats can have on the security of space operations. Facilitating and dispersing authorization for attacks could also create greater instability. It should be noted, however, that interference with satellite communications and ground stations is generally temporary and reversible and is less provocative and escalatory than other types of space system negation.

Trend 7.2 US leads in the development of space situational awareness capabilities to support space negation — 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 counterspace operations. China and India also have satellite tracking, telemetry, and control assets essential to their civil space programs. Canada, France, Germany, and Japan are actively expanding their ground-based space surveillance capabilities.

2007 Developments

- Space surveillance capabilities highlight vulnerability of satellites to detection
- Orbital Express satellite demonstrates automated approach using Space Situational Awareness data

Space security impact

Space surveillance can support both protection and negation activities. Efforts to develop and enhance space surveillance systems can have a positive impact on space security by increasing the ability of actors to safely operate in space, enhancing transparency of outer space activities, and providing a redundancy of capabilities. But the potential for such capabilities to support deliberate attacks against satellites and other space objects is demonstrated through the centrality of space surveillance in identifying foreign satellites, space control efforts, and close proximity operations, depending on the extent to which the capability were integrated into military command systems. Transparency in the collection and use of space surveillance data would enhance its positive contribution to the security of outer space.

Trend 7.3 Ongoing proliferation of ground-based capabilities to attack satellites — The development of ground-based ASAT weapons employing conventional, nuclear, and directed energy capabilities dates back to the Cold War when a variety of US and USSR programs were initiated. Since then technologies have proliferated. The capability to launch a payload into space to coincide with the passage of a satellite in orbit is a basic requirement for conventional satellite negation systems. Some 28 states have demonstrated suborbital launch capability and, of those, 10 have orbital launch capability. As many as 30 states may have low-power lasers to degrade unhardened satellite sensors. The US and China lead in the development of more advanced ground-based kinetic-kill systems with the capability to directly attack satellites. Both have deployed advanced missile and laser programs, which have inherent satellite negation capabilities in LEO.

2007 Developments

- China tests direct ascent missile against own satellite, triggers protective response
- US continues development of ballistic missile defense systems and considers use against a de-orbiting satellite
- Ballistic missile defense efforts in Japan, India may lay the foundation for potential ground-based ASAT capabilities
- Ongoing development of high energy lasers

Space security impact

The Chinese satellite intercept in January 2007 ended a 20-year pause in known ASAT testing and demonstrated a current capability to destroy LEO satellites. The successful destruction of FY-1C and the debris cloud created are both negative developments in space security, compounded by a potential spiral of capabilities and tests — indicated by US anti-ballistic missile activities — as well as other protective responses. The continued development of high energy lasers combined with adaptive optics could have a negative impact on space security as it has the potential to cause permanent damage to a satellite. The same technologies could also be applied to satellite tracking and identification. The development of theater-level ABM capabilities by the various actors, although not a direct threat to space objects, is cause for concern, because most of the necessary technologies, such as target detection, tracking, homing, command and control networks, and boosters, are also applicable to ASAT roles.

Trend 7.4: Increasing access to space-based negation-enabling 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. The US leads in the development of most of these enabling capabilities, although none appear to be integrated into dedicated space-based negation systems.

2007 Developments

- US and European states testing space-based technologies with potential negation capabilities

Space security impact

The emergence of advanced space-based capabilities is likely to complicate space security because of the range of passive protection and more active negation functions that they can serve, with the line between these types of activities unclear. These technologies could be used to enhance knowledge of local space and gather information on other, potentially hostile, satellites or to support on-orbit servicing of satellites to extend their lifespans or recover from negation efforts. But all of the capabilities described have clear space negation applications. Currently, however, these programs are still experimental and their funding levels are relatively low. The more immediate consequence is the challenge posed by not knowing what the threats are, largely because of the secrecy of many technology programs.

Space-Based Strike Systems

Trend 8.1: While no space-based strike systems have been tested or deployed, the US continues to consider a space-based interceptor for its missile defense system — Although the US and USSR developed and tested ground-based and airborne ASAT systems between the 1960s and 1980s, there has not yet been any deployment of space-to-Earth or space-to-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 directed energy strike systems in the 1980s, although today these programs have largely been halted.

2007 Developments

- NFIRE successfully tests sensor system in space for missile defense

- Multiple Kill Vehicle received boost in FY08 budget allocation
- Congress cuts funding for Space Test Bed

Space security impact

The ongoing absence of space-based strike systems and infrastructure continued to support the security of outer space in 2007. While precursor technology development continued through the NFIRE test and MKV program, restraint exercised by US policymakers is positive and indicates concern for space security and the challenge of balancing terrestrial missile defense requirements with the need to maintain freedom from space-based threats.

Trend 8.2: A growing number of countries are developing more advanced space-based strike-enabling technologies through other civil, commercial, and military programs — The majority of advanced, space-based strike enabling technologies are dual-use and are developed through other 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 development does bring these actors technologically closer to this capability. For example, China, India, and Israel are developing precision attitude control and large deployable optics for civil space telescope missions. There are also five states in addition to the European Union that 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 the Earth.

2007 Developments

- Prompt Global Strike program authorized by the US Congress
- Report outlines the potential costs to deploy space-based weapons
- Upgrades in US global missile tracking and warning
- The US, Europe, China, and Russia continue research and development of global positioning systems
- Continued progress in air-based laser technology

Space security impact

Space-based weapons designed to strike terrestrial targets will require sophisticated technological developments that, at present, few spacefaring states seem able to exploit. The development of dual-use capabilities that also provide enabling technologies for space-based strike systems continued in 2007, although there is no evidence that states are developing such capabilities for strike purposes. Nonetheless, the potential for space-to-Earth strike systems will continue to pose a challenge to the international community as advanced space-based technologies continue to be developed. While some enabling technologies for space-based strike are specific to that purpose and include significant technology barriers, many are advanced technologies associated with other space applications and have been developed for a variety of purposes by several different actors; this means that if one actor were to pursue a space-based strike capability, others could follow.

CHAPTER ONE

1. The Space Environment

This chapter assesses trends and developments related to human activity in the space environment, with an emphasis on space debris and space resource issues such as the registration of orbital slots and the allocation of radio frequencies.

Space debris, which is predominantly caused by manmade objects, represents a growing threat to spacecraft. The impact of space debris upon space security is related to a number of key issues examined by this chapter, including the amount of space debris in various orbits, space surveillance capabilities that track space debris to enable collision avoidance, and efforts to reduce new debris and to potentially remove existing space debris in the future.

All space missions inevitably create space debris — rocket booster stages are expended and released to drift in space and exhaust products are created. The testing of anti-satellite (ASAT) weapons has also created thousands of long-lasting pieces of space debris, some 300 of which are reportedly still in orbit from USSR ASAT tests in the 1970s and 1980s.[1]

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 here. This chapter does not address natural phenomena such as solar flares and near-Earth asteroids, except in cases where technologies and techniques are developed to mitigate their impact.

Actors who wish to place a satellite in geostationary orbit must obtain 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 their national assignments are coordinated through the International Telecommunication Union (ITU) and recognized by the ITU Constitution as “limited natural resources,” given their finite number.

According to the Outer Space Treaty, space is considered open to everyone and not subject to sovereign claims, so the distribution and use of these two scarce resources have to be negotiated among states. 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 key space environment resources. This includes compliance with existing norms and procedures developed by 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. Due to very high orbital velocities of 7.8 kilometers per second (~30,000 kilometers per hour) in Low Earth Orbit (LEO), debris as small as 10 centimeters in diameter carries the kinetic energy of a 35,000-kilogram truck traveling at up to 190 kilometers 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 kilometers per hour. No satellite can be reliably protected against this kind of destructive force. See Figure 1.1 for types of Earth orbits.

The total amount of space debris in orbit is growing each year. LEO is the most highly congested orbit. 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 kilometers will remain a threat for decades and even centuries. There have already been a number of space debris collisions with civil, commercial, and military spacecraft. Although a rare occurrence, the reentry of very large debris can also pose a threat to humans and the Earth environment.

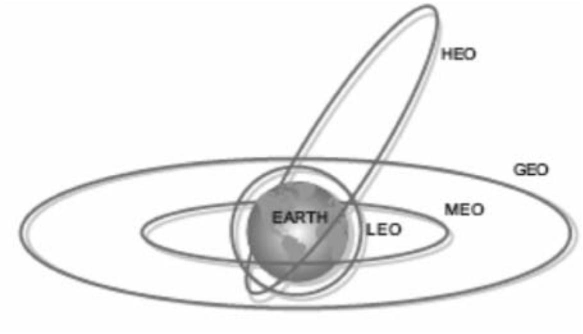
The development of surveillance capabilities to track space debris and avoid collisions clearly provides significant space security advantages. Efforts to mitigate the production of new debris through compliance with national and international rules, guidelines, standards, and practices can also have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

Resource distribution, including the assignment of orbital slots and radio frequencies to space actors, has a direct impact on the abilities 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.

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. There is a strong incentive for space actors to cooperate in the registration and use of radio frequencies and orbital slots — namely, confidence in the sustainability of their use. Cooperation in this area can also strengthen support for the application of the rule of law to broader space security issues.

Other space environment threats include radiation surges caused by solar flares, which damage on-board satellite microchips, interrupt shortwave radio transmissions, and cause errors in navigation systems. Near Earth objects (NEOs) are space-based objects that pose a threat to the Earth if the two collide. Research is ongoing into ways to mitigate the risk of impact with larger NEOs.

Figure 1.1: Types of Earth orbits



LEO = Low Earth Orbit (100-1,500 km)
MEO = Medium Earth Orbit (5,000-10,000 km)
GEO = Geostationary Orbit (36,000 km)
HEO = Highly Elliptical Orbit

Trend 1.1: Growing debris threats to spacecraft as rate of debris production increases

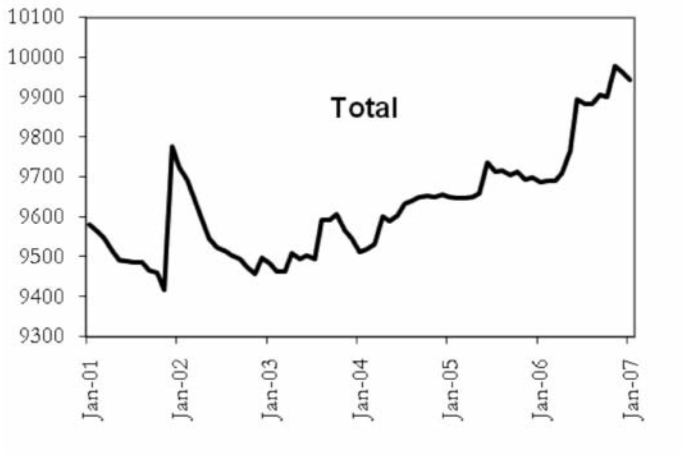
The US Space Surveillance Network (SSN) is the system that most comprehensively tracks and catalogs space debris, although technological factors limit it to spot checking rather than continuous surveillance, and limit the size of tracked objects to those greater than 10 cm in LEO and much larger in GEO. According to the latest reports, the US Department of Defense (DOD) is using the SSN to track more than 17,300 objects approximately 10 cm or larger, of which fewer than 10 percent are operational satellites.[2] It is estimated that there are over 300,000 objects measuring between one and 10 cm in diameter, and billions smaller.[3] Those objects which can be tracked repeatedly and whose source has been identified are placed in the satellite catalog, currently numbering almost 13,000 objects. This catalog is publicly available at http://www.space-track.org. The total number of cataloged objects increased significantly in 2003 when the Cobra Dane radar was reinstated as part of the SSN after being taken offline in 1994 due to budgetary constraints.[4]

Two key factors affecting the amount of space debris are the number of objects in orbit and the number of debris-creating launches each year. Growth in the debris population increases the probability of inter-debris collisions that have the potential to create even more debris. A recent study by NASA has shown that, in LEO, debris-debris collisions will become the dominant source of debris production within the next 50 years.[5] As debris collides and multiplies, it will eventually create a "cascade of collisions" that will spread debris to levels threatening sustainable space access.[6] As of 2003 it was estimated that 43 per cent of tracked debris resulted mostly from explosions and collisions.[7] Additional space debris in LEO could be created by ground- and space-based midcourse missile defense systems currently under development, or other weapons testing in space.[8]

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 resolution 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. Since 2004 an increase in the annual rate of debris production has again been observed.

The highest concentration of space debris is found in LEO, where more debris-producing activities take place. The overwhelming majority of debris in LEO is smaller than 10 centimeters — too small to be reliably tracked and cataloged. Space scientists estimate that there are tens of millions of objects smaller than 10 centimeters in size and approximately 100,000 between one and 10 centimeters (i.e., larger than a marble). Particles as small as two millimeters pose a serious hazard to the security of spacecraft, threatening unprotected fuel lines and other sensitive components.[9] Protection against particles one to 10 millimeters in size can be achieved by shielding spacecraft bodies, while protection against larger debris can only really be achieved through collision avoidance procedures. Debris fragments between one and 10 centimeters "will penetrate and damage most spacecraft," according to the Center for Orbital and Reentry Debris Studies. Moreover, "if the spacecraft bus is impacted, satellite function will be terminated and, at the same time, a significant amount of additional small debris will be created."[10]

Figure 1.2: Number of cataloged objects in Earth orbit[11]



Today, collisions between space assets like the International Space Station and very small pieces of debris are a daily but manageable problem.[12] A 1995 US National Research Council study found that within the orbital altitude most congested with debris (900-1,000 kilometers), 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, with even larger odds against impact in higher orbits.[13]

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."[14] 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.[15] While major collisions have so far been rare, there have been several incidents of varying severity as noted in Figure 1.3 below.

Figure 1.3: Space debris incidents[16]

The French military satellite Cerise had its stabilization arm severed in 1996 by a briefcase-sized portion of an Ariane rocket, and was temporarily put out of commission.
The Space Shuttle has been hit several times by particles bigger than one millimeter, and the first 33 Shuttle flights sustained debris damage to some of the tiles on the Shuttle's undersides. Several thermal windows must be replaced after each Shuttle mission because of space debris damage.
The 10-year-old Hubble Space Telescope, which orbits in LEO, had a 3/4-inch hole in its antenna that was created by debris.
The Russian Kosmos 1275 military navigation satellite experienced an unexpected breakup in July 1981, generally thought to have been a result of space debris, though officially assessed by Russian authority to have been caused by battery failure.
In 1985 a US kinetic energy ASAT test produced over 250 pieces of cataloged debris, some of which later came within 1.3 kilometers of the International Space Station. The last piece of debris generated from this test de-orbited in 2002.
The Long Duration Exposure Facility, a school bus-sized satellite in LEO, recorded more than 30,000 hits by debris or meteoroids during six years in orbit.

2007 Development

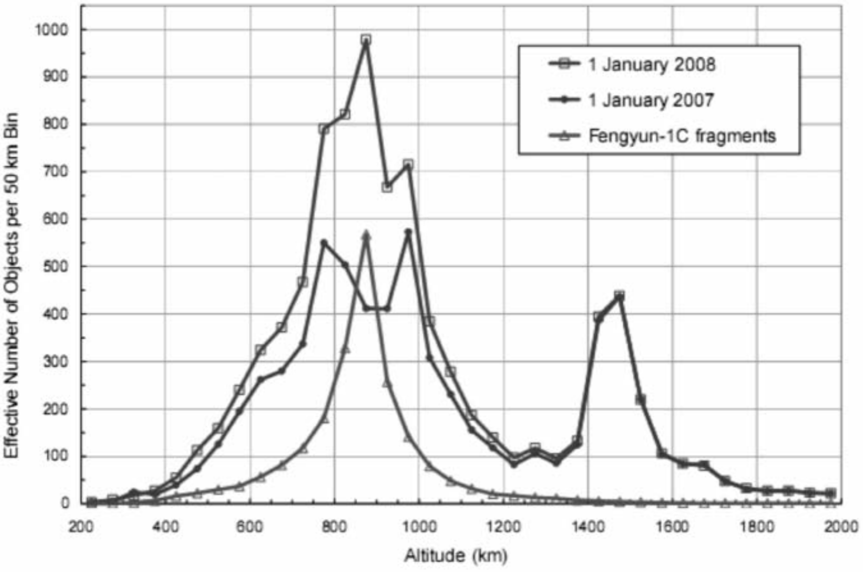
Chinese kinetic satellite intercept creates largest manmade debris field in history

On 11 January 2007 China launched a missile carrying a kinetic intercept vehicle, which impacted the defunct Fengyun-1C Chinese weather satellite at a closing speed of nearly 9 kilometers per second and an orbital altitude of 864 kilometers, creating a large debris cloud.[17] As of 1 February 2008 the US SSN had identified and cataloged 2,317 pieces from the event.[18] Figure 1.6 shows the spread of pieces across a wide range of altitudes as well as how the debris field has changed over time.[19] It is spread over a narrower range of inclinations, ranging from 95.14° to 105.57° from the original inclination of 98.7°.[20] It is estimated that the total number of pieces of the trackable debris population is close to 2,600. An estimate of the number of pieces of the untrackable population down to 1 cm, based on new tracking data from the Haystack X-band radar, is 150,000.[21]

The significance of the large increase in debris in LEO is heightened by the fact that the FY-1C was in one of the most crowded areas of orbit when it was destroyed. According to the US Air Force (USAF) the number of close approaches to the approximately 400 operational US satellites has doubled to almost 200 per week.[22] Additionally, Iridium has reported an increase in close approaches of 15 per cent for its 66 satellites in LEO after the test.[23] The definition of "close approach" differs greatly between satellite operators and so the above numbers should be seen as only a rough indicator of the increased danger to operational satellites. It has been confirmed, however, that NASA maneuvered its Terra satellite on 22 June 2007 to avoid a close approach with a piece of Fengyun-1C debris.[24]

The largest trackable debris field prior to the Chinese intercept of Fengyun-1C was generated by the breakup of a Pegasus launch vehicle on 3 June 1996.[25] The upper stage of the launch vehicle, known as the Hydrazine Auxiliary Propulsion System (HAPS), shut down prematurely and was stranded in orbit with fuel in its tanks. The HAPS was in an orbit 585 kilometers by 820 kilometers and at 82° inclination when it exploded,[26] creating 713 trackable pieces of debris.[27] As of 1 February 2008 63 pieces were still in orbit.[28]

Figure 1.4: Debris from the Chinese ASAT test[29]



Previous ASAT tests have been conducted by both the United States and the Soviet Union. Between 1963 and 1982[30] the Soviet Union tested a co-orbital ASAT system 23 times, including seven interceptions.[31] While these interceptions were of a less energetic nature than the Chinese and American ASAT tests, the nine tests generated more than 700 cataloged pieces of debris.[32] On 13 September 1985 the United States launched an ASAT missile from an F-15 flight aircraft and destroyed the Solwind satellite.[33] The Solwind was in an orbit 545 kilometers by 515 kilometers at an inclination of 97.8° and the impact created a debris field of 285 trackable pieces, the last of which reentered Earth's atmosphere in February 2004.[34] However, the space surveillance capability, primarily in the US, has since increased dramatically, resulting in a much greater ability to detect, track, and characterize satellite breakup events. It is not known how many additional pieces from the Solwind and Soviet tests would have been detected had they been observed with the current capability. However, the altitude of the Fengyun-1C is a major contributor to the severity of the Chinese test. Debris from the Solwind explosion at an altitude of approximately 300 kilometers de-orbited within 25 years. While most of the Fengyun-1C pieces should reenter within a few decades, the final pieces are likely to remain in orbit for centuries.

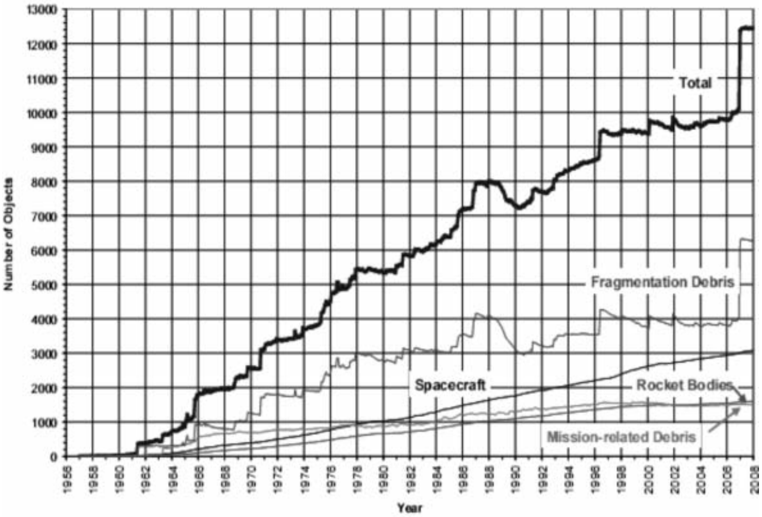
On 21 February 2008 the United States destroyed their USA 193 satellite with a Standard Missile 3 (SM-3) fired from the USS Lake Erie Aegis cruiser.[35] While this event used a kinetic impact kill very similar to the one used by the Chinese to destroy the Fengyun-1C, it occurred at a much lower altitude and produced only short-lived debris. A complete discussion of this event will be presented in *Space Security 2009*.

2007 Development

Trackable space debris population increases by 20.12 per cent

By the end of 2007 the total number of large and medium-sized objects (>10cm) in orbit cataloged by the US SSN stood at 12,456.[36] This number represents an increase of 2,507 objects or 20.12 percent over yearend data for 2006.[37] The locations of the space debris are correlated to the regions of space with the most activity.

Figure 1.5: Growth in on-orbit population by category[38]



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

In addition to the Chinese satellite intercept, several other breakups during 2007 contributed to the worst year for new debris creation. The most serious breakup occurred on 19 February when a Russian Briz-M rocket body exploded.[39] The Briz-M upper stage is commonly used on the Proton booster to place commercial payloads into geostationary orbit. This particular booster had failed to place in orbit the Arabsat 4A and was left almost fully fueled in an orbit 495 kilometers by 14,750 kilometers at 51.5° inclination.[40] Multiple observers recorded the event that is estimated to have produced at least 1,000 pieces of trackable debris. However, as of 1 February 2008 only 25 pieces had been placed in the satellite catalog.[41]

Other breakups in 2007 are summarized in Figure 1.6 below. While some types of breakup can be mitigated through use of best practices, others are more worrisome. Three out of the eight times the Delta-4 has been launched it has released debris, and the cause remains unknown.[42] Similarly, the Briz-M failed half-way to orbit and exploded; it is not clear how to mitigate such an event.

Figure 1.6: Summary of 2007 debris events[43]

Parent Object	Country	Date	Location	Estimated Pieces*	Catalogued Pieces**	Lifespan
FY-1C	PRC	11 Jan	846 km; 98.7°	2,600	2,300	Long
Beidou	PRC	2 Feb	195 km x 41,775 km; 25°	70-100	0	Long
CBERS-1	PRC/Brazil	18 Feb	775 km; 98.2°	100	66	Short
Aux Motor	CIS	14 Feb	260 km x 14,160 km; 46.6°	60+	0	Long
Briz-M	CIS	19 Feb	495 km x 14,750 km; 51.5°	1,000+	0	Long
H-2A	Japan	28 Jul	430 km; 98.2°	4	14	Short
UARS	USA	10 Nov	353 km x 468 km; 56.9°	4	4	Short
Delta IV	USA	11 Nov	Classified	25+	0	Short

* As initially estimated by the US SSN

** As of 1 February 2008

2007 Space Secuity Impact

The deliberate destruction of a satellite and creation of such a massive debris field at a relatively high altitude in a crowded orbit has a negative impact on space security, increasing the threat of debris collision for operational satellites in low Earth orbit and those launched in the future. Additional unintentional breakups demonstrate that even normal launch activity can further degrade the space environment, even if best practices are applied. Efforts must be made by all space actors to mitigate the threat to space security posed by debris.

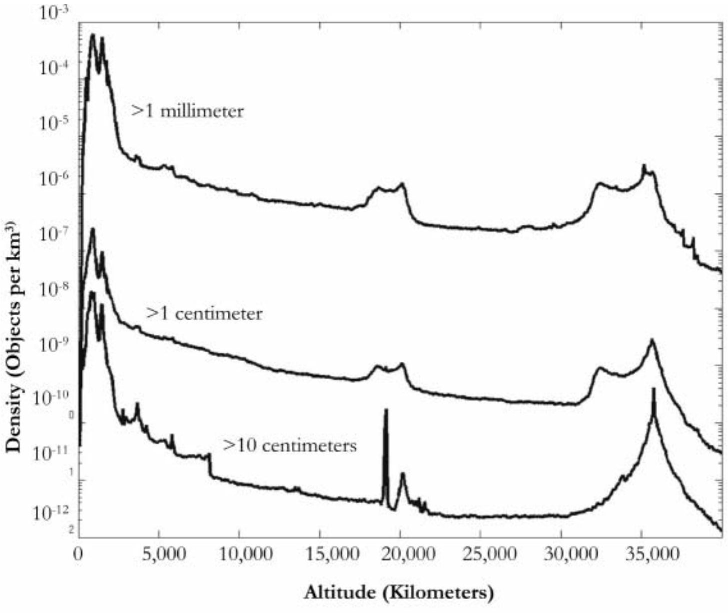
Trend 1.2: Increasing awareness of space debris threats and continued efforts to develop guidelines for debris mitigation

Growing awareness of space debris threats has led to the development of a number of international and national debris mitigation guidelines. The Scientific and Technical Subcommittee of the United Nations Committee on the Peaceful Uses of Outer Space

(COPUOS) began discussions of space debris issues in 1994 and published its Technical Report on Space Debris in 1999. In 2001 COPUOS asked the Inter-Agency Space Debris Coordination Committee (IADC) to develop a set of international debris mitigation guidelines, on which it based its own draft guidelines in 2005.[44] 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 national level, NASA 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 kilometers above GEO, and in 2005 new rules went into effect requiring satellite system operators to submit orbital debris mitigation plans.[45] The ESA initiated a space debris mitigation effort in 1998.

Figure 1.7: Density of space objects by altitude[46]



The *ESA Space Debris Mitigation Handbook* was published in 1999 and revised in 2002.[47] Also in 2002 ESA issued the European Space Debris Safety and Mitigation Standard[48] and issued new debris mitigation guidelines in 2003. Japan and Russia also appear to strongly support the mitigation of space debris production. China, although a member of the IADC, has been slow to adopt debris mitigation measures.[49] At the 2003 COPUOS annual meeting, 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."[50]

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.[51] All major national debris mitigation guidelines address the disposal of GEO satellites, typically in graveyard orbits some 235 kilometers above the GEO orbit, and most seek the removal of dead spacecraft from LEO within 25 years.[52]

In April 2004, the IADC released a revised debris "Protection Manual" describing design measures for spacecraft survivability against debris,[53] as well, a subcommittee of the International Organization for Standardization started drafting a set of standards that incorporate elements of the IADC guidelines.[54]

The progressive development of international and national debris mitigation guidelines has been complemented by research into debris mitigation technologies, such as electromagnetic "tethers" that could help safely de-orbit non-operational satellites.[55] 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."[56] Currently natural decay due to atmospheric drag remains the only technologically and economically feasible way to remove debris.

2007 Development

International debris mitigation guidelines adopted

At the 44th Session of the Scientific and Technical Subcommittee (STSC) of the UN COPUOS in February 2007 the member states adopted the Inter-Agency Space Debris Coordination Committee (IADC) guidelines for debris mitigation.[57] These guidelines are summarized in Figure 1.8.

Figure 1.8: UN COPUOS Space Debris Mitigation Guidelines[58]

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.

These guidelines are the end result of three years of work by the IADC and are intended to provide debris mitigation through all phases of space activity. The member states pledged to implement these guidelines within their national licensing or other applicable mechanisms "to the greatest extent feasible."[59] They were subsequently adopted by the UN COPUOS in June 2007[60] and the UN General Assembly in December 2007.[61]

On 15 August 2007 NASA implemented the latest version of its Procedural Requirements and Safety Standards.[62] These documents outline the debris mitigation standards to which all NASA spacecraft and missions will adhere for future missions. In addition NASA added explicit debris mitigation duties to four additional organizations, bringing to 14 the number of organizations with debris responsibilities within NASA.

Officials from China have also indicated that they are implementing similar wide-ranging debris mitigation standards throughout their space program. Several facilities in China have been identified as working on several key areas, including space debris surveillance, collision avoidance, satellite debris protection, and debris mitigation.[63]

2007 Development

Better implementation of mitigation guidelines by commercial actors

Despite the drastic increase in space debris caused by the Chinese satellite intercept, 2007 also saw better implementation of debris mitigation guidelines by commercial operators. In particular, they did better in disposing of old satellites in geostationary orbit. Of the 12 satellites that reached the end of their operational life, 11 were moved to a graveyard orbit 300 kilometers beyond GEO, although one was re-orbited too close to GEO. This compares to 2006, when "nine satellites were correctly reorbited, seven were reorbited too close and three were abandoned."[64]

2007 Space Security Impact

The approval of voluntary debris mitigation guidelines is a positive step for ensuring the sustainability of the space environment, but the number of breakup events in 2007 (see Trend 1.1) demonstrated that the challenge of space debris will require solutions on multiple fronts. If implemented by all space actors, the debris mitigation guidelines will reduce the chances of future space launches and missions from creating additional debris but will not reduce the debris creation from objects already on orbit. The record of implementation was mixed in 2007, with China worsening the problem of debris but commercial operators better managing end-of-life procedures for satellites in GEO. Solutions that help prevent collisions between operational satellites and other objects are still needed, as well as research into potential methods of removing debris from orbit.

Trend 1.3: Space surveillance capabilities to support collision avoidance slowly improving

Space surveillance capabilities are vital to the mitigation of environmental hazards. There is no international space surveillance mechanism, but several efforts to create one date to the 1980s. In 1986 Canada presented the so-called PAXSAT study, which proposed a space-to-space remote sensing system (PAXSAT A) based on non-superpower technology available at the time. In 1989 France proposed the creation of an Earth-based space surveillance system consisting of radar and optical sensors to allow the international community to track the trajectory of space objects. This proposal was presented in the Conference on Disarmament and evolved into a proposal to establish a UN International Trajectography Centre (UNITRACE). It was suggested that, in the context of rapid technological advances and easier access to high-quality information, the UNITRACE proposal could be revisited and updated. 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 and would be consistent with that agreement's anticipated multilateralization.[65] In the absence of an international system, countries are establishing independent space surveillance capabilities, with some degree of information exchange.

The US Space Surveillance Network (SSN) is the network that most systematically tracks and catalogs orbital debris. The system is comprised of approximately 30 radar and optical sensors at 16 sites worldwide.[66] The SSN can reliably track objects in LEO with a radar cross-section of ten centimeters in diameter or greater. It uses a tasked sensor approach, which means that not all orbital space is searched at all times; thus objects may be observed and then lost again. The system takes up to 500,000 observations daily. Although objects from one to five centimeters in size are not reliably tracked by the system, they can still damage or destroy a satellite. The Air Force Space Surveillance System or Space Fence is the oldest US space surveillance system and consists of three transmitters and six receivers. It provides the greatest number of observations of any sensor and is capable of making some five million detections each month of objects larger than a basketball.[67] Since 2004 the US has implemented stricter regulations on external access to its SSN data according to national security interests.[68]

The broader category of space situational awareness, within which space surveillance is a primary capability, remains one of the "most urgent space security shortcomings" of the US, according to leading experts.[69] The US has programs to bolster such capabilities, but they are generally under-funded and behind schedule. The US Deep View program plans to develop a high-resolution radar-imaging capability to characterize smaller objects in Earth orbit by 2010.[70] The US Space Surveillance Telescope program intends to "demonstrate an advanced ground-based optical system to enable detection and tracking of faint objects in space, while providing rapid, wide-area search capability" by 2009.[71] The Space Based Space Surveillance System (SBSS) is being developed to enhance capabilities for identifying and tracking debris in GEO, however the Orbital Deep Space Imager program was cancelled in 2006. This capability is also relevant for the broader US space control mission (see Space Systems Negation Trend 7.2).[72]

Russia is the only other state with a dedicated Space Surveillance System (SSS), which functions using Russia's early warning radars in space and more than 20 optical and electro-optical facilities at 14 locations on Earth.[73] The main optical observation system, Okno (tr. Window), located at an altitude of 2,200 meters in the mountains near the Tajik eastern city of Nurek, aims principally at objects from 2,000 to 40,000 kilometers in altitude.[74] The system cannot track satellites at very low inclinations and the operation of Russian surveillance sensors is reportedly erratic.[75] 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.[76] While information from the system is not classified, Russia does not have a formal structure to widely disseminate information about observations.[77]

France and Germany also emphasize space surveillance for debris monitoring. France's Air Force operates the Grande Réseau Adapté à la Veille Spatiale (GRAVES) space surveillance system, which has been fully operational since 22 December 2005. The system is capable of monitoring approximately 2,000 space objects, including orbital debris, in LEO up to 1,000 kilometers in altitude, 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.[78] 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.[79] The German Defense Research Organization operates the FGAN Tracking and Imaging Radar. The 34-meter-diameter antenna carries out observations in the L- and Ku-bands and can see objects as small as two centimeters in diameter at altitudes of 1,000 kilometers.[80] Also, the British National Space Centre (BNSC) is developing a new space surveillance system to map large areas of the sky quickly.[81]

The EU maintains information from the SSN in its own Database and Information System Characterising Objects in Space (DISCOS), which also takes inputs from Germany's FGAN Radar and ESA's Space Debris Telescope in Tenerife, Spain. The Space Debris Telescope, a one-meter Zeiss optical telescope, focuses on observations in GEO and can detect objects as small as approximately 15 centimeters in diameter in that orbit.[82] Other optical sensors, including three Passive Imaging Metric Sensor Telescopes operated by the UK Ministry of Defence, the Zimmerwald one-meter 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.[83] ESA's Space Operations Centre in Germany has begun to provide a Space Debris Avoidance Service using data from DISCOS for satellite operators.[84] The ESA has defined space surveillance as one of three main security priorities.[85] Although there is still not an integrated European network, option studies are ongoing and a formal proposal is expected in 2008.[86]

Since joining the IADC in 1995 China has also maintained its own catalog of space objects, using data from the SSN to perform avoidance maneuver calculations and debris modeling.[87] 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.[88] In 2005 the Chinese Academy of Sciences established a Space Object and Debris Monitoring and Research Center at Purple Mountain Observatory that employs researchers to develop a debris warning system for China's space assets.[89] 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.[90] These assets provide the foundation for space surveillance, but are believed to have limited capacity to track unfriendly space objects.

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 in diameter to a distance of 600 kilometers, and track up to 10 objects at once.[91] Two optical telescopes at the Bisei Astronomical Observatory — a 0.5-meter tracking telescope and a 1.01-meter reflecting telescope capable of viewing objects to 30 cm[92] — 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 future space surveillance efforts.[93] Canada is also developing the SAPPHIRE system, which will feature a space-based sensor that will provide observations of objects to high Earth orbits (6,000 to 40,000 kilometers). It is anticipated that the data will be included in the US space catalog, maintained by the North American Aerospace Defense Command (NORAD).[94] Canada's planned Near Earth Object Surveillance Satellite (NEOSsat) asteroid discovery and tracking mission, being developed by Defence Research and Development Canada and the Canadian Space Agency, will also have space surveillance capabilities at high altitudes between 15,000 and 40,000 km.[95]

Figure 1.9: Worldwide space situational awareness capability[96]

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 ISON scientific network

2007 Development

US focus on improving space situational awareness capabilities continues, but actions are modest

The Chinese satellite intercept and other space security concerns have increased awareness in the US military of the need for better space situational awareness (SSA), which includes surveillance capabilities for debris mitigation as well as for potential space protection and negation capabilities (see Space Systems Negation Trend 7.1). In 2007 US military leaders highlighted four major shortfalls in the current US SSA capability: the ability to track foreign satellites, predicting the effects of space weather, tracking orbital debris, and building a cadre of space experts.[97] Efforts to correct these shortcomings are proceeding on multiple fronts; the US Congress authorized an additional $100-million for SSA programs above the President's request in the FY2008 National Defense Authorization Act, including $42-million for the Maui Space Surveillance System, up from $5-million in FY2007. The Rapid Attack Identification Detection and Reporting System (RAIDRS) received an $11-million increase to $64-million. An initial cut in funding for the Space Fence was reversed and overall SSA operations spending has increased from $187-million to $197-million.[98] However, the focus was largely on counter-ASAT capabilities (see Space Systems Protection Trend 6.2).[99]

Meanwhile the USAF continued work on its "clean sheet" proposal, which examines options for bolstering SSA capabilities through the addition of special purpose sensors. Sensors currently in use were mostly built for other purposes such as missile early-warning.[100] This proposal would also set the USAF's long-term acquisition road map for SSA. However completion of the clean sheet analysis caused further delay to the SBSS program, which would enhance the capabilities of the Space Fence and the SSN by providing surveillance of objects in GEO. Launch of the initial pathfinder satellite is not expected before 2009 and costs have increased by $35-million over the FY2008 budget request, while the status of a follow-on system is in limbo.[101]

Despite growing concern for better space surveillance capabilities, funding for the Space Fence was scaled back significantly in 2007 and the timeline pushed back further. Approved in 1997, the Space Fence upgrade would switch from VHF radar to S-band radar, allowing it to track objects as small as 5 centimeters in diameter. The FY2008 request for the Space Fence was only $4-million — almost $10-million less than the amount anticipated the previous year — and figures for subsequent years of funding were also heavily reduced. Although the House approved up to $9.8-million in additional resources, the Space Fence upgrade appears to be continually under-funded and delayed.[102]

In a measure to improve SSA command and control, US Strategic Command (USSTRATCOM) revamped the primary military satellite space surveillance center. USSTRATCOM took over the space surveillance mission from United States Space Command (USSPACECOM) following its merger into USSTRATCOM and dissolution in 2002.[103] Formerly known as the Space Control Center (SCC) and located inside Cheyenne Mountain in Colorado Springs, the facility was renamed the Joint Space Operations Center (JSpOC) and completed its move to Vandenberg Air Force Base, California in August 2007.[104] The unit's mission is to collate the data from the SSN and provide both SSA and command and control for the US. Military leaders hope the move will provide more coherent command and control of US space assets and better integration with joint warfighters located in theaters worldwide.

2007 Development

Worldwide actors continue to develop independent space surveillance capabilities

Demonstrating the capacity of the French GRAVES system, officials announced that the radar had detected at least two dozen satellites that were not found in the official satellite catalog published by the US military (see Space Systems Negation Trend 7.1).[105] Ukraine is also reportedly launching a system to monitor debris and satellites in space.[106] Meanwhile the contract to develop and build the Canadian space-based surveillance satellite Sapphire was awarded to the Canadian defense contractor MacDonald, Dettwiler and Associates Ltd. (MDA).[107] The satellite will provide optical tracking from low Earth orbit and is planned to contribute to the US SSN.[108]

Chinese officials also announced the initiation of a major space surveillance project in late 2007. The network will consist of two lines of observatories, one north-south along 120th east longitude and one east-west along the 30th parallel with completion planned for 2010.[109]

2007 Space Security Impact

The international improvement of space surveillance and space situational awareness capabilities in 2007 may have a positive effect on space security by providing improved and redundant tracking of space objects for collision avoidance, as well as greater transparency of space activities. However, the trend toward secretive development of space situational awareness and the continued drive for *independent* space tracking systems indicate a broader mistrust that could reduce space security, particularly as many aspects of these capabilities are enablers for space system negation. In this context, greater transparency may not make actors feel more secure in space, as the growing focus on the space protection/negation elements of space situational awareness demonstrated (see Space Systems Negation Trend 7.1).

Trend 1.4: Growing demand for radio frequency spectrum and orbital slots

Radio frequencies

The radio frequency spectrum — the part of the electromagnetic spectrum that allows the transmission of radio signals — is divided into portions known as frequency bands. Frequency is generally measured in hertz, defined as cycles per second. Higher frequencies are capable of transmitting more information but require more power to travel longer distances compared to lower frequencies. Communications satellites tend to use the L-band (1-2 gigahertz) and S-band (2-4 gigahertz) for mobile phones, ship communications, and messaging. The C-band (4-8 gigahertz) is widely used by commercial satellite operators to provide services such as roving telephone services, and the Ku-band (12-18 gigahertz) is used to provide connections between satellite users. The Ka-band (27-40 gigahertz) 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 gigahertz, and 18-27 gigahertz, respectively) for the US military.[110]

For technical reasons, most satellite communication falls below 60 gigahertz, 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 gigahertz.[111] Additionally, the number of satellites operating in the 7-8 gigahertz band, commonly used by GEO satellites, has grown rapidly over the past two decades.[112] Since many satellites vie for this advantageous frequency and ever closer orbit slots, there is an increased risk of accidental signal jamming.

Increased military demand for communications bandwidth was apparent during the US-led invasion of Afghanistan in 2001, when the US military used some 700 megabytes per second of bandwidth, compared to about 99 megabytes per second during the 1991 US operations in Iraq.[113] It is reported that during Operation Desert Storm certain air tasking orders and time-sensitive intelligence information were delivered by hand, due to a lack of available bandwidth.[114] To address this challenge, the Wideband Global SATCOM system is designed to provide transmission capacity of up to 2.4 gigabits per second per satellite, more than 10 times the capacity of the most advanced Defense Satellite Communications System satellite currently used.[115]

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 (see Trend 1.5). 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 are also being produced with higher tolerance for interference than those created decades ago, reflecting the need for increased frequency usage and sharing.[116]

There is also significant research being conducted on the use of lasers for communications, particularly by the US military. Lasers transmit information on much higher frequencies and have very tight beams. These features allow very high bit rates and tighter placement of satellites to alleviate some of the current congestion and concern about interference. The US military Transformational Satellite Communications System proposes to use this technology, but not before 2014. The planned US NeXt Generation Communications Program also aims to alleviate frequency demand by allowing several users to share one band of frequency, with their respective devices intelligently searching through the allocated band for unused portions for transmission[117] (see Space Support for Terrestrial Military Operations Trend 5.1).

Today issues of interference arise primarily when two spacecraft require the same frequencies, or when their fields of view overlap. While interference is not epidemic, it is a growing concern for satellite operators, particularly in "crowded space segments" in Asia.[118] 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."[119]

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."[120] 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 DOD is releasing a portion of the military-reserved spectrum from 1,710-1,755 megahertz to the commercial sector for third-generation (3G) wireless communications.[121] India, however, has the world's fastest growing telecoms market, and there is an ongoing struggle between the commercial sector and the Department of Defence over spectrum use.[122]

Originally adopted in 1994, the current version of the ITU Constitution[123] 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."[124] Military communications are exempt from the ITU Constitution. Though they must observe measures to prevent harmful interference, "interferences from the military communication and tracking systems into satellite communications is on the increase."[125]

International negotiations over radio frequency allocations have become politicized, involving bargaining over systems and capabilities that can take years.[126] There is growing concern within the US that the open discussion of certain system characteristics and positioning information necessary to identify and resolve frequency and interference disputes among systems could compromise the security of the systems in question. The Aerospace Corporation noted in 2002 that "the spectrum-management community is moving toward more confidentiality, including the use of generic or non-identifying names instead of actual program names for registration submissions."[127]

Regional efforts are also underway 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's Galileo navigational system; details were finalized in 2007 (see below).[128] ASEAN and the EU are also seeking to harmonize regulations in Asia and Europe respectively.[129]

Orbital slots

Today's satellites operate in three basic orbital bands: LEO, Medium Earth Orbit (MEO), and GEO. There are approximately 850 operational spacecraft, approximately 36 per cent of which are in LEO, six per cent in MEO, 48 per cent in GEO, and about 10 per cent in either Highly Elliptical Orbit (HEO) or planetary trajectories.[130] 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 critical navigation systems such as the GPS and Galileo system. Most communications and weather satellites are in GEO, as orbital movement at this altitude is synchronized with the Earth's 24-hour rotation, meaning that it is always in the same position over the Earth.

Prime GEO slots are located above or close to the equator over regions with high populations and socioeconomic status. Low inclinations are also desired to maximize the reliability of the satellite footprint. The orbital arc of interest to the United States lies between 60 and 135 degrees west longitude because satellites in this area can serve the entire continental US;[131] these desirable slots are also optimal for the rest of the Americas. Similar desirable spots exist over Africa for Europe and the Philippines for Asia.

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 and the field of view of their ground antennas.[132] This is because 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.[133] This means that 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.[134] However in practice, the ITU has distributed orbital slots in GEO on a first-come, first-served basis.

Compounding these issues has been a rush of early registrations with the ITU, often for 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."[135] 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 new 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 more complex requests requiring extensive coordination.[136] 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.[137] Still, by May 2007 157 satellite network filings had been cancelled for non-payment of cost recovery fees.[138]

2007 Development

Cooperation and conflict over satellite navigation signals

The US and EU have been engaged in ongoing negotiations to make GPS and Galileo compatible, with key disagreements involving signal frequencies. The US in particular has been concerned that Galileo's open signal would be too close to the upgraded GPS military signal (M code), preventing the US from locally jamming open signals during a conflict without interfering with its own military use.[139] In July 2007, however, the two agreed to a common GPS-Galileo civilian signal to allow for interoperability of the two systems, while also maintaining the integrity of the US military signal.[140] But, added conflict has arisen from China's announcement that it too will build a global satellite navigation system; it has filled with the ITU to transmit on signals that would overlay both Galileo and the US M code.[141] An ITU working group is evaluating the threat of interference. Chinese sources indicate that it is willing to cooperate with the other systems, but there is no sign of efforts to reach an agreement.[142]

2007 Development

US efforts to increase military communications bandwidth

After another short delay, the first of five planned satellites for the US Wideband Global SATCOM (WGS) was launched on 11 October 2007 and successfully handed over to the USAF.[143] The full WGS constellation is expected to dramatically increase bandwidth availability for the US military and alleviate demands for commercial satellite bandwidth.[144] Other programs intended to contribute to greater bandwidth availability, including the Advanced Extremely High Frequency (AEHF) and Transformational Satellite Communications (TSAT) System, remain behind schedule and significantly over budget (see Space Support for Terrestrial Military Operations Trend 5.1).[145]

Another possible solution to the bandwidth crunch is the April 2007 announcement by Cisco Systems, Inc. on the development of packet-routing switches for satellites. Cisco's router technology already powers much of the ground-based Internet; Cisco is currently partnering with the USAF to develop similar systems for space.[146] These systems would allow space to be an extension of ground Internet links and digital packets could be routed through both systems with greatly reduced overhead, automatically bypassing bottlenecks.

2007 Development

Global efforts to solve spectrum demand issues

In October 2007 the World Radiocommunication Conference (WRC) of the ITU addressed the recent spread of broadband wireless capability, called International Mobile Telecommunications (IMT), and the resulting increase in demand for already sparse spectrum.[147] In the past such issues generally affected only a few countries and could be managed individually by states. The global spread of new wireless communications technologies means that this issue now needs to be tackled by many countries and requires international cooperation. Specifically, the Broadband Wireless Access technology, such as WiMax in the US, operates very close to the upper limit of the C-band frequency used by many communications satellites. The WRC voted to safeguard satellite C-band services by not giving IMT technologies global certification to operate within the C-band.[148]

Meanwhile, Northrop Grumman's announcement that it has developed the world's fastest transistor may indicate a technology development that could ease the spectrum crunch.[149] By enabling communication devices to operate at frequencies of over one terahertz, this technology would open up new areas of usable spectrum.

2007 Development

Unintentional radio frequency interference continues

In September 2007 reports of satellite TV interruptions spread across Israel and Lebanon.[150] The source of the interference was not positively identified, but started at the same time as an

Israeli air strike on a facility in Syria.[151] Originally it was thought to be caused by the jamming tactics used by the Israeli force to disrupt air defense radars, but an official Israeli investigation into the issue pointed to a different source of the interference: a Dutch ship operating as part of the United Nations Interim Force in Lebanon (UNIFIL) in the Mediterranean.[152] The Dutch government has since denied the claim and the investigation continues, with Russian and German vessels seen as possible sources.[153] The interference has disrupted the transmissions of the Israeli Yes satellite television company, resulting in the cancellation of thousands of viewer contracts and a class-action lawsuit against the company.[154] Eutelsat also investigated an unidentified source of interference in January 2007.[155] The Satellite Users Interference Reduction Group identified almost half of all reported interference incidents in 2007 as having an unknown source,[156] most likely accidental. There were only 36 reported cases, compared with 306 in 2006 and 1,282 in 2005.

2007 Space Security Impact

Radio frequency competition, coordination, and interference posed a challenge to space security in 2007, particularly for strategic uses. While international institutions such as the ITU continue to manage competition for space resources, the fact that military operators are outside this arrangement complicates the process, which will only become more difficult as demand from all users increases in the future. Nonetheless, recognition of the issue and progress toward solutions demonstrate the willingness of all space actors to work together on this issue.

Trend 1.5: Increased recognition of the threat from NEO collisions with Earth and progress toward possible solutions

Since the discovery of the Chicxulub crater and its likely associating with the extinction of the dinosaurs, scientists have been uncovering more and more evidence that celestial objects have a history of impacting the Earth and affecting its inhabitants. Over the past decade a growing amount of research started to identify the types of objects that pose threats to Earth and potential mitigation strategies.

Near Earth objects (NEOs) are asteroids and comets whose orbits bring them in close proximity to the Earth or intersect the Earth's orbit. NEOs are subdivided into Near Earth Asteroids (NEAs) and Near Earth Comets (NECs). Within both groupings are Potentially Hazardous Objects (PHOs), those NEOs whose orbits intersect that of Earth'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 PHA instead. A PHA is defined as an asteroid with an orbit that comes with 0.05 astronomical units of the Earth's orbit and has a brightness magnitude greater than 22 (approximately 150 meters in diameter).[157]

Original 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 undertook a survey to discover 90 percent of these objects by 2008. Of the estimated 1,100 objects in this class, NASA is currently tracking 746, or just under 80 percent.[158] 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.[159] Impacts of this class of objects would have the potential to destroy regions of the Earth's surface. Discovery of these objects, along with the 1 km and larger objects would identify 90 percent of the risk the Earth faces from NEO collisions.[160] Other efforts to identify NEOs include Canada's Near Earth Object Surveillance Satellite, which will be the first space-based telescope to find and track NEOs. It is planned for launch in 2009.[161]

However, there is now a growing consensus that the greatest threat is not from asteroids that can destroy the entire Earth or large regions, but rather those that have the potential to destroy 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 a threat of impact with the Earth.[162]

Technical research and discussion 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 can be divided into two categories depending on how much warning time there is for the impact event. If the warning times are on the order of years, there are several mitigation methods that could be used consisting of constant thrust applications to gradually change the NEO's orbit over time. The most promising of these is the gravitational tractor idea conceived by ex-astronaut Ed Lu, but it could also pose a risk to space security if used against uncooperative satellites.[163] If warning times are relatively short, then only certain kinetic methods can be applied. Types of kinetic mitigation methods may include ramming the NEO with a series of kinetic projectiles. NASA has advocated the use of nearby explosions of nuclear weapons to try and change the trajectory of the largest NEOs, but others have refuted this argument.[164] The use of nuclear weapons in space could damage satellites and other space assets, and have long-term consequences for the space environment (see Space Systems Protection Trend 6.3).

Out of the approximately 5,500 known NEOs there are currently 962 known PHAs.[165] 206 of these present a non-zero impact risk to the Earth.[166] This number is expected to jump to over 10,000 in the next 15 years, requiring international decision-making on those objects which present a threat. As a result, focus is now shifting towards discussion of governance issues for NEO detection and mitigation. The Association of Space Explorers (ASE) is currently leading this effort with a series of workshops and will be presenting its report to the United Nations in February 2009.[167] COPUOS also has an Action Team on Near Earth Objects under the Scientific and Technical Subcommittee that is developing recommendations for action at the international level.[168]

2007 Development

Ongoing debate on mitigation strategies for NEOs

At the second quadrennial Planetary Defense Conference held March 2007 in Washington, DC, global experts from a wide range of disciplines discussed the threat to Earth from Near Earth Objects (NEO) and potential mitigation strategies.[169] Attendees recommended that further steps be taken to identify and characterize the NEO threat and that conceptualization of mitigation techniques be continued. More analysis must be done on potentially serious legal, political, policy, and societal issues associated with an impact and after effects.[170]

Further, on 10 November 2007 the US House Committee on Science and Technology's Subcommittee on Space and Aeronautics held a hearing to discuss NEO discovery and characterization strategies. A NASA report published in March analyzed the status of its survey program and outlined the feasibility of various mitigation techniques, including nuclear standoff explosions.[171]

2007 Space Security Impact

Efforts to address potential threats from NEOs are positive in so far as they make the link between space and the security of Earth. However, some options to mitigate such threats such as the use of nuclear weapons, may have negative repercussions for space security by contributing to environmental hazards and instability. There is a need to further explore this issue with the aim of balancing protection of the Earth from space-based threats with long-term sustainability of the space environment.

CHAPTER TWO

2. Space Laws, Policies, and Doctrines

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

Space security-relevant international law has progressively expanded to include, among others, 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 access to space, as well as state responsibility to use space for peaceful purposes. They also restrict space from national appropriation and prohibit 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 space security-relevant multilateral institutions mandated to address uses of space, 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). The International Telecommunication Union (ITU) and the Inter-Agency Space Debris Coordination Committee (IADC) also address space issues regarding radio frequency spectrum, orbital slots, and space debris. These institutions are examined in the Space Environment chapter.

National space policies include authoritative national policy statements regarding the principles and objectives of space actors with respect to the access to and use of space. Such policies provide the context within which national civil, commercial, and military space actors operate. 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 interplay 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, or meteorological capabilities.

Space Security Impact

National and international laws have a direct impact on space security since they establish key space security parameters such as the common access to 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 (i.e., non-aggressive) purposes. International law can improve space security by restricting activities that infringe upon actors' secure and sustainable access to and use of space, or that result in space-based threats. International law, when applied, promotes predictability and transparency among space actors and helps overcome collective action problems. National legislation and international space law also play an important role in establishing the framework necessary for the sustainable commercial use of space.

Multilateral institutions play an essential role in space security, providing a venue to discuss issues of collective concern, negotiate potential disagreements over the allocation of scarce space resources in a peaceful manner, and develop new international law as necessary. Ongoing discussion and negotiation within these institutions also help to build a degree of transparency and therefore confidence among spacefaring states. Multilateral institutions also help to provide the technical support that is needed to ensure access to and use of space for all nations.

National space policies and doctrines both reflect and inform space actors' use of space, as well as their broad civil, commercial, and military priorities. Thus 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 space actors maintain explicit policies on international cooperation in space with the potential to enhance transparency and exert a related positive influence upon space security considerations. 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.

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 behavior more predictable.

Trend 2.1: Gradual development of legal framework for outer space activities

The web of national and international laws and regulations and international treaties that govern the use of space has become gradually more extensive. The international legal framework that governs the use of outer space includes space-specific UN treaties, customary international law, bilateral treaties, and other space-related international agreements.

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 by another state(s).[1]

Outer Space Treaty (OST)

Often referred to as the *Magna Carta* of outer space, 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 2.1).

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] One view is that space begins at 100 kilometers above the Earth, but some states disclaim the need for such a boundary to be established.[3]

There has also been debate regarding the expression "peaceful purposes." The position maintained by the US is that the OST's references to "peaceful purposes" mean "non-aggressive" purposes.[4] The interpretation initially favored by Soviet officials equated peaceful purposes with wholly non-military ones.[5] State practice over the past 40 years has generally supported the view that "peaceful" does mean "non-aggressive." Thus while space assets have been used extensively to support terrestrial military operations, actors have stopped short of actually deploying weapons in space. However, ground-based weapons have been tested against satellites in orbit — most recently by China in 2007 and previously by the US and Russia (see Space Systems Negation Trend 7.3). Article IV of the OST has been cited by some to argue that all military activities in outer space are permissible, unless specifically prohibited by another treaty or customary international law.[6]

There is no widely accepted definition of the term "space weapon." Various definitions have been advanced around the nature, place of deployment, location of targets, and scientific principle of weapons, as well as debates about whether ASATs and anti-ballistic missile weapons constitute space weapons.[7]

Figure 2.1: Key provisions of the Outer Space Treaty[8]

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 who 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.

Liability Convention

This Convention establishes a liability system for activities in outer space, which is instrumental in addressing threats from space debris and other 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."[9] If a launching state causes damage to another space object, it is liable only if it is at fault for causing the damage. The Convention has partly been applied in practice only once. 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, it was settled only partially within the channels of the Convention.[10] Liability for damage caused in space is more difficult to establish. Moreover, the Convention reiterates that states parties remain responsible for the activities of their national and nongovernmental entities. The commercialization and growing military uses of space are challenging the structure of the Liability Convention. For example, the growing number of private and international actors undertaking space launches is confusing the current definition of the term "launching state."

Registration Convention

This Convention requires states to maintain national registries of objects launched into space. Reporting to the Secretary-General of the UN on several data points is also mandatory, such as the date and location of the launch, changes in orbital parameters after the launch, and the recovery date of the spacecraft. 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. 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.[11] As of 2006, only 21 of 51 parties had submitted notice to the UN of a national registry.[12]

A 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. Part of the challenge is the growing number of private and international actors. For example, from 1980 to 1991 registration of space objects at both the national and international levels slipped from 99 percent to 91 percent, but between 2001 and 2003 it was only 75 percent.[13] Moreover, not one of the satellites registered has ever been described as having a military function.[14] Nor does the Convention 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 enumerated shortcomings of the Registration Convention and the Legal Subcommittee of COPUOS has been deliberating the issue since 2004.

Figure 2.2: Registered and unregistered satellites launched since 1957[15]

Launching state	Number of payloads				
	1957–1979		1980 – June 30 2006		1957 – June 30 2006
	Registered	Not Registered	Registered	Not Registered	Total
Soviet Union	1,415	18	1,317	0	2,750
United States of America	934	33	779	105	1,851
Russian Federation	0	0	473	3	476
Japan	18	0	89	8	115
The People's Republic of China	5	3	84	10	102
France	26	0	55	0	81
United Kingdom	6	1	27	20	54
European Space Agency	1	0	39	3	43
India	2	0	36	0	38
Federal Republic of Germany	3	1	25	4	33
Canada	3	0	19	1	21
Italy	4	0	7	7	18
Luxembourg	0	0	14	1	15
Saudi Arabia	0	0	0	13	13
Australia	1	0	8	1	10
Brazil	0	0	6	4	10
Indonesia	0	0	0	10	10
Sweden	0	0	9	0	9
Spain	1	0	5	3	9
Israel	0	0	2	7	9
Korea	0	0	8	0	8
Argentina	0	0	5	3	8
The United Mexican States	0	0	2	5	7
Czechoslovakia/Czech Republic	1	0	5	0	6
Thailand	0	0	0	6	6
Turkey	0	0	4	0	4
Malaysia	0	0	3	0	3
Ukraine	0	0	3	0	3
Eumetsat	0	0	3	0	3
The Netherlands	0	1	0	2	3
Denmark	0	0	0	3	3
Norway	0	0	0	3	3
United Arab Emirates	0	0	2	0	2
Pakistan	0	0	1	1	2
Egypt	0	0	0	2	2
Philippines	0	0	1	0	1
Chile	0	0	1	0	1
Algeria	0	0	1	0	1
Greece	0	0	1	0	1
Nigeria	0	0	1	0	1
Portugal	0	0	0	1	1
Singapore	0	0	0	1	1
South Africa	0	0	0	1	1
Morocco	0	0	0	1	1
Iran	0	0	0	1	1
Kazakhstan	0	0	0	1	1
Total	2420	57	3034	225	5734

Moon Agreement

This Agreement generally echoes the space security 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.[16] However, the Moon Agreement is not widely ratified and reflects contentious issues surrounding lunar exploration.[17] States continue to object to its provisions regarding 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

This Agreement 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 2.3: Signature and ratification of major space treaties

Treaty	Date	Ratifications	Signatures
Outer Space Treaty	1967	98	27
Rescue Agreement	1968	91	25
Liability Convention	1972	87	25
Registration Convention	1975	48	4
Moon Agreement	1979	12	4

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 2.4). Though these principles are not legally binding instruments, they retain a certain legal significance by establishing a code of conduct recommended by the members of the UNGA, reflecting the conviction of the international community on these issues.

Figure 2.4: 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.

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.[18] PAROS resolutions have generally passed unanimously in the UNGA, with only four abstentions on average, demonstrating a widespread desire on the part of the international community to expand international law to include prohibitions against weapons in space.[19] Starting in 1995 the US and Israel consistently abstained from voting on the resolution, and they cast the first negative votes in 2005.[20] Israel has since reverted to abstaining.

Multilateral and bilateral arms control and outer space agreements

Since space issues have long been a topic of concern, there are a range of other legal space security-relevant 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 a 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 non-interference 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 security-relevant provisions of these agreements is provided in Figure 2.5.

Figure 2.5: 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 for use as a weapon modification techniques having 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

Other laws and regimes

Coordination among participating states in the Missile Technology Control Regime (MTCR) adds another layer to the international regulatory framework.[34] The MTCR is not a treaty but rather a voluntary arrangement 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 (see Commercial Space Trend 4.3).[35] Another related effort is the International Code of Conduct against Ballistic Missile Proliferation (also referred to as the Hague Code of Conduct), which calls for greater restraint in developing, testing, using, and proliferating ballistic missiles.[36] To increase transparency and reduce mistrust among subscribing states, it introduces confidence-building measures such as the obligation to announce missile launches in advance.

Finally, the treaties that have an impact on space security 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 (LOAC). 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.[37] Therefore, attacks on satellites, it could be argued, may violate LOAC through direct or collateral damage on civilian satellites and/or the satellites of neutral parties.

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.[38] 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.[39]

Lastly, 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.[40] A concrete outcome of UNISPACE III is the United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER), passed by UNGA 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

The last 25 years have seen a number of proposals to address gaps in the space security regime, 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.” The proposed treaty would have banned the orbiting of objects carrying weapons of any kind and the installation of such weapons on celestial bodies or in outer space. States would also undertake not to destroy, damage, or disturb the normal functioning of unarmed space objects of other states. A revised text, the “Draft Treaty on the Prohibition of the Use of Force in Outer Space and from Space Against the Earth,” introduced to the CD in 1983, had a broader mandate and included a ban on ASAT testing or deployment as well as verification measures.[41]

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 ASATs. Canada, France, and Germany contributed to the space security debate in the CD by exploring definitional issues and verification measures.[42] In 1989 France proposed the creation of a shared space surveillance system consisting of radar and optical sensors for the international community to track the trajectory of space objects. The proposal presented in the CD became known as the International Trajectography Centre (UNITRACE).

After the CD agenda crisis led to the collapse of the PAROS ad hoc committee in the late 1990s, Canada, China, and Russia 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."[43] 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. Parties would also declare the locations and scopes of launching sites, the properties and parameters of objects being launched into outer space, and notify others of launching activities. Since then, China and Russia have presented several Non-Papers on verification measures for such a treaty and on existing international legal instruments on the topic of space weapons.

In 2005 the UNGA adopted a resolution sponsored by Russia entitled "Transparency and confidence-building in outer space activities," inviting states to inform the UN Secretary-General on 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."[44] The United States registered the only vote against the resolution and Israel the only abstention.

Nongovernmental organizations (NGOs) have also contributed to this dialogue on gaps in the international legal framework. For example, the Union of Concerned Scientists drafted a model treaty banning ASATs (1983).[45] In 2003 the Henry L. Stimson Center proposed a code of conduct on dangerous military practices in space.[46] Since 2002 the UN Institute for Disarmament Research has periodically convened expert meetings to examine space security issues and options to address them.[47]

2007 Development

Chinese satellite destruction raises concerns about the peaceful uses of outer space

On 11 January 2007 China successfully destroyed its own aging weather satellite in low Earth orbit with a ballistic missile, generating international concern about the peaceful uses of outer space. The US termed the test "inconsistent with the spirit of cooperation that both countries aspire to in the civil space area."[48] The UK stated that it did not believe that the test was inconsistent with international law, but was concerned at the lack of prior international consultation. The EU expressed deep concern about the event, stating that it was inconsistent with international efforts to avert an arms race in outer space and calling on all signatories to the OST to carry out their space activities in accordance with international law and in the interest of maintaining international peace and security.[49] Japan, on the other hand, expressed the opinion that the event was in contravention of international law.[50] Chinese authorities maintain that the test was "not targeted at any country and will not threaten any country."[51] Nonetheless, the action appears to be in contrast to China's longstanding advocacy of PAROS. Despite demarche attempts by several states, many questions remain unanswered.

Some reactions raised the question of the future of peaceful uses of outer space. The Israeli Minister of Defence and Air Force Chief warned that "emerging ASAT capabilities in the hands of regional adversaries would require Israel to deploy its own defenses against anti-satellite threats."[52] In India concern over the test led to calls supporting the establishment of an Aerospace Command to protect the nation's space-based assets.[53] Nonetheless, India remains committed to a "weapons free outer space."[54] Subsequently several states and civil society groups called for a review of the Outer Space Treaty to prevent similar activities in the future. The non-armament provisions of the OST are limited to the prohibition of the placement of nuclear weapons or other weapons of mass destruction in space (Article III) and the testing of weapons or military maneuvers on the Moon and other celestial bodies (Article IV).

2007 Development

Divisions remain on key space security Resolutions at the UN General Assembly

During the 62nd Session of the General Assembly of the United Nations (UNGA) held in 2007 the US maintained opposition to the adoption of the annual Resolution on Prevention of an Arms Race in Outer Space both in the First Committee and in the Plenary Session on the basis that there is no arms race in outer space.[55] Israel continued to abstain from the vote, while Côte d'Ivoire cast a positive vote after abstaining in 2006, quelling speculation of a growing trend of abstentions.

In accordance with UNGA Resolution 61/75 introduced by the Russian Federation and passed in 2006, replies on transparency and confidence-building measures (TCBM) in outer space were submitted by several states and considered by the UNGA in 2007.[56] Most states indicated general support for such measures; Cuba and the Russian Federation included specific measures that could be explored by the UNGA, ranging from informal measures based on exchanging information to more formal multilateral agreements. While stressing its opposition to the weaponization of space China expressed the view that TCBMs are only intermediate measures complementary to a negotiated international legal instrument.[57] On behalf of the EU Portugal suggested the adoption of a comprehensive code of conduct on space objects and space activities as a means of filling gaps in the existing legal framework, strengthening existing agreements, and codifying best practices.[58] The UNGA passed a Resolution on TCBMs by a vote of 179 with one against (United States) and one abstention (Israel).[59] The US cast a negative vote because it disagreed with the linkage between TCBMs and a negotiated treaty, not with the aim of TCBMs themselves.

2007 Development

Some governments and civil society call for regulatory approaches to space security

The concept of a Code of Conduct or rules of the road for space operations was supported by multiple stakeholders in 2007, including government and military officials, commercial representatives, and nongovernmental organizations.[60] For example, the Portuguese submission on Resolution 61/75 on transparency and confidence-building measures (see above) formed the basis of an EU "Draft Code of Conduct" to be submitted for international consultations in 2008. Key activities would include "the avoidance of collisions and deliberate explosions, the development of safer traffic-management practices, the provision of assurances through improved information exchanges, transparency and notification measures, and the adoption of more stringent space debris mitigation measures."[61]

In other examples, General Chilton, Commander of the US Strategic Command, indicated that the US "should examine the potential utility of a code of conduct or 'rules of the road' for the space domain, thus providing a common understanding of acceptable or unacceptable behavior within a medium shared by all nations" as a means of advancing space situational awareness.[62] Similarly David McGlade, CEO of Intelsat Corp. urged the US to begin an international dialogue on 'Rules of the Road' for space following the Chinese anti-satellite demonstration. Commenting on the utility of nonbinding guidelines and protocols, he stated that, "although there may be disagreement as to the value of additional laws or space treaties, there seems to be general acceptance that certain guidelines or norms developed by consensus may play a useful role in ordering our activities in space."[63]

Several civil society initiatives in 2007 aimed to provide a starting point for such regulatory initiatives. Following the 2006 *Cosmic Study on Space Traffic Management,*[64] prepared by the

International Academy of Astronautics, students at the summer session of the International Space University worked on developing a space traffic management system.[65] The study proposed, among several alternatives, a set of 11 technical traffic rules and two environmental rules as a basis for a long-term solution to the problem of space traffic management.[66] The Henry L. Stimson Center concluded a project with civil society partners from the US, Russia, France, Canada, Japan, and China to develop a Code of Conduct for space operations in the form of an executive-level agreement between states titled "Model Code of Conduct for Responsible Space-faring Nations."[67] Although a civil society delegation from China actively participated in the process leading up to the development of the Code, it did not sign off on the final product. While there seems to be broad support for the concept of a code of conduct as a regulatory approach to space security, there is no indication of consensus on the content of such an agreement.[68] For example, in contrast to the Stimson proposal that would ban all satellite interference, the US military currently emphasizes tactics of space denial based on localized, temporary, and reversible effects (see Trend 2.4).

2007 Space Security Impact

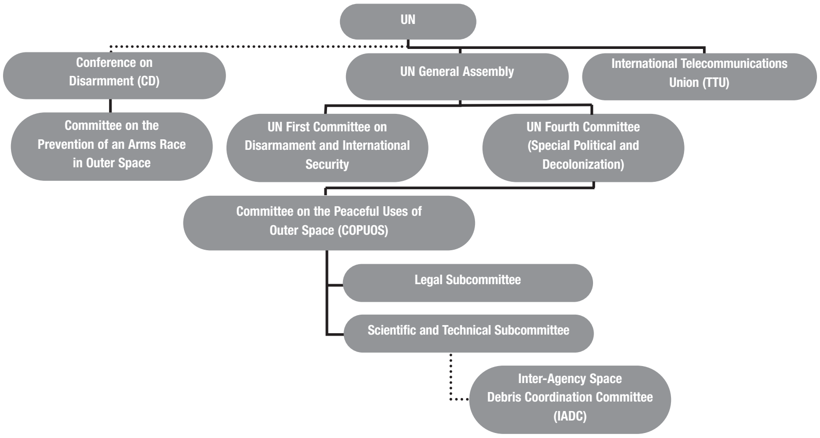
Although the Chinese satellite intercept and destruction raised concerns about the peaceful uses of outer space, including secure and sustainable access, it also focused the attention of the international community on the gaps in the current space security legal and regulatory framework. High-level support from government, military, and commercial officials for the increased use of regulatory approaches such as guidelines, rules of the road, and codes of conduct suggest that this might be a viable avenue to enhance the security of outer space in the future. Although significant political divisions remain, efforts in this direction are already being implemented with the adoption of space debris mitigation guidelines in 2007 (see trend 2.2). However, these alternative approaches rely on good-will implementation by states. Moreover, the division on implementation of UN-SPIDER demonstrates that secure and sustainable access to, and use of, space for all requires significant technical and financial support in addition to an enabling legal framework. Overall, developments in 2007 indicate the fragility of space security. Although international commitment to ensure space security now seems stronger, obstacles to meaningful action remain.

Trend 2.2: Progress in COPUOS but the Conference on Disarmament has been unable to agree on an agenda since 1998

An overview of the relationships among key space security-relevant institutions is provided in Figure 2.6. The UNGA is the main deliberative organ of the United Nations and issues of space security are often debated within the UNGA 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 UNGA has long held that the prevention of an arms race in outer space would make a significant contribution to international peace and security.

The UNGA created COPUOS in 1958 to review the scope of international cooperation in the peaceful uses of outer space, develop 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.[69] There are currently 67 Member States of COPUOS, which works by consensus. The IADC was established in 1993 as a standalone agency composed of the space agencies of major space actors, and has played a key role in developing and promoting space debris mitigation guidelines, which provided the basis for those drafted by the COPUOS Scientific and Technical Subcommittee in 2005.[70] 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 United States in particular emphasizes a strong distinction between peaceful uses and non-armament.[71]

Figure 2.6: International space security-relevant institutions



The CD was established in 1979 as the primary multilateral disarmament negotiating forum. The CD presently has 66 Member States plus observers that meet in three sessions on an annual basis and conduct work 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 that include its lack of verification or enforcement provision and 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 that effect.[72] 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."[73] 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.[74]

Extension of the PAROS committee mandate faltered in 1995 over an agenda dispute that linked PAROS with other agenda items. Since 1998 the CD agenda negotiations have been stalled and the CD has remained without a formal plan of work. The US has prioritized the negotiation of a Fissile Material Cut-off Treaty (FMCT) over action on PAROS, while China has reverse priorities, with a resulting stalemate on both issues. In 2000 then President of the CD Ambassador Amorim of Brazil attempted to break the deadlock by proposing the creation of four subcommittees, including one to "deal with" PAROS and another to "negotiate" the FMCT.[75] The 2002 "Five Ambassadors' Initiative" again attempted to resolve the blockage, proposing an agenda that decoupled the establishment of an ad hoc PAROS committee from any eventual treaty on the non-weaponization of space, which received support from China in 2003, leaving only the US in disagreement. 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. Since 2005 the CD has been advancing discussions on space security themes through informal sessions hosted by delegates.

2007 Development

COPUOS addresses the Registration Convention and Space Debris Mitigation Guidelines and charts future role and activities aimed at peaceful uses and sustainability

The COPUOS Legal Subcommittee endorsed a Working Paper on the practice of states and international organizations in registering space objects.[76] The Working Paper is the culmination of efforts initiated in 2003 when the registration of space objects was adopted as an agenda item based on a four-year work period.[77] It recommends specific actions to improve state practice in registering space objects and adherence to the Registration Convention, including 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.'[78] The Working Paper subsequently provided the basis of a draft resolution submitted by France to the UNGA, passed on 17 December 2007.[79]

On 21 February 2007 the Scientific and Technical Subcommittee of COPUOS adopted voluntary, technical guidelines on space debris mitigation based on those previously adopted by the IADC.[80] The guidelines were subsequently endorsed by COPUOS and the UNGA.[81] Yet China's intentional destruction of a satellite in low Earth orbit on 11 January 2007 created one of the worst manmade debris-creating events to date, demonstrating a potential weakness in the ability of voluntary guidelines to regulate behavior in outer space (see Space Environment, Trend 1.1 and 1.2).

Informal consultations held by the Chairman of COPUOS from July 2006 to April 2007 resulted in a working paper submitted on the future role and activities of the Committee on the Peaceful Uses of Outer Space. The objective is for the Committee to take a "deeper look at the longer-term issues facing the future peaceful uses of outer space and identify where the Committee can best contribute to the sustainability of space activities."[82] An initial list includes supporting the use of space systems to understand the monitor the Earth; supporting increased benefits of satellite navigation systems to the global community; contributing to the work of the Commission on Sustainable Development; developing 'rules of the road' to support long-term sustainability of space activities; support participation by developing countries in space exploration initiatives; consider conservation of designated areas of the Moon and other parts of the solar system; consider the non-technical aspects of future commercial space transportation; and continue to work on recommendations pertaining to near-Earth objects.

2007 Development

Renewed efforts toward resumption of substantive work in the CD

In January 2007 the six presidents (P6) of the 2006 session of the CD presented a vision paper to facilitate the resumption of substantive work in the CD.[83] The paper summarized lessons learned from the structured debates and informal consultations held in 2006 and identified elements for substantive discussions, including the establishment of subsidiary bodies (as opposed to Ad Hoc Committees) to address the core issues of the CD agenda and the adoption of a schedule of activities to provide an efficient framework for substantive discussions, pending agreement on the program of work.[84] Coordinators were appointed to arrange and chair deliberations on seven identified agenda items under the auspices of the P6.[85] Canada served as Coordinator for Prevention of an Arms Race in Outer Space and held two rounds of informal discussions, which largely focused on the issue of the Treaty on the

Prevention of the Placement of Weapons in Outer Space, the Threat or Use of Force against Outer Space Objects (PPWT) being developed by Russia and China.[86]

The work of the seven coordinators culminated in a Presidential Draft Decision L.1, which proposed the appointment of four coordinators to preside over substantive discussions on four agenda items without prejudice to future work and negotiations.[87] The four items selected were: (1) nuclear disarmament and the prevention of nuclear war; (2) a non-discriminatory and multilateral treaty banning the production of fissile material for nuclear weapons or other nuclear explosive devices; (3) issues related to Prevention of an Arms Race in Outer Space; and (4) appropriate international arrangements to assure non-nuclear weapon states against the use or threat of use of nuclear weapons.[88] Support for the Presidential Proposal was mixed and reservations were expressed by China, Pakistan, and Iran.[89] L.1 was not adopted but remains on the table for the 2008 session.

2007 Space Security Impact

Developments in 2007 demonstrated both the expediency and flexibility of technical, regulatory guidelines to address key threats to the security of outer space, as well as the potential weakness of such an approach to enforce behavior. Moreover, events in COPUOS and the CD suggest that a growing division between states that advocate such technical tools and states that insist on a treaty-based approach to space security could result in blocked progress on all fronts. More generally, however, indications of greater cooperation and support for discussions on space security issues were a positive development for 2007.

Trend 2.3: Spacefaring states' national space policies consistently emphasize international cooperation and the peaceful uses of outer space

The national space policies of all spacefaring states explicitly support the principles of peaceful and equitable use of space. Similarly almost all emphasize the goals of using space to promote national commercial, scientific, and technological progress, with countries such as China, Brazil, and India also emphasizing economic development. Virtually all space actors underscore the importance of international cooperation in their space policies; however, it is often delineated by national security concerns.

The US has the most to offer to international cooperative space efforts. While the US is perhaps the least dependent upon such efforts to achieve its national space policy objectives, the 2006 US National Space Policy nonetheless sets a goal to "encourage international cooperation with foreign nations and/or consortia on space activities that are of mutual benefit and that further the peaceful exploration and use of space," as well as to "advance national security, homeland security, and foreign policy objectives."[90] 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."[91]

Russia is deeply engaged in cooperative international space activities, asserting that international cooperation in space exploration is more efficient than breakthroughs by individual states.[92] The International Space Station (ISS) and the Russian-American Observation Satellite Program (RAMOS) for detection of missile launches are examples of this strategy, although RAMOS was cancelled in 2004.[93] Russia is also a major partner of the European Space Agency.[94] Russia's other key partners on space cooperation are China and

India (see Civil Space and Global Utilities Trend 3.3 and 3.4).[95] Russia has also undertaken cooperative space ventures with Bulgaria, Canada, France, Germany, Hungary, Israel, Pakistan, and Portugal on various occasions.[96] 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).[97]

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."[98] While China actively promotes international exchanges and cooperation, it has stated that such efforts must encourage independence and self-reliance in space capabilities.[99] The White Paper also emphasizes that, while due attention will be given to international cooperation and exchanges in the field of space technology, these exchanges must operate on the principles of mutual benefit and reciprocity.[100] In the spirit of these principles, 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.[101] China has pursued space cooperation with 13 states and is collaborating with Brazil on a series of Earth resources satellites.[102]

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 MOUs with Australia, Brazil, Brunei, Canada, China, Darussalam, the European Space Agency (ESA), France, Germany, Hungary, Indonesia, Israel, Italy, Japan, Mauritius, Mongolia, Myanmar, Norway, Peru, Russia, Sweden, Syria, the Netherlands, Thailand, the UK, Ukraine, the US, and Venezuela. 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.[103]

The ESA facilitates European space cooperation by providing a platform for discussion and policymaking for the European scientific and industrial community.[104] 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 the 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. The principles of space activity advanced by France have emphasized free access for all peaceful applications, maintenance of the security and integrity of orbital satellites, and consideration for the legitimate defense interests of states. Autonomy is also a goal of European national space policies, as exemplified by the Ariane launch and Galileo navigation programs.

2007 Development

European Space Policy highlights European independence and civil-military synergies within a context of peaceful uses of outer space

On 22 May 2007 a new European Space Policy was adopted by a resolution of the Fourth Space Council, a joint meeting of the Council of the EU, and the Council of the European Space Agency.[105] The policy's strategic mission is based on the "peaceful exploitation of Outer

Space by all states," through which it seeks to: serve the public in key fields, including the "environment, development, and global climate change," "meet Europe's security and defence needs," "ensure a strong and competitive space industry," "contribute to the knowledge-based society," and "ensure independent European space applications."[106] To achieve this strategic mission the policy calls on member states to take new steps to increase synergies between defence and civil space programs and technologies, taking into account institutional competencies.[107] While stressing the peaceful use of outer space, the policy notes that "[t]he economy and security of Europe and its citizens are increasingly dependent on space-based capabilities which must be protected against disruption" and emphasizes the need for European states to maintain independent access to space[108] A number of specific short-term actions are identified to implement the policy, with a strong focus on independent space access and applications such as launch vehicles, navigation, and environmental monitoring.[109]

2007 Development

China's five-year Space Development Plan reaffirms the importance of commercial development and national strength within a context of peaceful uses of outer space

On 10 May 2007 China's State Council released the country's 11th five-year Space Development Plan for 2006–2010, which follows a blueprint developed by the Commission of Science, Technology, and Industry for National Defense (COSTIND).[110] Program priorities include manned space flight, lunar exploration, launch vehicle development, and high-resolution Earth observation. The plan also emphasizes China's determination to promote the commercial development of space, particularly in the areas of telecommunications, navigation, and remote sensing.[111] While stressing the peaceful nature of China's exploration of space, the Chinese President called on space exploration efforts to help to build China's social, economic, and technological strength.[112] This is in keeping with the 2006 White Paper on Space Activities, which suggests that China intends to be a major competitor in the space industry and links space activities to its national interests and "comprehensive national strengths."[113] While focused on civil space efforts, the technologies are dual-use and the policy resonates with the White Paper *China's National Defense in 2006,* which stresses "informationization" as a key strategy in the modernization of the People's Liberation Army. [114]

2007 Development

14 national space agencies develop framework for coordination of outer space exploration efforts

On 31 May 2007 14 national space agencies jointly released the document *The Global Exploration Strategy: The Framework for Coordination*.[115] The document marked the culmination of efforts toward international collaboration in outer space exploration initiated by NASA in 2006. It asserts that "[s]ustainable space exploration is a challenge that no one nation can do on its own," and "elaborates an action plan to share the strategies and efforts of individual nations so that all can achieve their exploration goals more effectively and safely."[116] The action plan would allow for the establishment of a voluntary, non-binding international Coordination Mechanism for space agencies to exchange information on their respective space exploration plans.[117] This mechanism is intended to help identify gaps, overlaps, and synergies in the space exploration plans of participating agencies.[118] According to the document, "this new era of space exploration is intended to strengthen international partnerships through the sharing of challenging and peaceful goals."[119]

2007 Space Security Impact

States continued to express commitment to international cooperation and the peaceful use of outer space in their civil space policies in 2007, demonstrated most strongly by the Global Exploration Strategy. Yet independence in space is also emphasized. The peaceful use of space is increasingly viewed as strategic, which could limit opportunities for cooperation. The impact on space security will depend on whether or not states pursue independent or collective measures to achieve the strategic goals set out in their space policies.

Trend 2.4: Growing focus within national military doctrines on the security uses of outer space

Fueled by the revolution in military affairs, the military doctrine of a number of states increasingly reflects a growing focus on space-based applications to support military force enhancement functions (see Space Support for Terrestrial Military Operations). Related to this trend is a tendency among major space powers and several emerging space powers to view their space assets as an integral element of their national critical infrastructure.

While there is a specific hierarchy in US military space doctrine documents, some emphaize space control, defined as the "freedom of action in space for friendly forces while, when directed, denying it to an adversary."[120] It is US policy, under *Joint Publication 3-14* and Department of Defense (DOD) *Space Control Policy*, to emphasize tactical denial, meaning that denial should have localized, reversible, and temporary effects.[121] There is currently an active debate within the US on how best to assure the security of vulnerable national space assets. Some advocate the development of space control capabilities, including enhanced protection, active defense systems, and space-based counterspace weapons. The 2003 US Air Force (USAF) *Transformation Flight Plan* in particular calls for onboard protection capabilities for space assets, coupled with offensive counterspace systems to ensure space control for US forces.[122] The 2004 USAF document on *Counterspace Operations* doctrine makes explicit mention of military operations conceived "to deceive, disrupt, deny, degrade, or destroy adversary space capabilities."[123]

Others in this debate advocate enhanced protection measures, but oppose the deployment of weapons in space.[124] Much official US military space doctrine has remained focused primarily on force enhancement, as reflected in the US DOD 1999 S*pace Policy.*[125] The authoritative US joint doctrine on such matters, *Joint Publication 3-14,* as well as the *2004 USAF Posture Statement* reflect a continuing emphasis on using space assets for traditional force enhancement or combat support operations, as well as other passive measures such as space systems protection and responsive space access.[126]

Interest in developing an antiballistic missile system in the US has fuelled discussion and plans for space-based interceptors and space-based lasers. Most notable was President Reagan's Strategic Defense Initiative of 1983. The National Missile Defense Act of 1999 makes it the policy of the US to "deploy as soon as is technologically possible an effective National Missile Defense…against limited ballistic missile attack."[127] While not explicitly mentioning particular space-based systems, the 2006 *National Space Policy* calls on the Secretary of Defense to provide space capabilities to support "multi-layered and integrated missile defenses."[128]

In all military doctrine documents since 1992, Russia has expressed concern that attacks on its early warning and space surveillance systems would represent a direct threat to its security.[129] Therefore a basic Russian national security objective is the protection of Russian space systems, including ground stations on its territory.[130] These concerns derive from Russia's assessment that modern warfare is becoming increasingly dependent on space-based force enhancement capabilities.[131] In 2001 Anatoliy Perminov, then Commander-in-Chief of the space corps, stated that the international trend of armed force modernization demonstrates "the continuously rising role of national space means in ensuring the high combat readiness of troops and naval forces."[132] In practical terms, Russian military space policy appears to have two main priorities. The first is transferring to a new generation of space equipment capabilities, including cheaper and more efficient information technology systems.[133]

Russia's second priority is upgrading its nuclear missile attack warning system. Together, these recent developments are seen as having a critical role in guaranteeing Russia's secure access to space.[134] 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.[135] Thus Russia has actively argued for a treaty prohibiting the deployment of weapons in space. In the interim Russia has pledged not to be the first to deploy any weapons in outer space and has encouraged other spacefaring nations to do the same. However, various Russian officials have also threatened retaliatory measures against any country that attempts to deploy weapons in space.[136]

China's military space doctrine, should it exist, is not made public. China's 2006 White Paper on Space Activities identifies national security as a principle of China's space program.[137]As part of the modernization of its armed forces, the 2004 National Defense White Paper describes China's plans to develop technologies, including "dual purpose technology" in space, for civil and military use.[138] 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 purposes, and asserts an international security strategy based on developing cooperative, non-confrontational, and non-aligned military relations with other states.[139] Nonetheless, in contemporary Chinese military science, the military use of space is inextricably linked to attaining comprehensive national military power.[140] China demonstrated significant counterspace capabilities via missile intercept of an orbiting satellite on 11 January 2007, but maintains that the test was "not targeted at any country and will not threaten any country," and has remained publicly committed to the non-weaponization of space.[141]

Space is important for the European Security and Defence Policy (ESDP). 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.[142] The *European Space Policy* "ESDP and Space" paper approved 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.[143] 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. In the 2005 *Report of the Panel of Experts on Space and Security* EU experts concluded that "Europe must establish a new balance between civil and military uses of space" to effectively protect its borders in a changing security environment, although political support for this recommendation is unclear.[144] The panel also recommended that the EU develop a security-related space strategy to protect civil and military satellite systems, including defensive and anti-jamming countermeasures. The report notes that since EU member states possess the industrial capacity needed to develop space systems, member states should coordinate efforts to establish a well developed space security program.[145] In addition, at the third EC Space Council Meeting in November 2005 elements of the space policy, including the Global Monitoring for

Environment and Security (GMES) initiative, were confirmed as priorities. The EU *European Space Policy* Green Paper and the subsequent *European Space Policy* White Paper also suggest that the EU will work to strengthen and enforce international space law.[146] In 2005 the European Commission (EC) dedicated more than $5-billion to "Security and Space" programs for 2006–2013 and doubled its budget for space-related research programs.[147]

At the national level, French military space doctrine recognizes the primordial role of space support for terrestrial military operations and the Ministry of Defense has emphasized the role of space power in maintaining sovereignty.[148] UK military space doctrine calls for greater satellite use for communications and intelligence. For its part, the ESA has traditionally focused on civil uses of space, a role mandated by the reference in its statute to "exclusively peaceful purposes."[149]

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 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.[150] India's army doctrine, released in 2004, noted plans to make extensive use of space-based sensors for what it predicts will be short and intense military operations of the future.[151] The Indian Air Force is also working toward the creation of an Aerospace Command, intended to make "effective use of space-based assets for military needs."[152] Japan is considering a bill to allow the government to carry out space activities for non-aggressive military and/or defense purposes.[153] Recent Canadian Air Force doctrine documents have highlighted the importance of space systems in support of terrestrial military operations, space situational awareness, and space systems protection.[154]

2007 Development

Japan considers new space law to permit military use of space

In June 2007 the ruling coalition of the Liberal Democratic Party and the New Komeito in Japan submitted a bill to the legislature for a new basic space law, literally translated as Japan's Fundamental Act of Outer Space. However, passage of the bill was delayed due to domestic political changes.[155] Presently, under a strict interpretation of the 1967 Outer Space Treaty contained in the 1969 Parliamentary (Diet) Resolution adopting the Law on the Establishment of the National Space Development Agency (NASDAct), Japan's use of space is limited to non-military purposes. If passed, the new bill would relax existing regulations and allow the Japanese government to carry out space activities for non-aggressive military and/or defense purposes, such as the development, launching, and operation of remote sensing satellites by the Ministry of Defense.[156] It would also create a space strategy headquarters and upgrade the JAXA into an executive agency.[157] Meanwhile, on 6 July 2007 Japan issued its Annual Defense White Paper, citing concerns about North Korea and China and their continued efforts to extend their military capabilities into space.[158]

2007 Development

India continues to consider an Aerospace Command and greater military use of space

In January 2007 the Indian Air Chief Marshall again announced plans for the establishment of the long-anticipated Indian Aerospace Command, originally envisioned as part of the Indian Air Force.[159] This would substantially increase the role of India's military forces in space. However, instead of a fully fledged aerospace command, a space cell has been established under the Air Vice Marshal,[160] and a dialogue on the shape of the eventual Command is expected to take place among the three branches of the Indian Armed Forces to establish a tri-services Aerospace Command. Training was also started for a core group of people to staff the Command in the future. In 2007 India also reportedly took steps to revise its defense doctrine to exploit the use of space to enhance the functional effectiveness of its armed forces. Indian Army Commanders ratified *Space Vision 2020* — the philosophy of using space in future warfare — at an Army Commander's conference in October 2007.[161] The document, drawn up by a special space cell at the Indian Army Headquarters, reportedly emphasizes aspects of force modernization, including battlefield transparency, long-range precision engagement, and integral air mobility. This follows a space policy reportedly developed by the Indian Air Force in 2007, as well as a new Air Force defense doctrine.[162] Media reports indicate that the revised doctrine, which stresses the primacy of air power, also features the utilization of "space for real-time military communications and reconnaissance missions, ballistic missile defence and delivery of precision guided munitions through satellite signals."[163]

2007 Development

Greater use of space for security purposes considered in Europe

The primary focus and competency of the EU in relation to space is on civil space applications, with military and defense issues the exclusive reserve of national governments. Nonetheless, the European Space Policy adopted in 2007 highlights implementation of the space dimension of the European Security and Defence Policy (ESDP). Since 2003 when the European Commission adopted the White Paper titled "Space: a new European frontier for an expanding Union," the EU has consistently stressed the strategic importance of space in implementing its Common Foreign and Security Policy (CFSP), including the ESDP. Along this line, the European space policy seeks to develop synergies between defense and civil space programs and also to guarantee EU independent access to space.[164] 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."[165]

In France a working group on the strategic directions of defense space policy (GOSPS) was established by the Minister of Defense to assess and advise on which security and defense space capabilities will enable France to guarantee its strategic autonomy and meet its key requirements. The GOSPS presented a classified report to the Minister in 2004 and a public version containing key issues was released in 2007. In the report, the GOSPS acknowledged that space control will be important in the future and therefore should be included in France's future defense strategy.[166] Accordingly, it was recommended that national efforts should be increased by 50 percent to reach an annual budget of $954-million, besides efforts at the European level, while resorting to European cooperation and dual-use as much as possible. It is expected that the recommendations of the GOSPS will be taken into consideration during deliberations for the next military program law.[167]

2007 Space Security Impact

In 2007 states continued to emphasize the use of space for national security purposes through military doctrines and some new programs. A positive impact of this development is an increase in transparency, allowing states to better predict the behavior of others in space, although this is limited to broad goals and objectives. On the other hand, these policies and doctrines also demonstrate a growing concern for the need to protect space assets and capabilities, which may have a positive or negative impact on space security, depending on whether such protection is pursued through passive or aggressive means, collectively or independently.

3. Civil Space Programs and Global Utilities

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 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, MIR, the Hubble Space Telescope, and the International Space Station (ISS). Key capabilities associated with launch vehicles related to civil programs that enable actors to access space are also addressed. Finally, the sector includes international collaborations that facilitate space access for countries without launch or other technical capabilities.

The chapter examines trends and developments among civil space actors. It also reviews the number of actors with either independent access to space or access via the launch capabilities of other actors; the number, scope, and priorities of civil programs, including the number of human and civil satellite launches made by each actor; and the funding trends of civil programs. It also assesses the degree and scope of international civil space collaboration, often seen as the hallmark of civil space programs.

Global utilities are space-based applications provided by civil, military, or commercial providers, which can be freely used by any actor equipped to receive the data they provide, 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, search and rescue satellites, and some telecommunications satellites with global utility services, such as amateur radio satellites. Finally, the chapter includes satellite navigation systems that provide geographic position (latitude, longitude, altitude) and velocity information to users on the ground, at sea, or in the air. An example of a global utility is the US Global Positioning System (GPS).

This chapter examines trends and developments in global utilities of all space actors, including the number and types of such programs, their funding, and the number of users. It also assesses trends in conflict and cooperation between actors in the development and use of global utilities.

Space Security Impact

Civil space programs can affect space security in several positive ways. First, they are one of the primary drivers behind the development of capabilities to access and use space, in particular space launch capabilities, increasing the number of actors with secure access to space. Second, civil space programs and their technological spin-offs on Earth underscore the vast scientific, commercial, and social benefits of secure and sustainable uses of space, thereby increasing global interest in the maintenance of space security. Third, civil space programs develop and shape public interest and awareness of the peaceful uses of space.

Conversely, civil space programs can have a negative impact on space security by enabling the development of dual-use technologies for space systems negation or space-based strike capabilities, and by contributing to the overcrowding of scarce space resources such as orbital slots and radio frequencies. Civil-military cooperation can have a mixed impact on space security. On the one hand, it helps to advance the capabilities of civil space programs to access and use space. On the other hand, it may encourage adversaries to target dual-use civil-military satellites, or make such targeting too costly, depending on how other space actors react.

Millions of individuals rely on global utilities on a daily basis for weather, navigation, communications, and search-and-rescue functions. Consequently, global utilities are important for space security because they broaden the community of actors who have an investment in space security and the peaceful uses of space. However, global utilities can also be used for dual-use functions, providing data that can support terrestrial and space military operations (see Space Support for Terrestrial Military Operations, Space Systems Negation Trend 7.2 and Space-Based Strike Systems Trend 8.2).

International cooperation remains a key aspect of both civil space programs and global utilities. Such international cooperation can benefit space security by enhancing transparency regarding the nature and purpose of certain civil programs that can have military purposes. Furthermore, international cooperation in civil space programs can assist in the transfer of skills, material, and technology for the access to, and use of, space by emerging space actors. Finally, international cooperation in civil space programs can serve to highlight areas of mutual benefit in achieving space security and reinforce the practice of using space for peaceful purposes. On the other hand, competition for access to and use of space resources in the longer term, particularly on the moon, could generate tensions between space powers.

Trend 3.1: Growth in the number of actors gaining access to space

Civil space programs, in collaboration with military space programs, contribute to an increase in the number of space actors. The number of actors that have demonstrated an independent orbital launch capability continues to grow and now includes nine states in addition to the European Space Agency (see Figure 3.1). This total does not include non-state actors such as Sea Launch[1] and International Launch Services (ILS)[2] — two consortia that provide commercial orbital launch services using rockets developed by state actors. Ukraine has not yet conducted an independent launch but has demonstrated a capability by building the Zenit launch vehicle used by Sea Launch. Kazakhstan, Brazil, South Korea, and Iran are also developing launch vehicles.

There are a further 18 actors that have suborbital capability, which is required for a rocket to enter space in its trajectory, but not 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.[4] In addition, Iran and North Korea maintain long-range missile programs that could enable them to develop an orbital launch capability.

By the end of 2007 a total of 47 civil actors had accessed space, either with their own launchers or those of others. This number is expected to continue to grow, largely through the efforts of non-state actors such as the UK's Surrey Satellite Technology Ltd., and countries like China, which are helping states to develop affordable small satellites. Since the early 1990s Surrey Satellite has assisted seven states (Algeria, Malaysia, Nigeria, Portugal, South Korea, Thailand, and Turkey) in efforts to build their first civil satellites.[5]

A notable shift in this trend is the growing significance of African states as space actors in an effort to capture the socioeconomic gains that access to space provides. Leaders of this effort include South Africa, Nigeria, Egypt, and Algeria.[6]

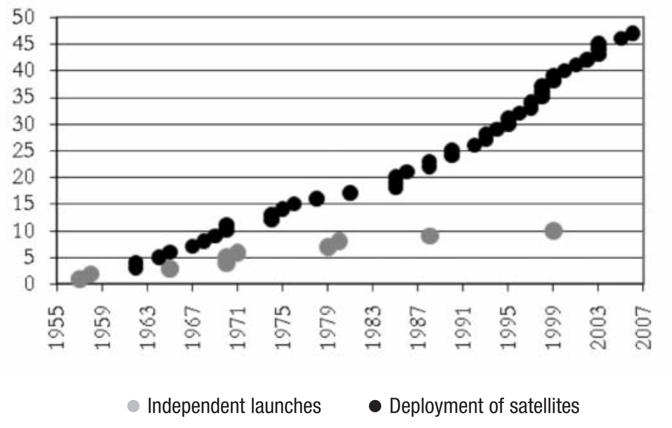
Figure 3.1: Independent orbital launch capability and launch sites of states[3]

State/actor	Year of first orbital launch	Launch vehicle
USSR/Russia	1957	R-7 rocket
USA	1958	Juniper-C
France*	1965	Diamant
Japan	1970	Lambda
China	1970	Long March
UK*	1971	Black Arrow
ESA	1979	Ariane
India	1980	SLV
Israel	1988	Shavit
Ukraine**	1999	Zenit

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

** Ukraine manufactures the Zenit rocket used by Sea Launch. Ukraine attempted its own commercial launch of the Zenit in 1998, but failed.

Figure 3.2: Growth in the number of civil actors accessing space[7]



Microsatellites

The trend in the 1990s toward miniaturization in electronics helped to reduce the size and weight of civil satellites, which can now perform the same functions as their bulkier predecessors but at a decreased cost. One of the first satellites to implement this technology was the US Clementine lunar mission in 1994. Thus, despite decreasing funding levels, the number of US missions has held relatively constant as this technology enabled 'smaller, faster, cheaper' space missions.

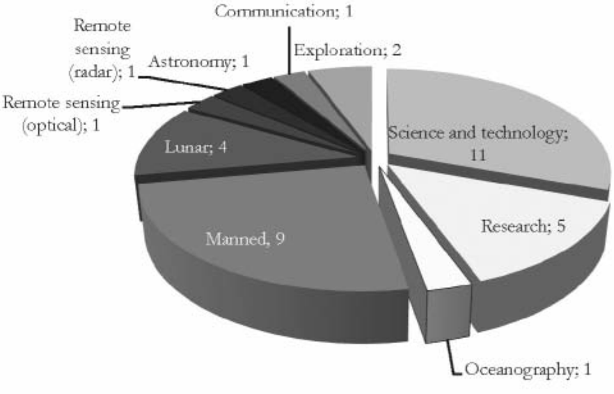
Microsatellites are now increasingly used for civil missions, including, for example, the multinational Disaster Monitoring Constellation and France's joint military-civil Myriade series of microsatellites.[8] These developments have enabled European actors, China, and Japan to expand their civil programs to the point where they now together equal the US or Russia's civil efforts. In 2004 China established the world's largest microsatellite industry park.[9] As well, microsatellite technologies and civil-commercial partnerships have allowed an increasing number of states to afford satellites.

2007 Development

Global efforts to increase access to and use of space through development of launch capabilities and institutions

In 2007 39 civil space objects were launched, down from 47 in 2006 but still significantly higher than 2005 launches. It was a significant year for the launch of civilian remote sensing spacecraft, with both optical and radar capabilities launched, as well as lunar objects (Trend 3.2). Figure 3.3 provides an overview of 2007 launches.

Figure 3.3: Number of civil space missions in 2007



Although no new actors gained access to space in 2007, Iran and South Korea continued efforts to develop independent launch capabilities. On 25 February 2007 Iranian state television reported that the country had launched a suborbital sounding rocket that officials at the Aerospace Research Center said carried a research payload and reached an altitude of 151 kilometers.[10] The payload was jointly produced by the Aerospace Research Center and the Ministry of Defence. Iran has previously stated that it intends to improve its Shahab-3 ballistic missile by developing a satellite launch capability. Another test launch is set for 2008.[11] South Korea plans to launch its first Korea Space Launch Vehicle (KSLV) in 2008. Development of the rocket is said to cost $3.9-billion.[12] The launch is scheduled to take place from South Korea's new Naro space center.[13]

A growing interest in space activities was demonstrated in 2007 through the creation of new national space bodies, particularly in developing countries. These are aimed at taking advantage of the technology, economic, and social development benefits that outer space offers. Vietnam inaugurated the Space Technology Institute, which will focus on "researching into designing and assembling small satellites, applying space technologies in life, and constructing space facilities, including laboratories and earth stations."[14] The National Space Agency of the Republic of Kazakhstan was instituted in 2007.[15] It has been tasked with drafting a law on space activities for Kazakhstan and developing the country's space industry.[16] South Africa announced that its Space Agency, approved on 5 December 2007, will open in March 2008 and will report to the Minister of Science and Technology.[17] Poland, which became the fourth cooperating state with the ESA in 2007, also announced plans to create a National Space Agency, with a budget of $10.6-million for research in 2008.[18]

2007 Development

Microsatellites contribute to increased accessibility of space

The ongoing enhancement of microsatellite capabilities is also driving increased access to space at reduced cost because these satellites are cheaper to produce and to launch. In 2007 India's ISRO announced plans to launch satellites weighing less than 100-kilograms to meet the needs of developing countries and the domestic scientific community.[19] The Romanian Space Agency signed a contract with the company BITNET-CCSS to build and operate its first microsatellite.[20] In cooperation with China, Nigeria launched its first communications microsatellite, NigcomSat-1, which will operate over Africa, parts of the Middle East, and Southern Europe.[21] Although microsatellites are generally less capable than larger spacecraft, they are increasingly used for more traditional functions, such as communications and remote sensing.

The ability of microsatellite technology to perform more advanced capabilities was demonstrated in 2007. The Russian NPO Lavochkin is developing the unified micro-platform "Karat" for the creation of small satellites of different types. Microsatellites will be launched with the heavy rockets as an extra payload. NPO Lavochkin already has 25 projects for both Russian and international space programs, with the first launch announced for 2008.[22] The ESA contracted with Surrey Satellite Technology Ltd. to build a geostationary small satellite platform (200-kilograms) within the Micro Satellite Applications in Collaboration (Mosaic) program for $3.35-million.[23] Finally, NPO Lavochkin will construct small space vehicles for Russia that will be used to explore the Moon and Mars and will weigh no more than 100 kilograms.[24]

2007 Space Security Impact

Although no new space civil space actors emerged in 2007, nations expanded their civil space capabilities, particularly regarding launch and microsatellite technologies. This is an indicator that space remains accessible for use and exploitation for peaceful purposes. On the other hand, the proliferation of civil space technologies such as launch capabilities also provides more actors with abilities that could potentially be used to threaten access to and use of space by other states. The growing number and diversity of space actors also places increased demand on available space resources and on efforts to coordinate space traffic and implement international legal obligations. In the long term, an increased number of satellites launched into outer space will also add pressure to the problem of space debris.

Trend 3.2: Changing priorities and funding levels within civil space programs[25]

Space agencies

Different states and regions have varying types of civil space institutions. The US maintains two main civil agencies — NASA and the National Oceanic and Atmospheric Administration (NOAA). While much work is fielded out to major contractors such as the Boeing Company and the Lockheed-Martin Corporation, mission design, integration, launch, and operations are undertaken by the space agencies themselves. During the Cold War Soviet civil space efforts 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.[26]

A Russian space agency (Rossyskoe Kosmicheskoe Agenstvo) was established in 1992, and has since been reshaped into Roscosmos. While this new agency has more centralized powers than previous organizations, 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. This continued decentralization of civil activities makes obtaining accurate comprehensive budget figures for Russian civil space programs difficult.[27]

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 in 1989 (ASI), 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 the principal space agency of the region today. Although 17 states are members of ESA, most funding is provided by a few states with active national space programs. Germany and France regularly provide between 40 and 50 percent of the ESA budget.[28]

In China, civil space activities began to grow 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). The 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. The Institute of Space and Aeronautical Science of the University of Tokyo, the National Aerospace Laboratory, and, most importantly, the National Space Development Agency undertook most of the work over the years. These efforts were merged into the Japanese Aerospace Exploration Agency (JAXA) in 2003.[29] India's civil space agency, the Indian Space Research Organisation (ISRO), was founded in 1969. Israel's space agency was formed in 1982, Canada's in 1989, and the Brazilian Agência Espacial Brasileira was formed in 1994. South Africa's cabinet approved plans for a space agency in 2006.[30]

For a complete list of civil space agencies please visit www.spacesecurity.org.

Expenditures

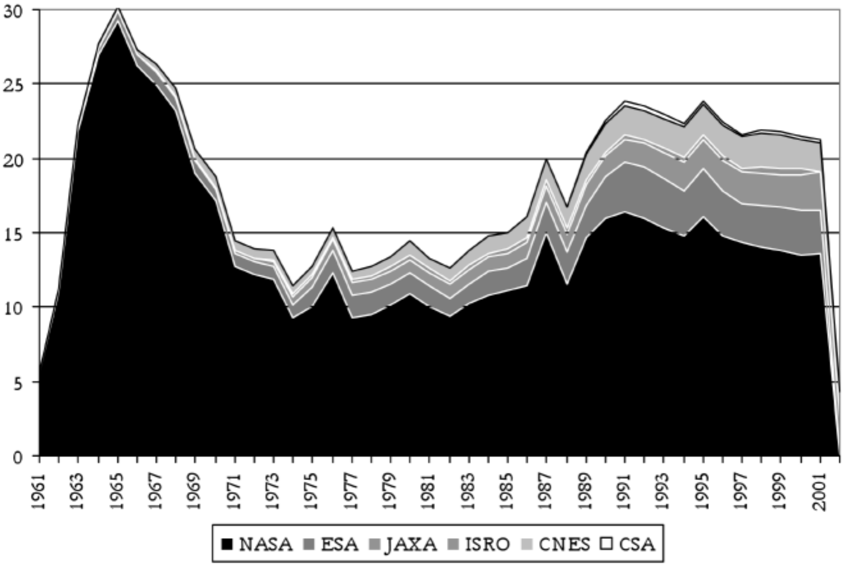
Civil expenditures on space continue to increase considerably in India and China, due in large part to growth in civil program activities, including large satellites and human spaceflight programs. India's space budget increased by 24 percent in 2005 and an additional 35 percent in 2006, when it reached $815-million.[31] The Chinese space budget is complex and figures are not public. Officials have been quoted as saying that the Chinese civil space budget is as low as $500-million. Media sources place the budget closer to $2-billion. While it is safe to speculate that it falls somewhere between these two figures, there is no reliable evidence.[32] Nonetheless, China now has the "fourth largest satellite space program" and the "fastest growing launch rate of any space-faring power," launching 39 satellites (eight of which were military) between 1996 and 2006, 75 percent in the latter five years.[33]

Decreases in civil space budgets in the US, the EU, and Russia have begun to rebound. Although still dwarfing the civil space budgets of other actors, the NASA budget dropped 25 percent in real terms between 1992 and 2001.[34] 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.[35] Both budgets have begun to increase modestly since 2001. The NASA budget has increased annually at a rate of three to four percent since 2004 when President George W. Bush released the *Vision for Space Exploration,* which contains a renewed focus on human space flight.[36] In 2006 it remained at $16.62-billion.[37] The ESA budget was increased by 10 percent in 2005.[38] It is now steady at approximately $3.5-billion per year.

The USSR/Russia was the most active civil space actor from 1970 to 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 had fallen 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.[39] This steady decline was reversed in 2005, however, when Russia approved a 10-year program with a budget of approximately $11-billion.[40] Under this plan the Federal Space Agency's annual budget grew by approximately 30 percent in 2006 to roughly $873-million.[41] This budget may not provide an entirely accurate reflection of the status of Russian civil space capabilities, since Russia also raises funds externally through industry investments and commercial space launches and continues to launch more civil satellites than any other state.

Expenditures are not the sole indicator of capabilities, however, because of the differences in production cost from one country to another, as well as local standards of living and purchasing power.[42] For example, Russia, which has a significantly lower budget than NASA, has historically launched more satellites than any other state.

Figure 3.4: Historic annual civil space agency budgets of major space agencies (billion 2001 dollars)[43]



Human spaceflight

On 12 April 1961 Yuri Gagarin became the first human to travel into space onboard a Soviet Vostok 1 spacecraft. Human spaceflight was dominated in the early years 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 about 100 missions with a capacity of three humans on each flight. The 2006-2015 Federal Space Program maintains an emphasis on human space flight, featuring ongoing development of a reusable spacecraft, the Kliper, to replace the Soyuz vehicle, and completion of the Russian segment of the ISS.[44]

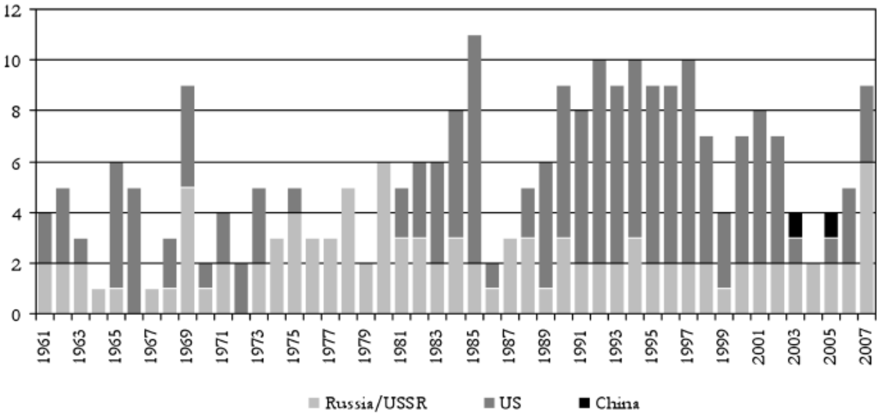
The first US human mission was completed on 5 May 1961, with the suborbital flight of the Mercury capsule launched on an Atlas-Mercury rocket. This was followed by the Gemini flight series and then the Apollo flight series, which ultimately took humans to the Moon. The US went on to develop the Skylab 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 up to seven people to Low Earth Orbit (LEO). The Shuttle was first launched in 1981, has completed about 100 launches, and is currently the only human spaceflight capability for the US. 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.[45] On 4 December 2006 NASA announced its new strategy for lunar exploration.[46] Future plans include human return to the moon, and a permanent human presence on the lunar surface.[47] This announcement followed a report in March 2006 that $3-billion will be cut from NASA's space science budget over the course of three years, reflecting a shifting priority toward human space flight.[48]

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.[49] A second mission was successfully completed in 2005, and a third is planned for 2008. Although there have been unofficial reports that China intends to develop a human space station, there are currently no plans in place.[50] The

2003 Space Shuttle Columbia disaster and the subsequent grounding of US Space Shuttle missions reduced the total annual number of US human missions. Russia was temporarily the only actor performing regular human missions, with its Soyuz spacecraft providing the only lifeline to the International Space Station (see Figure 3.5). This may once again be the case, with the Space Shuttle scheduled for retirement in 2010.[51]

Other civil programs are also turning to human spaceflight. 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.[52] The ESA also has a long-term view to send humans to the Moon and Mars through the Aurora program and India approved a human spaceflight program in 2006.[53]

Figure 3.5: Number of human launches[54]



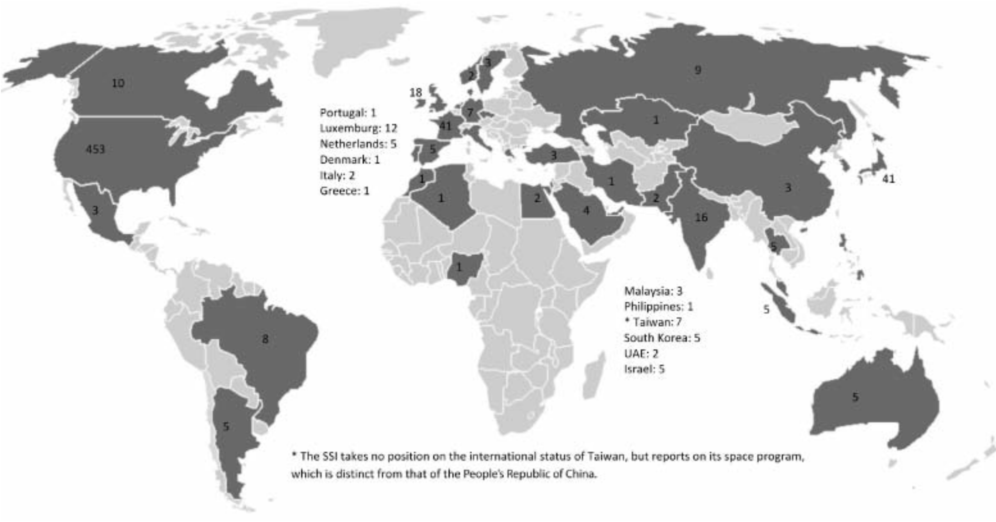
New directions for civil programs

A growing number of civil space projects are now also 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.[55] 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-kilogram 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.[56] 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."[57]

Civil space programs are increasingly being used for national security missions, particularly in the field of meteorology and Earth observation science. 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."[58]

Civil programs also continue to generate significant economic and technological spin-offs. It is estimated that for every dollar the US spends on research and development in its civil space program, it receives seven back in the form of corporate and personal income taxes from increased employment and economic growth.[59] Recent examples of these spin-offs from NASA's programs include scratch resistant lenses, virtual reality equipment, more efficient solar cells, microlasers, advanced lubricants, and programmable pacemakers.[60]

Figure 3.6: Number of satellites by actor, December 2006[61]



* The SSI takes no position on the international status of Taiwan, but reports on its space program, which is distinct from that of the People's Republic of China.

2007 Development

Space budgets grow in India and Russia as focus shifts to large-scale projects

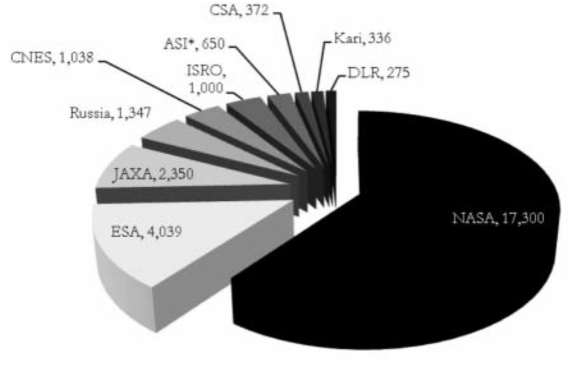
India and Russia posted significant civil space budget gains in 2007 as both countries focus on enhancing capabilities, launching human missions, and exploring the Moon. In 2007 ISRO's budget increased by up to 30 percent after a 35 percent jump in 2006, bringing its 2007-2008 budget to just under $1-billion. The recent increase is intended to fund India's human space program, while earlier hikes supported significant new satellite applications.[62] The budget for Russia's Federal Space Agency (Roscosmos) also grew substantially in 2007 to $1.347-billion compared to about $832-million in 2006.[63] According to the Federal 2008 Budget Law, Roscosmos will receive more than $1.5-billion in 2008.[64] These budgetary figures do not include financing for the GLONASS system, which has a separate budget of roughly $4.19-million plus $3.49-million for system maintenance.

Elsewhere civil space budgets remained fairly steady, and some apparent gains in Figure 3.2 reflect the lower value for the US dollar rather than new investments, particularly in Europe. France was the only major contributor to ESA to increase budgetary resources, adding approximately $15-million to the budget for the Centre National d'Etudes Spatiales (CNES). This brought the CNES budget to a total of $1.038-billion, in addition to $1.013-billion paid to ESA.[65]

NASA continued to dominate the world in civil space spending in 2007, with a budget approval of $17.3-billion for FY2008, a modest increase over the previous year.[66] Spending is focused on human space programs rather than science:[67] The Constellations Systems program received $3-billion; the International Space Station (ISS) $2.2-billion (an increase of 26 percent); and the Space Shuttle program $4-billion.

Chinese officials have been quoted as saying that the Chinese space budget is as low as $500-million while media sources place the budget closer to $2-billion, although there is no reliable evidence.[68] However, ongoing plans for space exploration, new launchers, and human missions suggest that the budget may be increasing. No notable new investments were observed in South Korea, despite its ambitious vision for a space launcher and lunar and human missions.

Figure 3.7: Civil space budgets in 2007 (in USD millions)[69]



* includes contribution to European Space Agency

2007 Development

Use of remote sensing to support sustainable development

The launch of remote sensing satellites was significant in 2007 and coincided with a growing effort to use space applications to support economic and social development. In China the Yaogan-2 and Yaogan-3 (Remote Sensing Satellite-2 and -3) were launched on 25 May 2007 and 12 November 2007 respectively. Yaogan-2 is an optical imaging satellite while Yaogan-3 uses advanced synthetic aperture radar (SAR) for all-day/all-weather/all-terrain imaging. According to Chinese media, both satellites were built by the China Academy of Space Technology (CAST) and will be used for "scientific research, land resources surveying, crop yield estimate and disaster forecast."[70] Moreover, China and Brazil agreed to provide land images from their joint optical imaging CBERS-2B (China-Brazil Earth Resource Satellite-2B) launched in September 2007 freely to African and Asian countries.[71] They will also provide the software needed to read the data, which is intended to help respond to threats such as deforestation, desertification, and drought.[72]

India also declared that it will share remote sensing data for disaster management in the Asia-Pacific region and provide data analysis and training to countries without independent access. India has also instituted a Disaster Management Support System in Hyderabad.[73] In 2007 it launched Cartosat-2, its 12th remote sensing satellite, which will be used for, among other applications, urban and rural infrastructure development and management.[74]

Egypt had its first remote sensing satellite launched in 2007, jointly built by Egypt's National Authority for Remote Sensing and Space Sciences and the Ukrainian Yuzhnoye Design Bureau.[75] According to Egyptian officials, it will be used "to support development in the fields of construction, cultivation and fighting desertification.[76]

Like most civil space technologies, remote sensing capabilities are dual-use. Many of the civilian spacecraft described above are also suspected of providing data for military use (see Space Support for Terrestrial Military Operations, Trend 5.2).

2007 Development

Strong interest in Europe, Russia, US, and India with respect to developing human spacecraft, but efforts progress slowly

While China's Shenzhou-7 underwent extensive testing in preparation for an announced spacewalk in 2008,[77] efforts to develop next-generation human spacecraft in Russia, Europe, and the US also progressed, albeit slowly. The Russian-ESA plan to produce the Kliper, a winged, human spacecraft designed by RKK Energiya to replace the Russian Soyuz capsule, was cancelled in 2006, but the Kliper concept resurfaced in 2007.[78] Although Kliper was being described by Roscosmos as the final stage of Russia's human spacecraft overhaul, RKK Energiya decided to market it to international investors as a profit-making venture.[79] In December 2007 the chief of Roscosmos indicated that India may be interested in developing with Russia a new reusable spaceship, presumably the Kliper.[80] The projected timeframe for Kliper operations to begin is 2013-2015. In the meantime Russia is continuing to work with the ESA on a study for an Advanced Crew Transportation System (ACTS) for Low Earth Orbit and potentially the Moon. The study, which is expected to be completed in 2008, is focused on a simpler, Soyuz-like design rather than the more advanced Kliper model.[81]

In the US, a six months-late Preliminary Design Review of the Ares-1 may cause a delay of over a year for the first launch of humans aboard the spacecraft. Initial plans forecasted a first launch in 2015.[82] Ares is part of NASA's Constellation Program, which also includes the Orion spacecraft and various support systems designed to replace the US Space Shuttle. The Program was reviewed by NASA in 2007. A preliminary design review is planned for 2008 and a critical design review in early 2010.[83] To address the gap between the retirement of the Space Shuttle and the completion of the Constellation Program, NASA has signed several funding and information-sharing agreements with the private sector to develop interim transportation to the International Space Station (see Commercial Space Trend 4.3).[84]

India made progress in developing an indigenous human spacecraft with the successful recovery of the Space Capsule Recovery Experiment on 22 January 2007.[85] In December 2007 Europe's first human-rated spacecraft, the Jules Verne Automated Transfer Vehicle, was being prepared for launch in 2008.[86]

2007 Development

Space agencies continue to focus on the Moon, Mars

The Moon, and to a lesser extent Mars, were a focus of civil space programs in 2007. On 14 September 2007 Japan launched its Kaguya lunar probe into orbit. At a cost of $478-million, it is considered to be the most extensive mission to investigate the Moon since the US Apollo program in the 1960s and 1970s.[87] It consists of a three-ton main orbiter and two 50-kilogram subsatellites and is equipped with 14 scientific instruments and a high-definition television camera.[88] This is Japan's second lunar orbiter; the first was launched in 1990. Kaguya is intended to study the Moon's origin and evolution and to assess it for future use.[89]

Japan's lunar mission was followed on 24 October 2007 by the launch of Chang'e-1 by the Chinese National Space Administration (CNSA), with cooperation from the ESA. The first step of China's lunar program aimed at robotic exploration of the Moon's surface for mapping and to analyze its chemical composition.[90] Its cost is estimated at $187-million. Although reports emerged in 2007 that China intends to have a human presence on the Moon,[91] Chinese officials have indicated that no official plans exist.[92]

Other announcements for new lunar exploration programs came from Europe, India, and South Korea. Germany announced potential plans to send a robotic spacecraft to orbit the Moon for scientific research as early as 2012.[93] Meanwhile India was preparing for its first lunar mission, the Chandrayaan-1, scheduled for launch in 2008.[94] ISRO's Moon mission is estimated to cost $14-million per year over five years, or approximately two percent of its total budget.[95] South Korea also announced its plans to send a probe into lunar orbit by 2020 and another to the surface of the Moon by 2025 as part of its indigenous rocket program. However, the rocket alone is estimated to cost $3.9-billion over the next decade and to date South Korea's space budget has not increased to reflect such ambitions.[96] Russia and China added a focus on Mars with the announced 2009 launch of Russia's Phobos Explorer satellite along with a small Chinese satellite intended to probe the Martian surface; preparation was ongoing in 2007.[97]

2007 Space Security Impact

Activities in 2007 demonstrated the continuation of a recently renewed interest in large-scale space projects, particularly lunar exploration and human spaceflight. Although developments in 2007 indicate some cooperation on these projects, competition may increase if such capabilities become strategic in the future, as indicated by historical trends. Nonetheless, it remains to be seen if these large-scale projects will gain the necessary investment to come to fruition; only in India, Russia, and possibly China are resources growing significantly. Outer space continues to be dominated by a few states. Delays in construction of new human spacecraft in the US, may adversely influence space security in the future by limiting human access to space, in particular the ISS. Finally, the growing use of remote sensing satellites for sustainable development is drawing more stakeholders into space, and strengthening the relationship between security in space and security on Earth. However, what is essentially the proliferation of dual-use spacecraft may contribute to the expression of regional tensions in space (see Space Support for Terrestrial Military Operations Trend 5.2).

Trend 3.3: Steady growth in international cooperation in civil space programs

Due to the huge costs and technical challenges associated with access to and use of space, international cooperation has been a defining feature of civil space programs throughout the space age. Scientific satellites in particular have been a driver of cooperation.[98] 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."[99] Moreover, if government support for space science decreases, such cooperative efforts may also decline. A March 2006 report indicates that $3-billion will be cut from NASA's space science budget over the course of three years as priority shifts toward human space flight.[100]

The 1980s saw a myriad 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.[101] From 1995 to 1998 there were nine dockings of the US Space Shuttle to the MIR space station, with various crew exchanges.[102] 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 international engineering project ever undertaken. The project partners are NASA, the Russian Aviation and Space Agency, ESA, JAXA, and the Canadian Space Agency. Brazil participates through a separate agreement with NASA. The first module was launched in 1998; the station is still under construction. By 2006, 58 launches had carried components, equipment, and astronauts to the station.[103] The ISS is projected to cost $129-billion.[104]

Space-based global utilities, discussed in more detail in Trend 3.4, represent another area of international cooperation. The EU Galileo satellite navigation system is a partnership between the EU and the ESA and includes several international partners.[105] Algeria, China, Nigeria, Spain, Thailand, Turkey, Vietnam, and the UK are collaborating on the Disaster Monitoring Constellation. The project, initiated by China, foresees the deployment of 10 dedicated microsatellites, five of which have been deployed to date. International cooperation on Earth observation is also discussed below.

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 uses, and EU-China cooperation on Galileo. There are also increasing levels of cooperation among developed and developing countries, and new and unprecedented partnerships such as the Sino-Brazilian Earth observation satellite effort.[106] A 2006 Chinese white paper indicated that China had signed 16 international space cooperation agreements with 13 different countries, space agencies, and international organizations over the course of five years.[107] Pakistan, Nigeria, and Venezuela were identified as future partners in efforts to develop and launch satellites.

However, export controls remain a hindrance to increased cooperation, particularly in the US (see Commercial Space Trend 4.3).

2007 Development

International cooperation emerging for Moon/Mars exploration

Despite claims of a new space race to the Moon, significant international cooperation is developing for Moon and Mars missions. In 2007 the 14 largest space agencies agreed to coordinate future space missions in a document titled "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.[108] Chinese authorities have also indicated that a mechanism for cooperation is being developed in Asia among countries pursuing lunar exploration programs.[109]

Significant bilateral cooperation on Moon and Mars missions also took place in 2007. Russia and India signed an agreement to cooperate on lunar research and exploration, according to which the two countries will build and launch a Moon rover in 2011.[110] The agreement is valid until 2017 and establishes the technical, organizational, and legal aspects of the proposed Moon exploration. Russia and the ESA agreed in 2007 to cooperate on a next-generation human spacecraft aimed at taking humans to the Moon.[111] Russia and NASA also took steps to continue Russian-US cooperation in space exploration through an agreement on two new scientific projects, LEND and DAN. The Russian LEND (Lunar Exploration Neutron Detector) instrument to find water near the lunar poles is designed to be carried aboard the American Lunar Reconnaissance Orbiter (LRO). Russia's DAN (Dynamic Albedo of Neutrons) instrument will take part in the American Mars Science Laboratory mission, which is scheduled for 2009 and is aimed at measuring water content of soil on Mars.[112] NASA is also considering support for the UK's robotic lunar mission Moonlite.[113] Finally, in 2007 ESA provided technical support and knowledge-sharing for both China's Chang'e-1 lunar orbiter and India's Chandrayaan-1 lunar orbiter.

2007 Development

International cooperation on the ISS, space science, and launch technology

The ISS continued to be a focus of international space cooperation in 2007, with the US and Russia coordinating plans for the development and use of the ISS until 2011.[114] Within this framework, Roscosmos signed a contract with NASA for nearly $1-billion to supply cargo shuttles for the US section of the ISS.[115] Science also drove international cooperation, one of the major examples being an agreement signed by NASA, the Canadian Space Agency, and the ESA to build and launch a powerful orbital telescope to replace the Hubble telescope. The new James Webb telescope is to be launched in 2013 at an estimated cost of $3.5-billion.[116]

Launch efforts were also a source of cooperation in 2007, with construction of a Soyuz launch base in French Guiana to increase the launcher's lift capability.[117] Russia also reached an agreement with Indonesia to begin implementation of the Air Start project, which will allow Russia to develop and use a new launch facility on the island of Biak, with launching activities planned to start in 2009-2010.[118] This project is part of a $1.2-billion agreement by Indonesia to purchase Russian military hardware.[119] Rocketry is also part of a newly ratified agreement between Russia and South Korea on measures to cooperate on space exploration and other peaceful uses of outer space.[120] The two countries agreed to expand cooperation in space science, including rocket building and astronaut training, and may establish a joint company to make aerospace-related electronic parts and a working-level committee to explore the development of liquid-fuel rockets.

2007 Development

US-Chinese cooperation falters

There were some indications of future cooperation between the civil space activities of China and the US when NASA Chief Administrator Michael Griffin visited China in September 2006,[121] but this faltered following the Chinese intercept and destruction of one of its own satellites on 11 January 2008. Although substantial cooperation on major projects such as the ISS and lunar/Martian exploration missions was not evident in the short term, NASA officials claimed that the action undermined an agreement between the two leaders to cooperate on civil space projects reached in April 2006.[122] The US is consequently reevaluating cooperation with China.

2007 Space Security Impact

Growing cooperation and collaboration between major and less developed space powers enhance space security by providing partner countries with greater access to space through shared resources and technology. Larger networks of cooperation such as the "Global Exploration Strategy" could also result in greater transparency of space activities, mitigating uncertainties or mistrust that may arise as more countries gain access to space. There is a risk, however, that sensitive military technologies may proliferate. Moreover, as regional cooperation becomes stronger there may be negative geopolitical tensions and rivalries in space — as the tensions between China and the US demonstrate, civil space cooperation is often influenced by strategic concerns. Yet cooperation efforts on the Moon and Mars in 2007 suggest that what is often characterized as a new space race may not in fact become a reality.

Trend 3.4: Continued growth in global utilities as states seek to expand applications and accessibility

The use of space-based global utilities, including navigation, weather, and search-and-rescue systems, has grown dramatically over the last decade. For example GPS unit consumption grew by approximately 25 percent per year between 1996 and 1999; sales revenue increased from $6.2-billion in 1999[123] to $21.8-billion in 2005.[124] 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 large-scale operational 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 kilometers in Medium Earth Orbit (MEO). A GPS receiver must receive signals from four satellites to determine its location, accurate within 20 meters 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 military allies

Begun as a military system, GPS diversified and grew to the point that, in 2001, military uses of the GPS accounted for only about two percent of its total market. The commercial air transportation industry, which carries over 2 billion passengers a year, relies heavily on GPS.[125] US companies receive about half of GPS product revenues, but US customers account for only about one-third of the revenue base. The growth rate of GPS units in use continues to increase, particularly outside of the US.[126]

The Russian GLONASS system uses principles that are similar to those used in the GPS. It is designed to be composed of 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 kilometers.[127] 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 underway to complete the system once again.[128] 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 as of 2007.[129] Russia has extended cooperation on GLONASS to China and India.

China, Japan, the EU, and India are all engaged in the research and development of additional satellite navigation systems.[130] The Chinese Beidou system, designed for regional use in and around China, has been under development since the late 1990s. It uses a different principle than that of the GPS or GLONASS, operating four satellites in geostationary orbit.[131] In 2006 China announced that it will develop a global system called Compass or Beidou-2 for military, civilian, and commercial use.[132] The global system is planned to include five satellites in GEO and 30 in MEO. The initial regional system is expected to provide service in 2008.

India announced plans to develop an independent regional satellite navigation system. Called the Indian Regional Navigation Satellite System (IRNSS), it will consist of a seven-satellite constellation independent of India's current involvement in the ESA's Galileo project and Russia's GLONASS.[133] Japan has begun 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.[134] In 2004 an internal programmatic dispute caused a deadlock in development.[135]

Perhaps most significantly, the EU and ESA are jointly developing the Galileo navigation system, which is to consist of 30 satellites in a constellation similar to that of the GPS. Significant effort on Galileo began in 2002, with the allocation of $577-million in development funds by the European Council of Transport Ministers.[136] The Galileo project has been opened to international partners to support the development of the system; by 2006 these included Israel, Ukraine, India, Morocco, Saudi Arabia, and South Korea. Russia has agreed to launch Galileo satellites. China's partnership status was clarified in 2004, when it was announced that China would not be granted access to the secure Public Regulated Service government channel.[137] 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.[138] The project is currently in its testing phase, but is already over budget; the completion date has been extended from 2008 to 2013.[139]

The development of competing independent satellite navigation systems, although conceivably interoperable and able to extend the reliability of this global utility, has incurred several conflicts. The US and EU are engaged in ongoing negotiations to make GPS and Galileo compatible, with key disagreements involving signal frequencies. The US in particular is concerned that Galileo's open signal will be too close to the upgraded GPS military signal (M code), preventing the US from locally jamming open signals during a conflict without interfering with its own military use.[140] As well, in 2006 it was announced that China's global Compass system may use the same frequency for its military signal as that used for the EU encrypted service and the GPS military signal,[141] making it difficult to jam during a potential conflict and hindering the possibility of cooperating systems.

Earth observation

Remote sensing satellites are used extensively for a variety of Earth observation functions, including weather forecasting; surveillance of borders and coastal waters; monitoring crops, fisheries, and forests; as well as monitoring natural disasters such as hurricanes, droughts, floods, volcanic eruptions, earthquakes, tsunamis, and avalanches.

The European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) has launched eight satellites into GEO since 1972 to provide meteorological data for Europeans. Similarly, the US National Oceanic and Atmospheric Administration (NOAA), founded in 1970, has launched over 34 satellites to provide US meteorological services.[142] 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.[143] In a significant shift of policy regarding weather satellites, distribution of the data collected by EUMETSAT's constellation of MetOp meteorological satellites will be restricted by security concerns. A 2006 agreement between EUMETSAT and the US NOAA will create a 'data denial list' that stipulates agencies that are restricted from accessing data from the MetOp satellites. This agreement comes as the US DOD and NOAA merge their weather satellites, giving the DOD a vested interest in any agreements made with EUMETSAT. The satellites will be under EUMETSAT control but subject to US third party restrictions.[144]

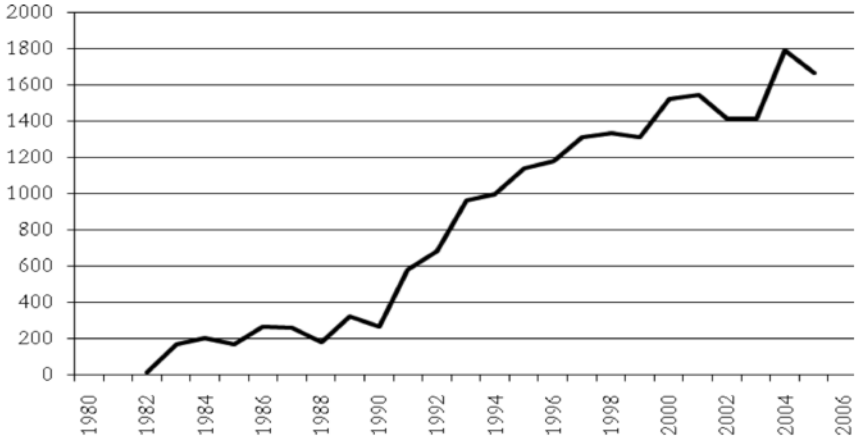
Another recent global space-based utilities initiative is the Global Earth Observation System of Systems (GEOSS), which has the goal of "establishing an international, comprehensive, coordinated and sustained Earth Observation System."[145] It is being coordinated by the Group on Earth Observation, whose members currently include 75 states and the European Commission. GEOSS will be constructed on the basis of a 10-year implementation plan from 2005-2015. Benefits will include disaster reduction, resource monitoring and management, sustainable land use and management, better development of energy resources, and adaptation to climate variability and change.[146]

Space has also become critical for measuring climate change. Several countries, including Algeria, China, Nigeria, Spain, Thailand, Turkey, the UK, and Vietnam, are collaborating on the Disaster Monitoring Constellation to deploy 10 microsatellites dedicated to this use.[147] Four are currently in operation.

Search and rescue

In 1979 COSPAS-SARSAT, the International Satellite System for Search and Rescue Satellites, was founded by Canada, France, the USSR, and the US to coordinate the satellite-based search-and-rescue system. Since 2001 SAR has provided emergency communications for people in distress and has been credited with saving the lives of approximately 1,500 people per year (see Figure 3.8).[148] This figure is double that of 1996. Currently COSPAS-SARSAT operates 12 satellites.[149]

Figure 3.8: Lives saved annually by COSPAS-SARSAT[150]



2007 Development

A difficult year for space navigation utilities

The year 2007 was marked by challenges in the establishment of space-based navigation systems in Europe and Russia. After a delay of five years, European governments have agreed to provide the necessary $5-billion to continue work on Galileo — a proposed 30-satellite space navigation system intended to provide Europe with independent capabilities. The EU planned to formally adopt the program in March 2008 and the ESA anticipated opening contracts by the end of that year.[151] EU budget ministers agreed to provide the funding entirely from the EU 2007 and 2008 budgets following the public-private partnership scheme failure.[152] By the end of 2007 only one experimental satellite, built by Surrey Satellite Technology Systems, was in orbit and the system is not set to be deployed by 2013. Galileo is highlighted as a priority in the 2007 European Space Policy.[153]

In Russia a presidential decree on the use of the global navigation satellite system GLONASS was signed, aimed at addressing the socioeconomic development needs of Russia. Accordingly, unrestricted access to civil navigation signals will be freely provided to users.[154] Demonstrating renewed investment to complete the system, three GLONASS satellites were launched at the end of 2007, bringing the current constellation to 18, of which only 14 are believed operational. According to Russian media sources, 20 GLONASS satellites are needed to provide complete coverage of Russia, and 24 for global coverage.[155] The budget for GLONASS has been increased significantly to complete the project that was initiated during the Cold War: In 2007 $380-million was allocated and in 2006 $181-million.[156] Nonetheless, fears were expressed that the system will not be completed before 2010-2011 and that ongoing problems with the ground segment may hamper its success.[157] The inadequacies of the GLONASS system are becoming more apparent. Not only is it inaccurate, providing at best positional accuracy of 10-17 meters, but it is unstable, sometimes providing no reading at all.[158] Russia and India signed an agreement to jointly use the GLONASS system, which supports both civil and military users.[159]

Demonstrating the growing importance of satellite navigation for civilian uses, US President George W. Bush announced that next-generation GPS Block III satellites will not have the Selective Availability capability to degrade the civilian signal. (The US pledged to stop intentional degradation in 2000.) 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."[160] The US launched two GPS-2RM satellites on 20 December 2007 as part of an ongoing modernization process that provides a second civilian signal in addition to two new military signals.[161] The GPS Block III upgrade, which is a response to anticipated European capabilities, will not be ready until 2013.[162] In another positive development, the US and EU agreed in July 2007 on a common GPS-Galileo civilian signal to allow for interoperability of the two systems, while also maintaining the integrity of the US military signal.[163]

China launched two navigation satellites in 2007: an experimental Beidou navigation satellite into GEO on 2 February 2007 and the first next-generation Compass satellite into MEO on 13 April 2007.[164] The Beidou system, currently composed of four satellites, is providing regional navigation data to China. The Compass system is intended to build on Beidou and gradually become a global system, with initial services available in 2008 (see Space Support for Terrestrial Military Operations Trend 5.2). The system is dual-use, providing military support as well as services for economic development, such as monitoring transportation.[165] Fears were expressed in 2007 that the Compass system could pose a threat to the success of the European Galileo system and potentially GPS if China opts to use the same signal as their encrypted codes. Chinese sources indicate that it is willing to cooperate with the other systems, but no agreements have emerged.[166]

2007 Development

Civil space applications for global monitoring focus on climate change

Europe's Global Monitoring for Environment and Security (GMES) program received a boost in 2007 with the allocation from the EU Commission to the ESA of $52.5-million, which is intended to ensure the coordination and timely supply of satellite-based remote sensing data for the initiative's preoperational phase in 2008-2010. The funding will also support initial GMES services, which include three fast-track services focusing on land, sea, and emergency; and two pilot service projects focusing on security and atmospheric composition.[167] GMES is an EU-led initiative in partnership with the ESA to combine ground- and space-based Earth observations to develop an integrated environmental and security monitoring capability. ESA and Thales Alenia Space signed a $346-million contract to design and develop Sentinel-1, the first remote sensing satellite to be built for the initiative.[168] It will weigh around 2,200 kilograms and image the Earth in swaths 250 kilometers in diameter, with a ground resolution of five meters; launch is planned for 2011.

Also in 2007 the US NOAA environmental satellite operations center was officially opened. The center provides 24-hour data for weather and climate prediction.[169] In a separate development, NOAA and NASA agreed to restore a planned climate sensor to the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project. The sensor is designed to provide climate researchers with a more precise depiction of the structure of the ozone layer. The NPOESS is a tri-agency environmental monitoring program directed by the Department of Commerce (NOAA's parent agency), the Department of Defense, and NASA. With the launch of the first spacecraft planned for 2013, NPOESS will bring improved data and imagery that will allow better weather forecasts, severe weather monitoring, and detection of climate change.[170] An internal report in 2007 to the White House about an impending crisis in the US satellite-based global climate observing system followed an earlier decision to remove the sensor.[171]

2007 Space Security Impact

On the one hand, the growth in global utilities, particularly navigation systems, should have a positive impact on space security by providing redundancy of capabilities and increasing access to space through collaborative efforts, particularly if they are interoperable. Yet ongoing disputes over the use of signals and the development of *independent* capabilities indicate that cooperation is difficult and that this utility remains an important military application subject to potential interference. The growing use of civil space capabilities for climate change monitoring could enhance international commitments to maintain space security by further linking the security of Earth to the security of space.

Figure 3.9: Civil payloads launched in 2007

COSPAR	Launch Date	Launch Vehicle	Satellite Name	Launch State	State	Primary Function	Primary Manufacturer	Orbit Type
2007-063A	12/21/07	Ariane 5GS	Rascom-QAF 1	France	Africa	Communication	Thales/ Canne	GEO
2007-001D	1/10/07	PSLV	Pehuensat-1	India	Argentina	Technology	AMSAT	SSO
2007-010A	4/11/07	Chang Zheng 2C	Hai Yang 1B	China	China	Oceanography	SISE/ Shanghai	SSO
2007-019	5/24/07	Chang Zheng 2D	Zheda Pixing	China	China	Technology	Zhejiang	SSO
2007-019A	5/25/07	Chang Zheng 2D	Yaogan 2	China	China	Remote sensing (Optical)	SAST	SSO
2007-051A	10/24/07	Chang Zheng 3A	Chang'e-1	China	China	Lunar	CAST	*
2007-042A	9/19/07	Chang Zheng 4B	Zi Yuan 1-2B	China	China, Brazil	Remote sensing (Optical)	INPE/CAST	SSO
2007-012N	4/17/07	Dnepr	Libertad	Russia	Columbia	Technology	USergioArb	SSO
2007-012A	4/17/07	Dnepr	Egyptsat 1	Russia	Egypt	Technology	Yuzhone	SSO
2007-040	9/14/07	Soyuz-U	YES-2	Russia	ESA	Technology	Delta-Utec	LEO
2007-001B	1/10/07	PSLV	Cartosat-2	India	India	Remote sensing (Optical)	ISRO	SSO
2007-001C	1/10/07	PSLV	SRE-1	India	India	Space recovery experiment	VSSC	SSO
2007-013B	4/23/07	PSLV	AAM	India	India	Experimental	VSSC/LPSC	LEO
2007-001A	1/10/07	PSLV	LAPAN-TUBsat	India	Indonesia	Remote sensing (Optical)	LAPAN/TUB	SSO
2007-013A	4/23/07	PSLV	AGILE	India	Italy	Astronomy	CGS/MILANO	LEO
2007-039A	9/14/07	H-IIA 2022	Kaguya	Japan	Japan	Lunar Orbiter	NEC Toshiba	*
2007-039B	9/14/07	H-IIA 2022	Okina	Japan	Japan	Lunar Orbiter relay	NEC	*
2007-039C	9/14/07	H-IIA 2022	Ouna	Japan	Japan	Lunar Orbiter relay	NEC	*
2007-002A	1/18/07	Soyuz-U	Progress M-59	Russia	Russia	Human	Progress	LEO
2007-008A	4/7/07	Soyuz-FG	Soyuz TMA-10	Russia	Russia	Human	Energiya	LEO

COSPAR	Launch Date	Launch Vehicle	Satellite Name	Launch State	State	Primary Function	Primary Manufacturer	Orbit Type
2007-017A	5/12/07	Soyuz-U	Progress M-60	Russia	Russia	Human	Progress	LEO
2007-033A	8/2/07	Soyuz-U	Progress M-61	Russia	Russia	Human	Progress	LEO
2007-040A	9/14/07	Soyuz-U	Foton-M No. 3	Russia	Russia	Micro-gravity	TsSKB	LEO
2007-045A	10/10/07	Soyuz-FG	Soyuz TMA-11	Russia	Russia	Human	Energiya	LEO
2007-064A	12/23/07	Soyuz-U	Progress M-62	Russia	Russia	Human	Progress	LEO
2007-012B	4/17/07	Dnepr	Saudisat 3	Russia	Saudi Arabia	Technology	Saudisat	SSO
2007-004A	2/17/07	Delta 7925-10C	THEMIS 1	US	US	Research	Swales	HEO
2007-004B	2/17/07	Delta 7925-10C	THEMIS 2	US	US	Research	Swales	HEO
2007-004C	2/17/07	Delta 7925-10C	THEMIS 3	US	US	Research	Swales	HEO
2007-004D	2/17/07	Delta 7925-10C	THEMIS 4	US	US	Research	Swales	HEO
2007-004E	2/17/07	Delta 7925-10C	THEMIS 5	US	US	Research	Swales	HEO
2007-012P	4/17/07	Dnepr	CAPE 1	Russia	US	Technology	UL-Lafayette	SSO
2007-015A	4/25/07	Pegasus XL	AIM	US	US	Scientific	OSC	SSO
2007-024A	6/8/07	Space Shuttle	Atlantis	US	US	Human	BNA/Palmdale	LEO
2007-034A	8/7/07	Delta 7925-9.5	Phoenix	US	US	Exploration	LMA/Denver	*
2007-035A	8/8/07	Space Shuttle	Endeavour (STS-118)	US	US	Human	BNA/ Palmdale	LEO
2007-043A	9/27/07	Delta 7925H	Dawn	US	US	Exploration	OSC/Dulles	*
2007-050A	10/23/07	Space Shuttle	Discovery (STS-120)	US	US	Human	BNA/ Palmdale	LEO
2007-055A	11/11/07	Chang Zheng 4C	Yaogan 3	China	China	Remote sensing (Radar)	SAST	SSO

CHAPTER FOUR

4. Commercial Space

This chapter assesses trends and developments in the commercial space sector, including the builders and users of space hardware such as rockets and satellite components, and space information technologies such as telecommunications, data relay, remote sensing, and imaging. It also examines the relationships between governments and the commercial space sector, including the government as partner and the government as regulator. Much work on civil and military programs is contracted out to the commercial sector, which today has the same capabilities as any other space actor.[1]

The commercial space sector has experienced dramatic growth over the past decade, largely related to rapidly increasing revenues associated with satellite services. These services are provided by organizations that operate satellites, as well as the ground support centers that control them, process their data, and sell that data to others. The bulk of the revenue in the satellite services sector is generated by telecommunications.[2]

The second largest contribution to the growth of the commercial space sector has been made by satellite and ground equipment manufacturing. 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 launch vehicles and launch services developed by commercial sector programs. The companies that operate launch facilities, design and manufacture vehicles intended to place payloads in space, and manufacture launch components and subsystems are examined. 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 a stabilization and increase in launch pricing.

Governments play a central role in commercial space activities as users of certain services, by supporting research and development, by subsidizing certain space industries, by underwriting insurance costs, and by adopting enabling policies and regulations. Indeed the space launch and manufacturing sectors survive largely on government funding. 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.

Several states have begun to consider commercial space as a critical infrastructure for national security. In addition, the military sector, which has been unable to meet its communication and imagery needs with its own assets, has taken advantage of commercial capacity, thereby creating a dependence on commercial systems for military applications.

Space Security Impact

The pervasive role that the commercial space sector plays in launch, communications, imagery, and manufacturing, in addition to its role of supporting government civil and military programs, means that the commercial space sector both affects and is effected by changes in space security. A healthy space industry will tend to increase commercial competition and can lead to decreasing costs for space access and use. This could have a positive impact on space security by increasing the number of actors who can access and use space or space products, thereby increasing the number of stakeholders in the maintenance of space security. Increased competition 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, building transparency and trust through international collaboration. Additionally, the development of the space industry could influence 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.

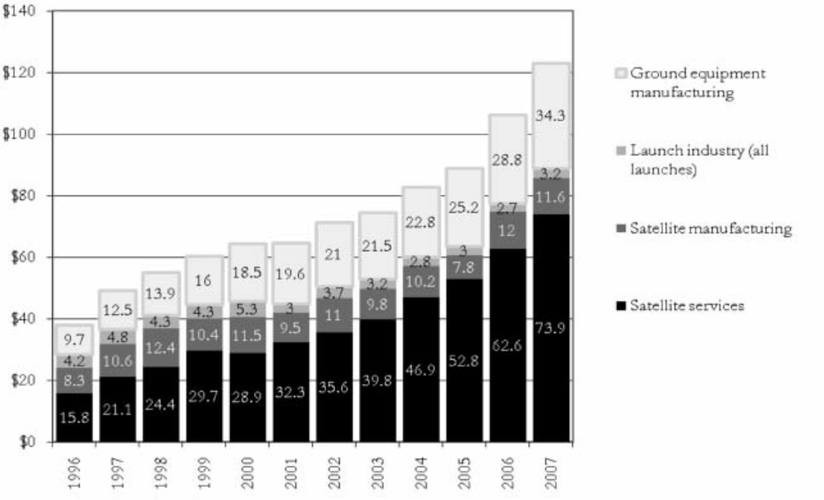
Some commercial space actors also note that issues of ownership and property pose an increasing challenge to the growth of the industry. For example, while the non-appropriation clause of the Outer Space Treaty is generally understood to prohibit states from making sovereignty claims in space, this clause also raises questions about the allocation and use of space resources. There is concern that the clause could stifle entrepreneurship and growth in the commercial space industry. As well, 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 radio frequencies. To date, national regulators and the International Telecommunication Union have been able to manage inter- and intraindustry 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 dependence of the commercial space sector on military clients or, conversely, the reliance of militaries on commercial space assets could also have an adverse impact on space security by making the industry overly dependent on one client, or by making commercial space assets the potential target of military attacks.

Trend 4.1: Continued overall growth in the global commercial space industry

The commercial space sector continues to grow, but at an uneven rate. The years 2003 and 2004 saw the slowest annual growth rates since the mid-1990s, followed by a rebound in 2005. Global space revenues have been estimated as totaling $143.31-billion in 2006 — a growth of almost 23 percent over 2005, overwhelmingly led by satellite services.[3] The satellite services sector more than tripled in size between 1996 and 2006, generating revenues estimated at between $62.6-billion and $111.14-billion in 2006, or up to 60 percent of the commercial satellite sector's total revenues (see Figure 4.1).[4]

Figure 4.1: World satellite industry revenues by sector (billion)[5]



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 the telecommunications giant AT&T.[6] Satellite industry revenues were first reported in 1978, when *US Industrial Outlook* reported 1976 Communication Satellite Corporation operating revenues of almost $154-million.[7] By 1980 it is estimated that the worldwide commercial space sector already accounted for $2.1-billion in revenues,[8] and in 2006, the sector collected revenues estimated at between $106.1-billion and $143.31-billion.[9] A significant portion of this growth can be assigned to individual users, particularly for Direct Broadcasting Services but also use of satellite navigation services and commercial satellite imaging.

A number of new companies were founded in the 1980s to take advantage of anticipated growth in the space telecommunications services sector. This sector was deregulated in many countries during the 1990s; the previously government-operated bodies International Maritime Satellite Organisation (Inmarsat) and International Telecommunications Satellite Organization (Intelsat) were privatized in 1999 and 2001 respectively.[10] PanAmSat, New Skies, GE Americom, Loral Skynet, Eutelsat, Iridium, EchoStar, and Globalstar were some of the prominent companies to emerge during the 1990s. Hughes also entered the market with DirecTV, a new satellite television broadcast system.

More recently, increased demand from individual users has driven significant growth in satellite services such as direct broadcast services. Other factors fueling sector growth include the decreasing costs of both communications equipment and launches. Current major satellite telecommunications companies include SES Global, Intelsat, Eutelsat, and Telesat Canada.[11]

The 2000 downturn in the technology and communications sectors affected the commercial space sector, reducing market take-up of satellite telephony, thus creating a related launcher overcapacity problem. Commercial satellite launches dropped from a peak of 38 in 1999 to 16 in 2001, but are beginning to recover.[12] Revenue from commercial satellite launches peaked at $5.3-billion in 2000, but has since leveled at around $3-billion annually.[13] Despite the persistent overcapacity of the space-launch market, there has been a consolidation of space launch prices since 2004[14] (see Trend 4.2). In 2006 commercial launch revenues hit their highest point since 2002 with an increase of 20 percent over 2005, reflecting the joint trends of higher demand for launches to GEO and higher launch costs. These figures are only beginning to reflect the rising costs to access space, however, as most launches in 2006 were ordered prior to price increases.[15] The commercial launch market has shifted away from the trend of low demand and high capacity, which had kept prices low. While government payloads still account for the majority of launch revenues, the proportion of commercial customers and revenues is increasing.[16] Of the 21 commercial launches in 2006, 16 went to GEO — the highest number since 2002, reflecting the growing demand for telecommunications services.[17] Moreover, revenues for commercial launches in 2006 reached their highest point since 2002, increasing 20 percent over those for 2005.

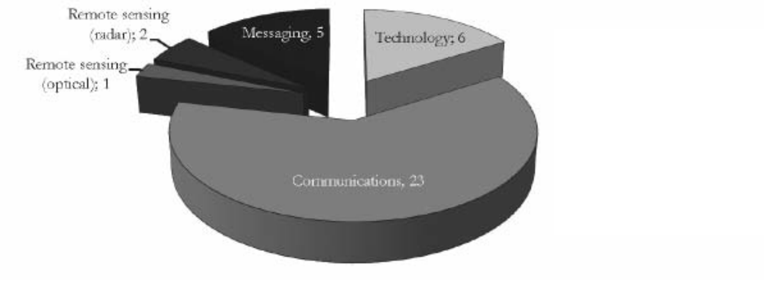
Satellite manufacturers worldwide collected an estimated $12.0-billion in 2006, close to the record high of $12.4-billion in revenue set in 1998; 2006 revenues grew by almost 54 percent over those for 2005.[18] Revenue is unevenly divided between government and commercial launches. The estimated value of government payloads was 75 percent of total revenues in 2006.[19] The five major manufacturers of commercial communications satellites are Alcatel Alenia Space, Boeing Satellite Systems, EADS Astrium, Lockheed Martin, and Space Systems/Loral. Newcomers NPO Prikladnoy Mekhaniki (Russia) and the Indian Space Research Organization (ISRO) are expected to make an impact in the future.[20]

2007 Development

Commercial space industry continues to grow, with individual users becoming more important stakeholders and new market entrants

The commercial space industry continues to rebound from a previous low with increasing revenues in the launch, services, and manufacturing sectors. The Space Foundation Index, which tracks the industry's growth based on 31 publicly traded companies, reported growth of 29 percent from June 2005 to December 2007. Although growth was only 8.4 percent in 2007, it outperformed the Standard and Poor's 500 Index.[21] Worldwide industry revenue growth is estimated at 16 percent from 2006 to 2007.[22]

Figure 4.2: Commercial spacecraft launched in 2007



Demand for commercial space transportation services, which are directly linked to activities in the global satellite market, continued to increase in 2007.[23] Of the 68 successful orbital launches in 2007, 23 were commercial launches,[24] marking the third consecutive annual increase since 2004.[25] These 23 launches carried 49 payloads, of which 27 were commercial spacecraft. Russia continued to lead the industry with 12 successful launches (Figure 4.6).[26] Revenue for commercial launches also increased modestly by $125-million to reach $1.55-billion. Although Russia dominated the industry in terms of the number of launches, Europe received the largest revenue, an estimated $840-million compared to Russia's $477-million.[27] The year 2007 was a record year for non-geostationary (GEO) launches, with 15 of 23 commercial launches executed largely to replace existing spacecraft. In contrast, since 2003 72 percent of all commercial launches have been to GEO; such launches generate the majority of revenue and are likely to continue to drive the market.

Satellite services continued to account for approximately 60 percent of total satellite industry revenues, growing by 18 percent in 2007.[28] Individual users are a significant driver of this growth, particularly through demand for satellite television, direct broadcasting, and navigation/positioning services. Satellite television and direct broadcasting posted an estimated 18 percent revenue increase in 2007; another estimate puts revenue from GPS equipment at 56.2-billion in 2007, a growth of 20 percent.[29] Satellite radio also continues to grow significantly, with profits doubling from 2005 to 2006 and increasing by another 33 percent in 2007 to $2.1-billion,[30] but as a new entrant it retains a small market share. Fixed Satellite Services and Mobile Satellite Services have grown by 20 percent and 18 percent respectively.

This steady growth of consumer services is also driving the ground equipment market, which holds the second largest share of market revenues and grew by 19 percent in 2007.[31] End-user products for services such as HD TV, satellite radio, and navigation are key drivers.

More satellite launches and a growing satellite services sector have a direct impact on the commercial manufacturing industry. Although satellite manufacturers continued to suffer from pressure to lower prices, strong demand for broadcasting, broadband, and mobile satellite services drove an increase in orders, which is projected to continue.[32] Nonetheless, revenues decreased slightly in 2007, in part due to the launching of a higher proportion of microsatellites.[33] Revenue from commercial satellites increased from 25 percent of all sales to 33 percent.

Although US industries continued to dominate the satellite manufacturing market, producing 46 of the 107 payloads launched in 2007 (43 percent), US market share declined by 10 percent from 2005.[34] Different strategies are being used to achieve growth in this industry. For example, EADS Astrium has leveraged its Skynet success into expansion beyond the UK, particularly to the US and Middle East/Saudi Arabia.[35] Thales-Alcatel, on the other hand, plans to consolidate two of its satellite product lines, radar and optical observation, into one line of products that could be used for either mission.[36] Boeing is using a multiple market approach — civil, military, and commercial — to maintain a stable business, while acknowledging that it preferred government sales to less lucrative commercial business; this position is shared by Lockheed Martin and EADS Astrium.[37]

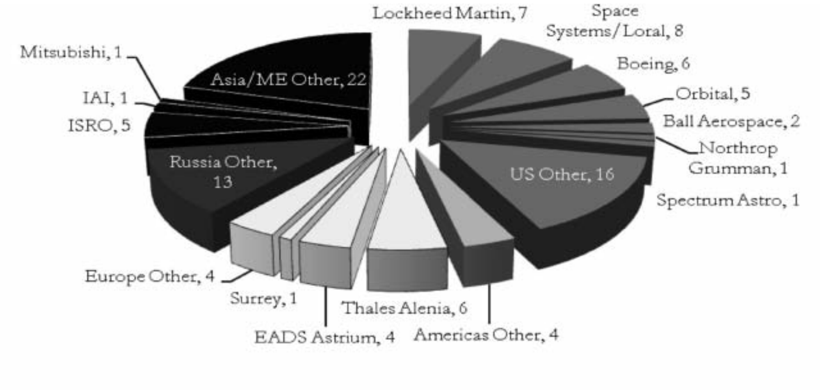
2007 Development

India and China influence the commercial space industry

India re-affirmed its entry into the commercial launch market on 23 April 2007 when the Polar Satellite Launch Vehicle (PSLV) took the Italian astronomy satellite AGILE into space. It has another contract in place to launch an Israeli classified remote sensing satellite in 2008.[38] India is reportedly positioning itself to compete for a portion of the commercial launch service market by offering low-cost launches. Although at $11-million to send a 352-kilogram spacecraft into low Earth orbit, rates do not appear to be far below similar, publicly known launch costs, it is difficult to compare costs across different launches and launchers.[39] India also intends to compete in the satellite manufacturing industry.[40] Affirming its growing importance in the space industry, an Aerospace Industries Association (AOA) survey showed that more than 86 percent of US civil and military aerospace contractors plan to sign agreements to form joint ventures or partnerships with small Indian aerospace companies in the next year, just as India is seeking new international partners for its space industry.[41] The European Space Agency has also expressed a desire to outsource to India subsystems and components for space missions to leverage cost benefits and reliable Indian research, but cannot because of constraints under current trade rules.[42] India bolstered its presence in the commercial space market with strong sales of remote sensing images to other countries. In September 2007 India claimed to have captured 20 percent of the global market.[43]

Although not commercially competed, China launched Nigeria’s Nigcomsat-1 communications satellite on a Long March 3-B rocket to geostationary orbit. This marked the first time that China had both manufactured and launched a satellite for another country[44] and signaled its reentry into the commercial launch market. Chinese officials claim that China has been “commissioned to send about 30 foreign satellites into space and signed several contracts offering commercial launching services for foreign satellites.”[45] Developing countries are the prime focus of these efforts.[46] Moreover, because it uses no US components, China is marketing its manufactured satellites as ITAR-free at prices below industry standard. This new reality spurred Arianespace to call for vigilance against Chinese dumping (see Trend 4.3).[47]

Figure 4.3: Manufacturer share of satellites launched in 2007[48]



2007 Space Security Impact

Continued growth in the commercial space sector is reflected largely by higher revenues and not necessarily an increase in space activity. However, individual users are becoming more important stakeholders in space as they demand not only more communications services, but also satellite navigation/positioning and remote sensing products. Ongoing growth of the industry suggests that there is overall confidence in the security of space and the ability of both companies and consumers to continue to rely on space resources. Growing competition in the commercial launch market may also contribute to space security by providing greater access to outer space, although tensions may arise if future demand for space resources exceeds supply.

Trend 4.2: Commercial sector supporting increased access to space

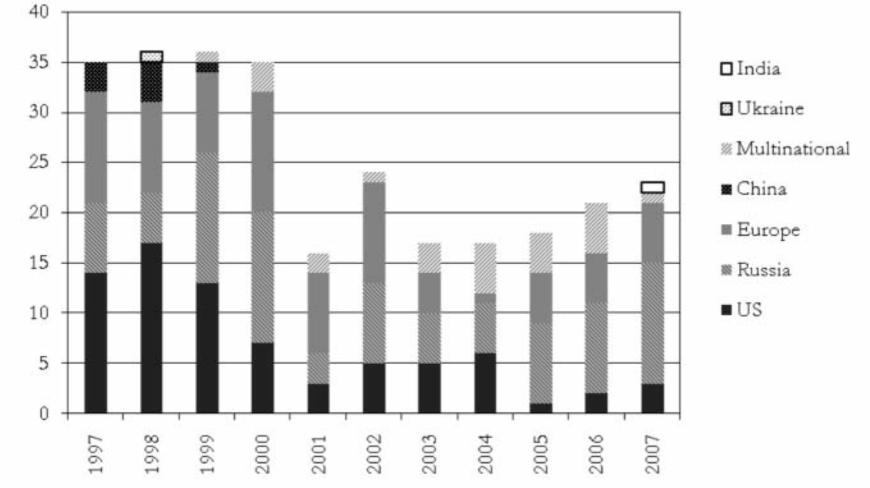
Space launches

A commercial launch is defined as one in which at least one satellite payload's launch was contracted internationally, so that, in principle, a launch opportunity was available to any capable launch services provider.[49] Russian, European, and American companies remain world leaders in the commercial launch sector, with Russia launching the most satellites, both commercial and in total in 2007.[50] 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."[51]

Commercial space access grew significantly in the 1980s. At that time, NASA viewed its 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 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] China has opened the possibility of reentering the commercial spaceflight market by 2020.[54] Today Ariane, Proton, and Zenit rockets dominate the commercial launch market.

Figure 4.4: Worldwide Commercial Orbital Launches (1997-2007)[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] 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 in May 1999.[58]

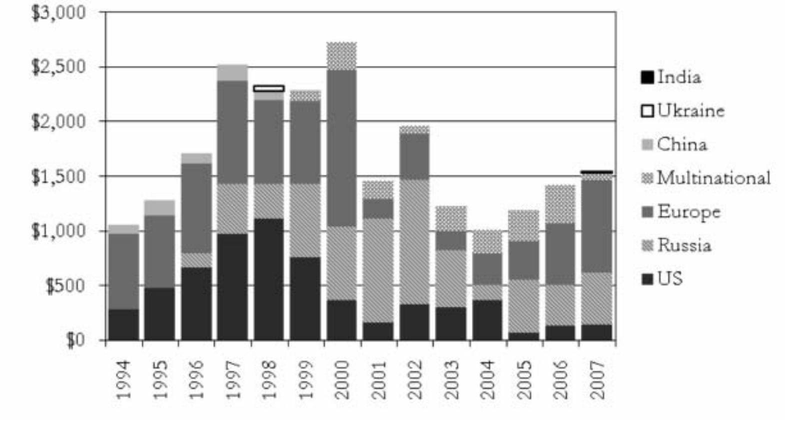
Today's top commercial launch providers include Lockheed Martin and Boeing Launch Services in the US, Arianespace in Europe, Energiya in Russia, and two international consortia — Sea Launch and International Launch Service (ILS).[59] Sea Launch, comprised of Boeing (US), Aker Kvaerner (Norway), RSC-Energiya (Russia), and SDO Yuzhnoye/PO Yuzhmash (Ukraine), launches from a sea-based platform located on the equator in the Pacific Ocean.[60] ILS was established as a partnership between Khrunichev State Research and Production Space Center (Russia), Lockheed Martin Space Systems (US), and RSC-Energiya (Russia). In 2006 Lockheed sold its share to US Space Transport Inc. New commercial launch vehicle builders such as Space Exploration Technologies (SpaceX) are seeking to compete by providing cheaper, reusable launch vehicle designs.

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 paying 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. Emerging technologies such as air-launch vehicles and hypersonic "scramjet" engines may lead to further cost reductions of space launch into LEO.[61]

Competition and the entry of non-Western launchers have supported a decrease in space access costs. Specific launch cost data indicates that the cost to launch commercial payloads into GEO declined by approximately 35 percent in the 1990s, from an average of about $40,000 per kilogram to $26,000 per kilogram in 2000. There was no clear pricing trend for commercial payloads going to LEO during this decade, but launches between 1995 and 2000 clustered around $5,000 per kilogram, with significant variances.[62] It should be noted that it is difficult to compare launch costs across payloads and launch vehicles due to the number of important differences between them and the fact that launches are negotiated project-by-project. Moreover, the price of a launch is often not made public, especially since the increase in competition after 2000.[63] Nonetheless, based on current public data it would appear that the trend in declining costs of the 1990s has ended and prices have consolidated.[64]

Greater launcher competition and stable launch costs have facilitated steady growth in the number of actors that can access space either through an independent launch capability or via the launch capability of others. Forty-seven states have now accessed space; almost all have been enabled in some way by the commercial sector. Yet despite significant decreases there has not been a notable increase in commercial space activity.[65]

Figure 4.5: Revenues for commercial space launches (million)l[66]



Commercial remote sensing 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.[67] Companies such as Surrey Satellite Technology Ltd. and SpaceDev have commercialized private research in the area of space and satellite technologies. There are currently seven companies in Canada, France, Germany, Israel, Russia, and the US 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. A growing consumer base is driving up revenues. Global commercial remote sensing revenue is estimated $1.12-billion for 2005 — an 18 percent increase over 2004 — and rose another 16 percent in 2006, with one report putting global expenditures on remote sensing products as high as $7-billion in 2006.[68] Security concerns have been raised, however, due to the potentially sensitive nature of the data (see Trend 4.3).

Commercial satellite positioning

The commercial GPS market has rapidly expanded with the introduction of new devices marketed to individual users. Handheld GPS equipment, which often integrates the GPS function into other electronics, is increasing demand for what was once a technology used primarily by government and large businesses.[69] The market for these converged devices is just starting to accelerate in the US, but has been strong in Europe and Japan for several years.[70] Sales of satellite navigation devices in Europe, the Middle East, and Africa doubled in 2006 and a significant increase in GPS-enabled Location Based Services subscribers is expected in the coming years. Consumer demand is also increasing for dedicated portable navigation devices.[71] Revenue, not included in the satellite market statistics above, is estimated at $40.7-billion for 2006 compared to $28.5-billion for 2005, as more and more consumers choose to access this space service.[72]

Commercial space transportation

An embryonic space tourism industry continues to emerge, seeking to capitalize on new concepts for advanced, reliable, reusable, and relatively affordable technologies for launch to near-space and low earth orbit. 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.[73] In 2006 the ESA announced the "Survey of European Privately-funded Vehicles for Commercial Human Spaceflight" to support the emergence of a European commercial space transportation industry.[74]

The market for commercial space transportation remains small but has attracted a great deal of interest. By 2006 four orbital space tourists had flown, all on the Russian Soyuz, and Space Adventures had taken deposits for over 100 space flights, with the cost increasing from $20-million to between $30- and $40-million.[75] In June 2004 SpaceShipOne, developed by US Scaled Composites, became the first private manned spacecraft.[76] By 2005 there were 19 suborbital launch vehicles under development, primarily for the space tourism market.[77] This market is also generating commercial investment in space infrastructure. For example, Bigelow Aerospace is building a privately owned, inflatable in-space platform.[78] While the industry continues to face challenges — including a lack of international legal safety standards, high launch costs, and export regulations[79] — important liability standards are beginning to emerge. In 2006 the FAA released final rules governing private human spaceflight requirements for crew and participants.[80] Final rules were also issued for FAA launch vehicle safety approvals.[81]

Insurance

Insurance is an important way of managing the risks associated with sustainable access to and use of space, with rates influencing both the cost of this access as well as the type of coverage pursued. Insurance rates also influence the ease with which start-up companies and new technologies can enter the market:[82] 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. Prior to 1998 the typical insurance rate for a launch plus 12 months of on-orbit coverage was about seven percent of the satellite and launch vehicle value; after that date a sharp increase in on-orbit anomalies forced rates up to 20 percent and higher.[83] In 2002 the space insurance industry paid out $830-million in claims while it collected just $490-million in premiums.[84] Eventually revenues stabilized with increasing premiums and few payouts, resulting in 2005 profits of $880-million.[85] As rates increased terms also became 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.”[86] Many companies abandoned insurance altogether. In recent years, however, there has been a softening of the launch insurance market, with rates dipping to the low teens.[87]

The market for in-orbit insurance has also been tumultuous, but operators have had more flexibility in dealing with it. Like launch insurance, rates skyrocketed in the early 2000s and terms tightened, leading many companies to discontinue insurance and instead self-insure through the production of satellite backups.[88]

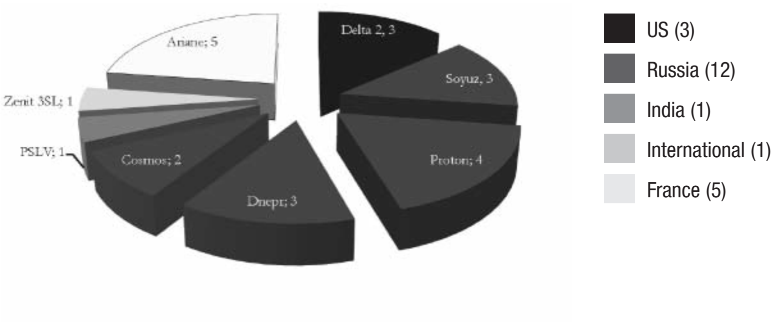
With the advent of space tourism, the space insurance industry may expand to cover human spaceflight. In the US, the FAA requires commercial human spacecraft operators to purchase third-party liability insurance, although additional coverage is optional. Each of the first two space tourists purchased policies for training, transportation, and time spent in space.[89]

2007 Development

Launch costs remain high in a tight market following failures

Following launch price increases in 2005 and 2006, prices remained high in 2007 as capacity remained tight following the 30 January 2007 explosion of Sea Launch’s Proton rocket, which damaged the launch platform and gas deflector.[90] The Sea Launch failure also delayed the introduction of Land Launch, which will use the same technology to launch from the Baikonur site in Kazakhstan; launch activity is not expected until 2009.[91] A second launch attempt of the SpaceX Falcon-1 was made on 21 March 2007, following the failure of the Falcon-1 launch attempt by SpaceX in 2006, but the second stage failed to reach its intended orbit.[92] Overall, high demand coupled with supply restrictions and rising costs for materials in 2007 raised launch prices.[93] Still, there are downward pressures on launch prices that might have an effect in the near future, including lower insurance costs and new entrants to the launch market.

Figure 4.6: Commercial space launches in 2007[94]



2007 Development

Lower insurance rates and new entrants to the launch market may reduce cost of access to space

Launch insurance affects both the cost and risk of access to space. In recent years some satellite owners had relied on self-insurance in the face of very costly insurance rates, but in 2007 many returned to more traditional risk management practices as rates declined.[95] Insurance capacity was greater than demand, allowing a 13 percent decrease in rates from the peak in 2004, while overall premiums have surpassed losses for five straight years. Premiums for launch and first year in orbit ranged from 12 to 18 percent, depending on the level of risk, with annual in-orbit rate at approximately 1.8 percent.[96] Moreover, rates for insurance seem to be gaining flexibility as the market matures. In May 2007 Intelsat secured insurance for eight of its satellites at well below going market rates, using leverage from the size of its fleet.[97] GeoEye was also able to obtain a good rate for its aging IKONOS satellite based on a new life expectancy analysis conducted by the manufacturer, Lockheed Martin.[98] New types of coverage such as third-party and product liability for private space ventures are being developed, which could lend support to small launch startups in the future; pricing is a sensitive issue that could constrain this emerging market.[99] Due to launch failures, however, insurers lost approximately $150-million in 2007, so premiums may rise in the coming year.[100]

New entrants to the space launch market may also contribute both extra capacity and competition, which may reduce the cost of space access. India and China are two such examples (see Trend 4.1), while others include Brazil and Ukraine, which entered into a partnership in 2007 to form a joint venture company to launch rockets and satellites from the Alcantara Base in the northeastern Brazilian state of Maranhao using Ukrainian launch technology. The commercial venture hopes to capture approximately 10 percent of the global market in the next eight years, marketing itself to countries with satellites, but without launch capability.[101] In the meantime, Arianespace moved to meet increased demand for launch services, entering into an agreement with Astrium to increase the production rate for Ariane-5 to seven per year beginning February 2008.[102] Arianespace also increased the mission capacity of Ariane-5, providing payload launch opportunities for MSS satellites of various sizes.[103]

In 2007 the first geostationary commercial launch contact for Falcon-9 was signed, bringing the total number of launch contracts to seven.[104] South Korea is developing a small launch vehicle, the Korea Space Launch Vehicle, which may signal Korea's entry into the commercial launch services market if it is successful.[105] Brazil may revamp its rocket launch capability. In December 2007 a Brazilian rocket commercially launched an Argentinean rocket 121 kilometers to conduct scientific experiments.[106] Brazil's first orbital launch attempt exploded in 1997. In the long term, Mitsubishi Heavy, which makes and markets Japan's H-2A heavy launcher, aims to compete in the commercial space market. Currently its launch costs, at roughly $90-million, are too high for the commercial market, but it is making efforts to bring down costs to between $60- and $70-million, in line with international rivals.[107] The H-2A conducted two successful launches in 2008. Even if new launchers do enter the market, however, untested technologies face significant challenges, including high insurance costs and a wary clientele.[108]

2007 Development

Private human suborbital spaceflight expanding, but capabilities limited

The promise of commercial human spaceflight generated continued activity in 2007. To support the emerging industry, the US Federal Aviation Administration implemented new guidelines to obtain experimental launch permits for reusable spacecraft, allowing personal spaceflight entrepreneurs multiple vehicles of a specific design and unlimited launches of the same per permit. The US projects a $1-billion- per-year market for suborbital flights by 2021.[109] Space Adventures bought two more seats on Soyuz flights to the ISS, intending to market them to space tourists — one for late 2008 and one for early 2009.[110] However, this market is subject to the same capacity constraints as the unmanned launch market: retirement of the space shuttle in 2010 means that NASA will rely on the Soyuz vehicles to deliver astronauts to the International Space Station, thus decreasing the number of seats available for commercial passengers. The cost of a ticket to the Space Station has subsequently risen from between $20- and $25-million to between $30- and $40-million.[111] This industry may soon generate excess capacity, however. The European Space Agency has shown interest in personal spaceflight, performing a study assessing the commercial suborbital market, identifying hindrances to market development, and determining ways to achieve European entry into the marketplace.[112] EADS Astrium also announced its intention to garner a piece of the suborbital market, hoping for subsidization from regional development funding.[113] Finally, in 2007 Amazon founder Jeff Bezos began advertising for engineers to join his privately funded space program. His new company, Blue Origin 9, is focusing on human space exploration and affordable spaceflights for the masses.[114]

Following the launch on 28 June 2007 of Bigelow Aerospace's second inflatable module, Genesis-2, the company has decided to fast-track the launch of its habitable Sundance module, in part due to rising launch costs.[115] It could be capable of supporting a three-person crew by 2010.[116] Bigelow projects that user crews would primarily consist of industry workers, and would not be space hotels, although some tourist use could occur.[117] It has set the price for sovereign customers (nations wanting to send their astronauts into space) at $14.95-million for four weeks in the inflatable module, with a possibility of extending the stay for $2.95-million for each additional four-week period. Private companies could lease the module for research at $88-million per year for a full module and $4.5-million per month for a half-module.[118]

2007 Development

Commercial spaceflight aims for the Moon

Google added its weight to the commercial spaceflight market in 2007: as the sponsor of the next X-Prize challenge it will provide $30-million to the first privately funded team that can soft-land a robot on the Moon, travel a minimum distance of 500 meters and transmit high-definition video and other images and data back to Earth for viewing over the Internet.[119] If the challenge is not met by 31 December 2012, however, the prize value will drop to $15-million; the final deadline for winning the prize is 31 December 2014, at which time it will be terminated unless extended by Google and the X Prize Foundation.[120] Seven teams have announced their intentions to compete for the Prize; the first official entrant is Odyssey Moon of the Isle of Man.[121] While the prospects of winning the prize remain distant, it is generating both substantial interest and substantial investments.

2007 Development

Greater commercial access to high-resolution remote sensing images

Higher resolution imaging is becoming increasingly accessible to the public market, with key developments taking place in 2007. The launch of DigitalGlobe's WorldView-1 spacecraft means that US DOD-sponsored 50-centimeter imagery will be commercially available at resolutions comparable to highly classified products. Moreover, Germany's TerraSar-X and Canada's Radarsat-2, launched in June and December 2007, are commercial radar remote sensing satellites offering high-quality resolution imaging, at one meter and three meters respectively (see Trend 4.3). India launched Cartosat II with one-meter resolution in January 2007, bringing Indian imagery in line with leading commercial services.[122]

In a separate development, Google and Spot Image entered into an agreement to improve the resolution of imagery available for Google Earth users. France's Spot Image will provide 2.5-meter resolution for extensive areas of Earth.[123] Although the data provided by Google Earth is not current, it has enhanced the general public's appetite for remote sensing.[124]

The use of commercial satellite remote sensing images by public users was demonstrated in 2007 when project "Crisis in Darfur" was launched to educate the 200 million users of Google Earth about the ongoing conflict in the region. The partnership between the US Holocaust Memorial Museum and Google Earth is being used to map the effects of the conflict, including the destruction of villages and movement of displaced persons. A similar initiative is planned to map key sites of the Holocaust.[125]

Demand for remote sensing products continues to grow, particularly as space-based data replaces aerial data; expenditures were almost $7.3-billion in 2007. Weather forecasting accounts for approximately 38 percent of the market — five times the market share of intelligence gathering.[126]

Figure 4.7: 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-1	Optical	10,000
		OrbView-2	Optical	1,000
		OrbView-3	Optical	1
		OrbView-4	Optical	1
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	AlSAT-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

Space security impact

Sustained competition in commercial space launch may slightly reduce the cost of access to space in the near future, but in the absence of revolutionized technologies, there is not likely to be a significant impact on space access. Although the commercial human space flight industry continues to develop, it has yet to deliver sustainable, low-cost launchers. Moreover, while some regulatory efforts are being made to support the prospect of private human access to space, such access may cause challenges to space security, both in terms of the sustainability of the space environment as well as the applicability of international laws, such as the Outer Space Treaty. Finally, while the space industry is facilitating greater use of space applications, in particular remote sensing, there are legitimate fears about the implications for security on Earth (see Trend 4.3 below).

Trend 4.3: Governments both support and regulate the commercial space sector as subsidies and national security concerns continue to play an important role

As national security concerns continue to play an important role in the commercial space industry, governments play the role of both partner and regulator. On the one hand, governments have played an integral role in the development of the commercial space sector. Most spacefaring states consider their space systems an extension of national critical infrastructure, and a growing number view their space systems as critical to national security. Full state ownership of space systems has now given way to a mixed system in which many larger commercial space actors receive significant government contracts and a variety of government subsidies. Certain commercial space sectors, such as remote sensing or commercial launch industries, rely more heavily on government customers, while the satellite communications industry is commercially sustainable even 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.

The US Space Launch Cost Reduction Act of 1998 established a low-interest loan program for qualifying private companies to support the development of reusable vehicles.[127] In 2002 the US Air Force requested $1-billion in subsidies from Congress for the period 2004-2009 for Lockheed Martin's Atlas V and Boeing's Delta 4 development as part of the Evolved Expendable Launch Vehicle (EELV) program.[128] 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 until the end of the decade.[129] The Air Force accordingly announced that it will divide its planned 23 EELV missions between the two companies rather than force price-driven competition.[130] In 2006 these two launchers were merged into a single company, the United Launch Alliance. A report commissioned by the FAA indicates that the success of the US commercial launch industry is viewed as "beneficial to national interests."[131]

Government involvement in commercial activities extends beyond the launch market, however; the 2003 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 US remote sensing industry."[132]

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.[133] 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.[134] It also supports a continued relationship with Russia to launch the Soyuz from the Kourou launch site in French Guiana.

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.[135] The Russian space program receives subsidies from the US in the form of contracts for the International Space Station (ISS). The vulnerability of the Russian commercial space sector was demonstrated in 2002, when Russia's financial struggles and inability to fully meet its subsidy commitments forced the Russian space launch company Energiya to default on loan payments. According to Russian media, the Russian space industry was to receive only $38-million in subsidies in 2003, not enough to cover existing debts or ISS commitments.[136]

China's space industry also has a close relationship with its government. The 2006 Chinese White Paper on Space Activities identifies the development of an independent space industry as a key component to its goals for outer space.[137]

Commercial satellite positioning

Initially intended for military use, satellite navigation has emerged as a key civilian utility with a strong commercial market. 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.[138] 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.[139] China's regional Beidou system may also be available for commercial use by 2008.[140]

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.[141] The crux 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.[142] 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, making it a mainstream electronic.[143] Global GPS revenues for 2005 were estimated at $21.8-billion.[144]

Export controls

Trade restrictions aim to strike a balance between commercial development and the proliferation of sensitive technologies that could pose security threats, but 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 regime most pertinent to commercial space security considerations is the Missile Technology Control Regime (MTCR).

The MTCR was formed in 1987 by a group of 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.[145] The 34 members of the MTCR include Australia, Brazil, Canada, France, Germany, Japan, Russia, South Korea, the UK, and the US, with China formally expressing interest in becoming a member in 2003.[146] However, export practices differ among members. Although the American "Iran Nonproliferation Act" of 2000 limited the transfer of ballistic missile technology to Iran, for example, Russia is still willing to provide such technology under its Federal Law on Export Control.[147] 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.[148]

From the late 1980s to late 1990s, the US had agreements with China, Russia, and Ukraine to enable the launch of US satellites from foreign sites. 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 and Loral. 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.[149] In effect, the new legislation treated satellite sales like weapons sales, making international collaborations more heavily regulated, expensive, and time consuming.

Exports of USML items are licensed under the International Traffic in Arms Regulations (ITAR) regime, which adds several additional reporting and licensing requirements for US satellite manufacturers. A recent US Government report noted that, in total, it now takes "nine to 20 months on average to gain approval for a satellite export and notify Congress."[150] A subsequent study of the market conditions for US satellite manufacturers argued that "nearly every potential international buyer of satellites in 2002 … indicated that the US export control system is a competitive disadvantage for US manufacturers."[151] Recently European satellite firms have been developing 'ITAR free' satellites that use no US components and thus avoid all ITAR restrictions.[152]

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.[153] In 2001 the French Ministry of Defense prohibited open sales of commercial Spot Image satellite imagery of Afghanistan.[154] Indian laws require the 'scrubbing' of commercial satellite images of sensitive Indian sites.[155] Canada has recently passed Bill C-25, creating a regulatory regime that will give the Canadian government "shutter control" — the control exercised by the executive branch of government over the collection and dissemination of commercial satellite imagery of a particular region due to national security or foreign policy concerns — and priority access in response to possible future major security crises.[156] Analysts note, however, that competition among increasing numbers of commercial satellite imagery providers may eventually make shutter control prohibitively expensive.[157]

Commercial space systems as critical infrastructure

Space systems, including commercial systems, are viewed by some states as critical national infrastructure and strategic assets, but the implications are not clear. 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 2001 the US military used 700 megabytes per second of bandwidth, 75 percent of which was from commercial systems.[158]

The US DOD is the single largest customer for the satellite industry. By November 2003 it was estimated that the US military was spending more than $400-million each year on commercial satellite services.[159] This figure jumped to more than $1-billion a year for commercial broadband satellite services alone by 2006.[160] "DoD estimates that commercial satellite systems are providing over 80 percent of the satellite bandwidth supporting Operation Iraqi Freedom."[161] In response, DOD is examining ways to facilitate satellite service procurement by studying different acquisition methods.[162] This would provide a more long-term, strategic partnership between DOD and its commercial providers.

This growing dependence upon commercial services prompted a December 2003 US General Accounting Office report to recommend 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.[163] A 2004 study of the US National Security Telecommunications Advisory Committee Satellite Task Force noted the great dependence of the national security and homeland security communities on commercial space.[164]

2007 Development

Governments and militaries partner with the commercial industry for satellite imaging, communications, and launch services

In 2007 governments and militaries continued to be significant consumers of commercial satellite imaging services, with the launch of publicly funded commercial remote sensing satellites. The first of two commercial WorldView satellites being developed by DigitalGlobe, and the only commercial imaging satellite to provide up to 50-centimeter resolution, was launched on 20 September 2007. It is part of the National Geospatial-Intelligence Agency's (NGA) NextView Program to combine commercial remote sensing with much more powerful optics, partly funded by the Pentagon.[165] NGA contributed $500-million to secure imagery for specific DOD high resolution needs.[166]

Canada's Radarsat-2 was launched on 14 December 2007. In a public-private partnership, the Government of Canada, primarily through the Canadian Space Agency, pre-purchased $445 million in data from Radarsat-2. The satellite's three-meter, all-weather, all-day, all-terrain satellite images will also be available for commercial sale in accordance with the terms of Canada's Remote Sensing Space Systems Act, administered by the Department of Foreign Affairs and International Trade.[167] Similarly, Germany's TerrSar-X, launched on 15 June 2007, is the result of a partnership between the German Ministry of Education and Science, the German Aerospace Center (DLR), and the Astrium GmbH.[168] It provides up to one-meter images for scientific research and applications and to the remote sensing market.[169] Finally, DigitalGlobe and GeoEye partnered with the US Geological Survey to support the many space and satellite agencies that form the International Charter "Space and Major Disasters."[170]

Remote sensing is not the only instance of such partnering. The Skynet-5 secure military communications satellite launched on 11 March 2007 is operated by Paradigm Secure Communications, a subsidiary of Astrium.[171] The UK has priority of use, with excess capacity available for sale to NATO and other UK allies. The US DOD partnered with Intelsat Ltd. and Cisco Systems Inc. in 2007 to initiate a technology development program that could eventually facilitate high-speed Internet access to mobile military units.[172] The initial technology development cost will be borne by Cisco and Intelsat, in the hope that the military will make long-term commitments to support future technologies and new acquisition procedures. The application will be added to an Intelsat satellite already under construction and is scheduled to be launched during the summer of 2009.

The US military has publicly recognized the importance of the commercial sector to meet capacity shortfalls.[173] The US National Security Space Office (NSSO) intends to upgrade the Transformational Communications Architecture (TCA), which serves the Department of Defense, intelligence community, and NASA; the new version will expand the potential role for COMSATCOM and leverage emerging commercial satellite capabilities. "Commercial satellites meet 80 percent of the needs of troops in Afghanistan and Iraq, four times as much as during Operation Desert Storm 16 years ago."[174] It is estimated that the US DOD is spending $1-billion a year on commercial satellite communications.[175] Former head of the NSSO Joe Rouge indicated that the US military will move forward on efforts to create long-term partnerships with industry.[176]

A key example of an attempt to shift the dynamic between commercial space and government space is NASA's $500-million Commercial Orbital Transportation Services (COTS) program. It is designed to spur private development of commercial spacecraft that can service the International Space Station when the Space Shuttle is retired in 2010, but is struggling.[177] The original program provided funding agreements to SpaceX and Rocketplane Kistler.[178] Although SpaceX remains on track,[179] Rocketplane Kistler was dropped from COTS in 2007 for failing to meet financial milestones; NASA then entered into agreements with SpaceDev, SPACEHAB, Constellation Services International, PlanetSpace, and t/Space.[180] NASA also plans to provide half of its space on the ISS as an incentive to participate in the COTS program,[181] and is shopping for commercial and military users of the Ares launch vehicles. NASA stated that "turning the taxpayer-funded launch vehicles over to other U.S. users would be an appropriate way for the U.S. government to support the commercial sector."[182] It is not clear if this strategy will be successful.

2007 Development

Galileo demonstrates the limits to public-private partnerships

The success of public-private partnerships in the commercial space imaging and communications sectors contrasts sharply with the experience of the Galileo project in Europe. After a delay of five years, due largely to bureaucratic obstacles and the failure of a public-private consortium, European governments agreed in December 2007 to provide the necessary $5-billion to continue work on Galileo — a planned 30-satellite space navigation system intended to provide Europe with capabilities independent from the US GPS. The European Commission abandoned the original plan for substantial participation by the private sector after interests of member countries on behalf of their national industries created a stalemate.[183] This was the first attempt at a global navigation system funded by a public-private partnership. Unlike other successful examples, it placed a significant risk and cost burden on the public sector for investment in a public utility that would only see long-term returns and would have to compete with existing freely available government systems.

2007 Development

Ongoing efforts to regulate access to commercial satellite imagery

Controversy surrounding the potential use of Google Earth images by terrorists in Iraq in 2007 sheds light on the ongoing struggle between access to commercial space services and security needs.[184] Although commercial services such as Google Earth are composed of unclassified photos many states have raised concerns and it is now routine for many commercial images to be blocked. Google replaced the images of Iraq with prewar data following complaints by the British government, and was asked by the Indian government to blur what it referred to as strategic locations in India. Similar policies exist in many other countries including Australia, Russia, South Korea, Thailand,[185] and Israel. In 2007, as commercial providers launched new, improved capabilities, the Director of the National Geospacial-Intelligence Agency acknowledged that controls on distribution might need to be put in place.[186] There is "little if any directly applicable international law" governing the controversy.[187] Images of China's new Jin-class submarine also appeared on Google Earth in July 2007.[188]

Germany has addressed the issue with its Satellite Data Security Act, which entered into force on 1 December 2007. The purpose of the law "is to provide a clearly defined and transparent procedure for the dissemination of RS [remote sensing]-data" and covers first-time marketing/dissemination of data, German satellites and satellites operated by German citizens, and high-grade remote sensing satellites, but excludes governmental satellites operated by either military or intelligence agencies.[189] Similarly, Canada's Radarsat-2 is the first commercial remote sensing satellite to be licensed under its new Remote Sensing Space Systems Act, which allows the government to regulate distribution of data and exercise shutter control to address issues of national or international security.[190]

In related developments, litigation was initiated between ImageSat International's (ISI) minor shareholders and current management based on claims of lost opportunities and company devaluaation through management decisions to bow to Israeli pressure and refuse to sell satellite imaging services to Venezuela.[191] Venezuela was able to obtain data from China, which is to be used in commercial and military applications, as well as satellite and launch facilities.[192] Similarly, Israel's Ministry of Defense sought agreement from the US government for China to participate as a Satellite Operating Partner with ISI, allowing it to select targets and stream images directly into Chinese ground stations. The US agreed, but not without several restrictions, which may disrupt the deal.[193] The issue of distribution of commercial satellite imagery is likely to intensify as technologies improve and capabilities proliferate.

2007 Development

Private industry joins government in space safety efforts

Few rules govern security and safety in outer space, but following the Chinese intercept of one of its own satellites on 11 January 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.[194] The importance of the private sector in space safety and governance issues has also been highlighted by the US government. Under a program called Neighborhood Watch, the US DOD is attempting to align government and industry resources to address growing space security challenges and to increase space situational awareness.[195] The program is intended to enhance safety and reduce risk and contribute to the sustainable use of key orbits.[196]

2007 Development

Export controls try to balance commercial interests with security concerns

US export controls remained a concern in the commercial space industry in 2007 and were an issue in the Aerospace Industries Association Election for 2008.[197] To facilitate reform, US industry groups formed a coalition to lobby administration officials to relax their interpretation of the export regulations and reduce the license applications backlog.[198] The effect of controls on industry is difficult to ascertain. While Boeing's chairman went on record stating that the company had become more efficient at working the ITAR process[199] — implying that they are not necessarily impeding sector growth — the impact on smaller businesses or start-ups with fewer resources to devote to the process may be different. In 2007 the US and the UK signed a treaty to ease ITAR restrictions after ITAR waiver discussions were aborted.[200] The same preferred status was given to Australia in a similar agreement.[201] Canada and the US also took a step to ease ITAR, beginning with access to defense articles and services for Canadian citizens with appropriate security clearance.[202]

Export controls were an issue in Europe as well in 2007; the European Commission unveiled its new European Space Policy to address the need for an appropriate legal and managerial framework and define security-related requirements.[203] The task is daunting as the many member states in the EU have their own separate national interests.[204]

An FBI investigation of India's Defense Research and Development Organization led to the arrest of at least five Indian nationals in 2007, creating tension between the countries. They were charged with acquiring and exporting US dual-use technologies, including computer chips for India's missile, space, and Light Combat Aircraft programs, without proper licenses from the Department of Commerce.[205] A Russian court convicted the Russian head of a Chinese rocket and space technology company in 2007 on similar charges of leaking sensitive technology.[206] Policy changes to a Commerce regulation in 2007 made it more difficult, but not impossible, for China to purchase high-tech items from the US; however, it only catches items not on ITAR or the normal Commerce Control List of export controls for China.[207]

Industries are maneuvering around ITAR restrictions by purchasing ITAR-free satellites and launch services, which do not use US components. 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.[208] Arianespace denounced Thales for flouting ITAR, despite its contracts to launch multiple spacecraft for Globalstar and an option for as many more.[209] Arianespace also cautioned the US against possible Chinese "dumping."[210]

Space security impact

The strong relationship between military and commercial uses of space and the security dimensions of many commercial services has a complex impact on space security. On the one hand, multiple-use spacecraft could become military targets in the future, resulting in an overall decrease in security. Alternatively, the proliferation of dual-use assets in space could make a military attack less useful and, therefore, less likely. Arguably, this could increase overall space security. There are also pros and cons for government users of commercial systems, including greater flexibility and options for using space, but fewer security features to protect this use. The failure of the Galileo partnership, however, demonstrates that the costs and risks of space access and use remain high, and governments must play a key role in ensuring that access. Efforts to regulate access to both commercial space technology and data in 2007 reflected ongoing attempts to balance the benefits of secure access to and use of space against the potential threats it may pose to space security. This balance was better addressed regarding access to commercial imagery in 2007, but striking a balance between these two components of space security will become more complicated if commercial capabilities continue to increase. Finally, the growing interest in the commercial space industry to advance and participate in space governance initiatives is a positive development for space security, since all actors share the same interest in the secure and sustainable access to space.

Figure 4.8: Commercial payloads launched in 2007

COSPAR	Launch Date	Launch Vehicle	Satellite Name	Launch State	State	Primary Function	Primary Manufacturer	Orbit Type
2007-012F	4/17/07	Dnepr	Aerocube 2	Russia	Aerospace Corporation	Technology	Aerospace	SSO
2007-020A	5/29/07	Soyuz-FG	Globalstar M065	Russia	American Globalstar	Communication	Loral	LEO
2007-020C	5/29/07	Soyuz-FG	Globalstar M069	Russia	American Globalstar	Communication	Loral	LEO
2007-020D	5/29/07	Soyuz-FG	Globalstar M072	Russia	American Globalstar	Communication	Loral	LEO
2007-020F	5/29/07	Soyuz-FG	Globalstar M071	Russia	American Globalstar	Communication	Loral	LEO
2007-028A	6/28/07	Dnepr	Genesis-2	Russia	Bigelow Aerospace	Technology	Bigelow	LEO
2007-036B	8/17/07	Ariane 5ECA	BSAT-3A	France	B-SAT	Communication	LM/Newtown	GEO
2007-012M	4/17/07	Dnepr	CalPoly CP3	Russia	CalPoly	Technology	Cal Poly	SSO
2007-012Q	4/17/07	Dnepr	CalPoly CP4	Russia	CalPoly	Technology	Cal Poly	SSO
2007-021A	5/31/07	Chang Zheng 3A	Xinnuo 3	China	China	Communication	CAST	GEO
2007-031A	4/5/07	Chang Zheng 3B	Zhongxing 6B	China	China	Communication	Thales/Canne	HEO
2007-041A	9/18/07	Delta 7920-10C	WorldView-1	US	DigitalGlobe	Remote sensing (optical)	Ball	SSO
2007-032A	7/7/07	Proton-M/Briz-M	DirecTV 10	Russia	DireccTV	Communication	Boeing/ES	GEO
2007-036A	8/17/07	Ariane 5ECA	Spaceway 3	France	Huges Network System	Communication	Boeing/HB	GEO
2007-007A	3/11/07	Ariane 5ECA	Insat 4B	France	Insat	Communication	ISRO/ISAC	GEO
2007-037A	9/2/07	GSLV	INSAT 4CR	India	Insat	Communication	ISRO/IISAC	GEO
2007-016B	5/4/07	Ariane 5ECA	Galaxy 17	France	Intelsat	Communication	Thales/Canne	GEO
2007-044B	10/5/07	Ariane 5GS	Intelsat IS-11	France	Intelsat	Communication	Orbital	GEO
2007-063D	12/21/07	Ariane 5GS	Horizons 2	France	Intelsat and Jsat	Communication	Orbital	GEO
2007-057A	10/17/07	Proton-M/Briz-M	Sirius 4	Russia	NSAB	Communication	LMCSS	GEO
2007-044A	10/5/07	Ariane 5GS	Optus D2	France	Optus Networks	Communication	Orbital	GEO

COSPAR	Launch Date	Launch Vehicle	Satellite Name	Launch State	State	Primary Function	Primary Manufacturer	Orbit Type
2007-012C	4/17/07	Dnepr	SaudiComsat-7	Russia	Saudi Arabia	Messaging	Saudisat	SSO
2007-012E	4/17/07	Dnepr	SaudiComsat-6	Russia	Saudi Arabia	Messaging	Saudisat	SSO
2007-012H	4/17/07	Dnepr	SaudiComsat-5	Russia	Saudi Arabia	Messaging	Saudisat	SSO
2007-012J	4/17/07	Dnepr	SaudiComsat-3	Russia	Saudi Arabia	Messaging	Saudisat	SSO
2007-012L	4/17/07	Dnepr	SaudiComsat-4	Russia	Saudi Arabia	Messaging	Saudisat	SSO
2007-016A	5/4/07	Ariane 5ECA	Astra 1L	France	SES Astra	Communication	LM/Sunnyvale	GEO
2007-056A	11/14/07	Ariane 5ECA	Star One C1	France	Star One	Communication	Thales/Canne	GEO
2007-009A	4/9/07	Proton-M/Briz-M	Anik F3	Russian	Telesat	Communication	Astrium	GEO
2007-012K	4/17/07	Dnepr	MAST	Russia	Tethers Unlimited Ink	Technology	TUI	SSO
2007-012R	4/17/07	Dnepr	CSTB 1	Russia	UK	Technology	Boeing	SSO
2007-048A	10/20/07	Soyuz-FG	Globalstar M067	Russia	Globalstar	Communication	Loral	LEO
2007-048B	10/20/07	Soyuz-FG	Globalstar M070	Russia	Globalstar	Communication	Loral	LEO
2007-048C	10/20/07	Soyuz-FG	Globalstar M066	Russia	Globalstar	Communication	Loral	LEO
2007-048D	10/20/07	Soyuz-FG	Globalstar M068	Russia	Globalstar	Communication	Loral	LEO
2007-061A	12/14/07	Soyuz-FG	Radarsat-2	Russia	Canada	Remote sensing (radar)	MDA	LEO
2007-026A	6/15/07	Dnepr	TerraSar-X	Russia	Germany	Remote sensing (radar)	EADS	LEO

5. Space Support for Terrestrial Military Operations

This chapter assesses trends and developments in the research, development, testing, and deployment of space systems that are used to support terrestrial military operations. This includes warning; communications; intelligence, surveillance, and reconnaissance (ISR); meteorology; as well as navigation and weapons guidance applications.

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 Lyndon Johnson to realize that fears of a missile gap between the US and the Soviet Union were greatly overstated. The space age opened new chapters 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 USSR 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.

At present the US leads in the deployment of space systems to support military operations, accounting for over half of all military satellites. Russia maintains the second largest number of military satellites. Together, these two actors dwarf the military space capabilities of all other states, although this situation is changing.

This chapter identifies the development of the military space capabilities of the US and Russia as a distinct space security trend. It also examines the efforts of a growing number of other states that have begun to develop national space systems to support military operations and their rapidly expanding capabilities, primarily in the areas of surveillance and communications. It does not examine military programs pertaining to space systems protection or negation, or space-based strike capabilities, which are described in their respective chapters.

Space Security Impact

Over half of all space systems to date have been developed to support terrestrial military operations, making the military space sector an important driver behind the advancement of capabilities to access and use space. In addition to encouraging an increasing number of actors to access space, military space has played a key role in bringing down the cost of space access, and many of today's common space applications 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 field, where they are associated with national security.

Space assets play an important strategic and, increasingly, tactical 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 driven an increasing dependence on space, particularly by the major spacefaring states.

An increasing number of state actors are integrating space capabilities and space-derived information into their day-to-day military planning. This can have a positive effect on space security by increasing the collective vested interest in space security through mutual vulnerability. The use of space to support terrestrial military operations can also have a negative impact on space security if potential 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.

Because the space systems that support military operations are seen as vulnerable, actors acquire greater incentives to protect them by developing space system protection and negation capabilities, which may lead to an arms escalation dynamic. Concern has been expressed that extensive use of space in support of terrestrial military operations blurs the notion of “peaceful purposes” as enshrined in the Outer Space Treaty, but state practice over the past 40 years has generally accepted these applications as peaceful insofar as they are not aggressive in space (see Space Laws, Policies, and Doctrines Trend 2.1). Space has been militarized since the first satellite, Sputnik, was placed into orbit. Of concern here is not whether militaries should use space, but rather how the use of space by militaries improves or degrades the security of space.

Trend 5.1: US and Russia continue to lead in deploying military space systems

During the Cold War, the US and USSR developed military space capabilities 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.

Despite this decrease in the number of dedicated military satellites, American 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 5.1 and 5.2 provide an overview of US and Russian military satellites.

United States

The US has dominated the military space arena since the end of the Cold War. The US currently outspends all other states combined on military space applications, allocating over $25-billion to military space expenditures in FY2007.[1] At the end of 2007, the US had approximately 136 operational dedicated military satellites, representing over half of all military satellites in orbit (see Annex Two).[2] It continues to place heavy emphasis on upgrading all aspects of its military space capabilities and by all indications is the actor most dependent on its space capabilities. By comparison, it is roughly estimated that Russia presently operates some 67 dedicated military satellites in orbit.[3] Nonetheless, the US is currently faced with significant challenges in attempts to modernize and upgrade almost all of its major military space systems, which have been marked with cost overruns and deployment delays.[4]

SATCOM

The US military relies heavily on satellite communications for a range of critical capabilities; they have been described as "the single most important military space capability."[5] 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). There is a plan to begin replacing Milstar satellites with four or five Advanced Extremely High Frequency (AEHF) satellites in 2008, which are designed to provide secure strategic and tactical command and control communications worldwide as part of a cooperative program with Canada, the UK, and the Netherlands.[6] The US hopes to deploy the next-generation Transformation Satellite Communications System (TSAT) to provide protected, high-speed internet-like information availability to the military, including laser communications in a second stage.[7] Development has been disrupted by budget constraints and technical challenges, however, causing the launch of the first reduced-capacity satellite to be rescheduled from 2009 to 2016.[8]

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 Advanced Wideband System (AWS), is expected to increase available bandwidth significantly.[9] The Global Broadcast System and Ultra High Frequency (UHF) follow-on satellites provide wideband and secure, anti-jam communications, respectively. The Wideband Global SATCOM (WGS) is intended to bridge the transition between retirement of the DSCS and full deployment of the AWS constellations. Currently, however, it is three years behind schedule.[10]

The US military also maintains a polar military satellite communications system to ensure communications in those regions. In addition to these dedicated systems, space-based military communications use commercial operators such as Globalstar, Iridium, Intelsat, Inmarsat, and Telstar.[11] Increased use of unmanned aerial vehicles (UAV) is straining both military and commercial capacity in places such as the Middle East and secure, high-speed, high-volume data transmission is critical to meet current and future demand.[12] The cost of commercial broadband satellite service is estimated at $1-billion a year. The US DOD will likely remain dependent on these services in the future, even with the deployment of new systems.

Earth Observation/Early Warning/Intelligence

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 (MiDAS), began to be deployed in a polar orbit in 1960. The current US Defense Support Program (DSP) early warning satellites were first deployed in the early 1970s in GEO, providing enhanced coverage of the USSR while reducing the number of necessary satellites to four.[13] 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.[14] However, SBIRS is behind schedule and significantly over budget, with a final estimated cost five times the original estimate, up to $10-billion.[15] The anticipated US Space Tracking and Surveillance System (STSS) is intended to work with SBIRS to support missile defense responses (see Space Systems Protection Trend 6.1 and Space Systems Negation Trend 7.2).

The first US optical reconnaissance Corona satellites were launched as early as 1959, with the Soviets following suit by 1962.[16] 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.[17] Gradually, resolution of these cameras was improved from about 10 meters to less than a meter. While the exact resolution of today's remote sensing satellites remains classified, the US is generally thought to have optical satellites with resolutions as precise as 10 centimeters.[18] 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. The Improved Crystal satellites have a resolution of up to 6 inches.[20] The US operates between 18 and 27 signals intelligence (SIGINT) satellites in four separate systems — the Naval Ocean Surveillance System, Trumpet, Mentor, and Vortex.[21]

The Future Imagery Architecture (FIA) is intended to provide next-generation reconnaisance capabilities through electro-optical and radar remote sensing. Following a five-year delay and cost increase from $6-billion to $18-billion,[22] it was put under review in 2006 and the DOD is considering the purchase of an interim capability in response to ongoing delays.[23]

The US military also uses commercial imagery services from DigitalGlobe and GeoEye (see Commercial Space). For example, Landsat is a dual-use remote sensing imaging satellite used by the US military for tactical planning. The Defense Meteorological Satellite Program provides environmental data in support of military operations. There are several dual-use civilian-military meteorology spacecraft, including the Geostationary Operational Environmental Satellite and the Polar-orbiting Operational Environmental Satellite.[24]

Navigation

In 1964 the first navigation system was deployed for military applications by the US Navy, and its position resolution was accurate to greater than 100 meters. This system and others that followed were ultimately replaced by the GPS, which was declared operational in 1993 and uses a minimum constellation of 24 satellites orbiting at an altitude of about 20,000 kilometers. On the battlefield GPS is used at all levels, from navigation of terrestrial equipment and individual soldiers to target identification and precision weapons guidance. GPS is also an important civil and commercial service (see Civil Space Programs and Global Utilities Trend 3.4).

Figure 5.1: Characteristics of key US dedicated military space systems[25]

Current programs	Function	Orbit	Constellation	Notes on potential follow-on systems
Defense Satellite Communications System III	Communications	GEO	9	Wideband Global SATCOM (2007); Advanced Wideband System (2009)
Military Satellite Communication System (Milstar)	Communications	GEO	5	Advanced Extremely High Frequency (2008); Transformational Satellite Communications System (TSAT) (2016)
Interim Polar Satellite Program	Communications	GEO	2	Enhanced Polar System (2014)
UHF Follow-on Satellite	Communications	GEO	9	Mobile User Objective System (MUOS) (2010)
Satellite Data System	Communications	GEO	4	
Defense Meteorological Satellite Program	Weather	LEO	5	
Global Positioning System	Navigation	MEO	31	
Defense Support Program	Early Warning	GEO	7	Space Based Infrared System (2009); Space Tracking and Surveillance System (2007)
N/A	Tactical Warning			Space Radar (2016)
Crystal	Remote sensing	LEO	4	
Lacrosse	Remote sensing	LEO	4	
Misty	Remote sensing	LEO	1	Program cancelled (2007)
Naval Ocean Surveillance System (NOSS)	SIGINT	LEO	17	
Mentor (Advanced Orion)	SIGINT	GEO	4	
Vortex (Mercury)	SIGINT	GEO	2	
Trumpet (SB-WASS)	SIGINT	HEO	3	

Launch

Since 2003 the US Air Force (USAF) has promoted Operationally Responsive Spacelift (ORS), which is a long-term program with 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. This could be made possible by new launch capabilities, combined with miniaturization technologies that have dramatically increased the "capability per kilogram on orbit" equation for satellites, and by having ground satellite spares ready to be launched.[26] It could allow the US to replace satellites on short notice[27] allowing the US to rapidly recover from space negation attacks and reducing general space system vulnerabilities. ORS would also allow deployments of space systems designed to meet the needs of specific military operations. For example, the US TacSat microsatellite series are intended for ORS demonstration, combining 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.”[28] The satellites are controlled directly by deployed US commanders.[29]

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 launch capabilities that could be used for both commercial and government purposes.[30] To meet future government requirements, both the Lockheed Martin Corporation and the Boeing Company are pursuing a Heavy Lift launch capability in a joint venture, the United Launch Alliance (see Commercial Space Trend 4.2). In 2004 Boeing tested the Delta-4 Heavy, which, despite some difficulties, is expected to provide lift capacity for 13,130 kilograms into GEO.[31] Lockheed’s Atlas-5 Heavy is described as “available 30 months from order,” but there are no specific launch plans.[32] As of November 2007 there were 19 successful EELV launches.[33]

The growing dependence of the US upon space systems to support military operations has raised concerns about the vulnerability of these assets. As early as 2001 the *Report of the Commission to Assess United States National Security Space Management and Organization* warned that US dependence on space systems made it uniquely vulnerable to a “space Pearl Harbor” and recommended that the US develop enhanced space control capabilities (see Space Systems Protection and Space Systems Negation).[34]

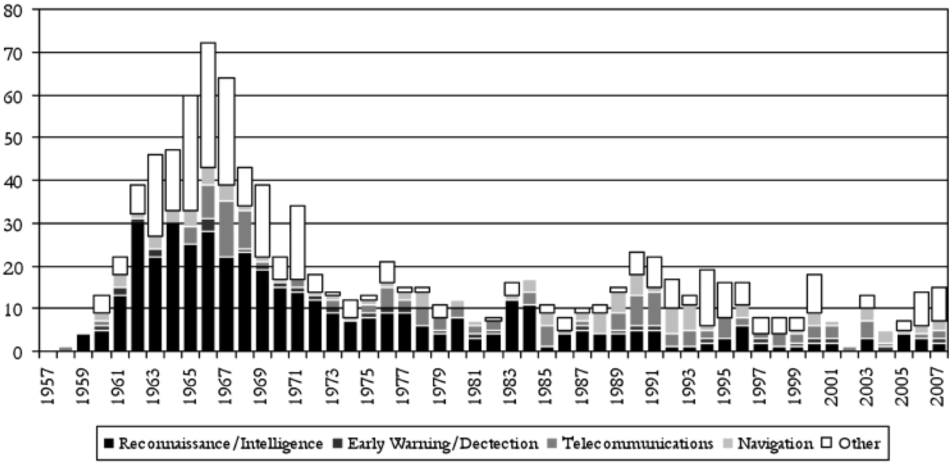


Figure 5.2: US military space launches (1957-2007)[35]

Russia

Russia maintains the second largest fleet of military satellites, but their capabilities remain focused primarily on providing strategic support. Its current early warning, optical reconnaissance, communications, navigation, and SIGINT systems were developed during the Cold War, and between 70 and 80 percent of Russian spacecraft have now exceeded their designed lifespan.[36] Some of Russia’s more critical systems have, however, been maintained and are currently being upgraded. In 2006, the first year of a 10-year federal space program, Russia increased its military space budget by as much as one-third over that for 2005, following a decade of severe budget cutbacks.[37] 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.

SATCOM

Russia maintains several communications systems, most of which are dual-use. The Raduga constellation of three satellites, promoted as a general purpose system, is reported to have secure military communications channels.[38] The Geizer system is designed to deploy four GEO satellites as a communications relay system for Russian remote sensing and communications satellites in Low Earth Orbit (LEO), but currently has only one operational satellite in orbit.[39] The Strela-3 military communications system was deployed in the late 1980s and more recently has been paired with commercial Gonets satellites in the same LEO orbits, potentially augmenting the military satellite system.[40] There are indications that maintenance of the Strela and Raduga systems will remain a priority for Russia.[41] Molniya-1 and -3 satellites are in Highly Elliptical Orbits (HEO) and serve as relay satellites for both military and civilian use. They are being replaced by the Meridian satellite system over the course of the next few years.[42]

Earth Observation/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.[43] By the end of the 1990s this system had been replaced by two satellites in HEO and one in GEO, which provide less reliable coverage of US ballistic missile fields, especially since one ceased to operate.[44] In 1991 Russia began launching US-KMO, a next-generation early warning satellite system, using a mixture of GEO and HEO satellites. While six satellites were in orbit by April 2003, the US-KMO system has been plagued with malfunctions and only one of these satellites is operational today.[45] A new system is being planned for 2009.[46] Plans have also been announced to restore the space-based component of its missile attack warning system (MAWS), for which funding has been increased.[47]

The USSR began using optical reconnaissance satellites in 1962 and by the 1980s it was electronically transmitting images while still maintaining a film-based system of photoreconnaissance.[48] Russia's optical remote sensing capabilities have declined since the Cold War. The three Russian photo electronic reconnaissance systems used today are the Kobalt, Arkon, and Orlets/Don systems, which in 2006, 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 will provide photos with a resolution of up to one meter while the Kondor-E satellite will have multirole radar that provides high-resolution images along two 500-kilometer sectors to the left and right of its orbit.[49] The current status of the program is unclear. Russia maintains two SIGINT 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.

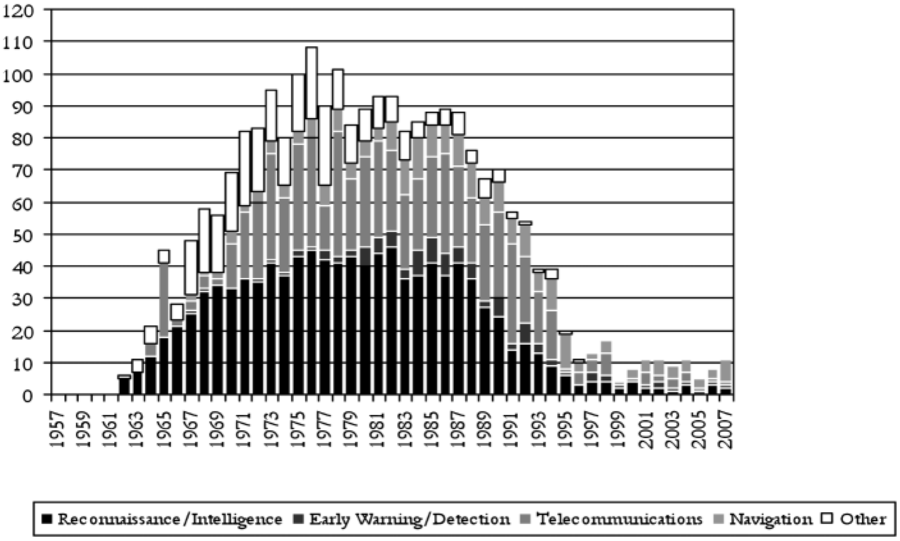
Navigation

The first Soviet navigational system is thought to have been 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 meters.[50] Currently, however, this constellation provides more services to the civilian than the military sector. The USSR began development of its second major navigation system, GLONASS, in 1982. 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-kilometer orbit.[51] With a full constellation, the navigational system is supposed to have resolution comparable to that of the GPS.[52] By December 2007 there were between 18 GLONASS satellites in orbit, approximately 14 of which were in operation (see Civil Space and Global Utilities Trend 3.4).[53]

Launch

As noted in Figure 5.3, Russia has tended to maintain an average annual satellite launch rate slightly higher than that of the US. This has not been sufficient, however, to keep its military space systems fully operational since Russian satellites have much shorter lifespans and require more frequent replacements. Forced to prioritize, Russia has focused first on its early warning systems, and more recently has moved to complete the GLONASS navigation system.[54] In 2004 Russia stated that it would focus on "maintaining and protecting" its fleet of satellites and developing satellites with post-Soviet era technology.[55]

Figure 5.3: USSR/Russia military space launches (1957-2006)[56]



2007 Development

US focus on major upgrades to critical systems, but some progress more than others

The US remained the world leader in both the number of military space launches and the development of military space capabilities in 2007, but its systems are beginning to age and require significant upgrades. The USAF has indicated that it will need $100-billion to purchase satellites and aircraft in the next five years alone, and will have to replace all of its satellites within the next decade as most are nearing the end of their lifespans.[57] Although some major program upgrades progressed in 2007, budget cuts and delays continued to affect others.

SATCOM

Launch of next-generation military communications systems was a major US focus in 2007 as the existing DSCS and Milstar program are aging and higher capabilities are required to meet current military demands for speed, bandwidth, and security. Although the Wideband Global SATCOM (WGS) program is several years behind schedule, the first of five satellites was launched on 10 October 2007. Once operational in 2008 it will be the US DOD's highest capacity communications satellite, providing more bandwidth than the entire DSCS system, but with fewer protection capabilities.[58] The complete system is valued at $1.8-billion. Negotiations are ongoing with US allies to participate in the program and contribute to its funding.[59] In 2007 Australia agreed to bear the costs for the fifth satellite.[60] Funding for the

Advanced Extremely High Frequency (AEHF) satellite program was reduced in the budget request by $20-million to $700-million. The authorization bill for FY2008 added $125-million, however, for procurement of a fourth satellite, reflecting continuing "concerns about a potential gap in protected communications."[61] Intended to replace Milstar until TSAT is operational, the program has suffered from delays as well as a 20 percent cost increase, but is now on track for a first spacecraft launch in 2008.[62] The Milstar system, which has been operating for four decades, was successfully reconfigured on-orbit to maximize the output of its communications system.[63]

TSAT remained a priority in 2007 despite setbacks. The program, which is intended to provide 100 times more bandwidth than the current Milstar system, only has funding until 2013, but launch of the first satellite has been pushed back once again from 2014 to 2019 or 2020.[64] Funding levels have also been scaled down: the FY2008 budget request for the TSAT program was $964-million, or half of what was projected two years ago.[65] Nonetheless, the program continues to be a priority, and funding has steadily increased, by 43 percent in FY2007 and another 30 percent in FY2008.[66] Its total procurement cost is estimated at $25-billion.

Early Warning

The 23rd and final US DSP satellite was launched into GEO on 10 November 2007 onboard a Delta-4 Heavy launch vehicle.[67] The DSP satellites are the mainstay of the US space-based missile early-warning system and have been in operation since November 1970. As the service life of the remaining DSP satellites comes to an end, DSP function will be shifted to the USAF's next-generation SBIRS. The SBIRS system is currently planned to include three satellites in GEO and two sensor payloads piggybacking on classified reconnaissance satellites in HEO. However, the constellation is not expected to provide global coverage without a fourth GEO satellite.[68] Although launch of the first SBIRS GEO satellite was planned for 2007, design failure caused change requirements of $1-billion and forced a launch delay of one year.[69] Overall, the SBIRS program is estimated to cost $11-billion and is seven years behind schedule. The program received almost $1-billion in FY2008[70] (see Space Systems Protection Trend 6.1).

Congressional support faltered in 2007 for the Alternative Infrared Satellite System, renamed Third Generation Infrared Surveillance Program (3GIRS), which approved only $75.9-million of the USAF's $230.887-million request for FY2008. Once viewed as a potential replacement for SBIRS, the program is now articulated as a next-next-generation system (see Space System Protection Trend 6.1).

Earth Observation

The National Polar-Orbiting Environmental Satellite System (NPOESS) program completed a restructuring process in 2007 following significant delays and cost overruns, particularly due to issues with sensor development. A program review was conducted by the DOD, NASA, and the Department of Commerce, which have jointly invested in the program.[71] The new plan for the project decreased its complexity, increased its cost to $12.5-billion, and delayed launch of the first two satellites by three to five years.[72] The NPOESS is a next-generation low-earth orbiting satellite system that will monitor the Earth's weather, atmosphere, oceans, land, and near-space environment for both civil and military users. Several technologies for the system underwent testing in 2007, but the first satellite is not expected to be launched until 2013.[73] The NPOESS Preparatory Project, consisting of one satellite being built by Ball Aerospace, constitutes a risk reduction platform for the NPOESS mission, by providing data continuity between the Earth Observing System Terra and Aqua missions and NPOESS.

Navigation

The most recent phase of modernization for the GPS neared completion in 2007 with delivery of the eighth and final 2R block satellite to the USAF and launch of the fourth and fifth 2R-M satellites on 7 and 20 December 2007. The constellation currently consists of five 2R-M satellites and 12 original 2R satellites in a 30-satellite constellation.[74] The 2R-M satellites feature modernized antenna panels, which give increased signal power to receivers on the ground.[75] A critical review of the next modernization process, GPS 3, was completed in 2007. It will provide improved navigation and timing accuracy and be less vulnerable to jamming.[76] GPS 3 was authorized to receive $487.2-million for FY2008, a $100-million cut from the budget request that reflects concern for challenges between the development and acquisition plans[77] To address reliability concerns for commercial users of the GPS system, President Bush announced his decision to eliminate the degradation capability, known as Selective Availability (SA), from the new GPS 3 line of satellites. This additional step was taken to assure users of GPS availability after the 2000 announcement by the US that it would not intentionally degrade its signal through its SA ability.[78]

Launch

The US DOD opened the Operationally Responsive Space (ORS) Office on 21 May 2007, as mandated in the FY2007 Authorization Act and as part of an acquisition plan for ORS.[79] Defense Advanced Research Projects Agency (DARPA) and the ORS Office continued to examine the utility of microsatellites for the US military in 2007, following the success of the TacSat mini-satellite program.[80] The TacSat-2 microsatellite launched on 16 December 2006 ceased operations on 21 December 2007. In its one year of operational life it demonstrated rapid development and deployment of a spacecraft suitable for tactical use, collecting tactically relevant imagery and signals intelligence data, among other things. The longevity of the satellite has boosted plans to further develop the ORS concept.[81] The TacSat-3 spacecraft bus was delivered to the USAF in September 2007. The program is designed to meet the demands of the US forces for flexible, affordable, and responsive satellite systems. The critical design and review, integration, and delivery for TacSat-3 were completed in less than 24 months.[82] See also Space Systems Protection Trend 6.4.

2007 Development

US continues to face setbacks on remote sensing projects

Reports emerged in 2007 that the NRO's classified Future Imagery Architecture (FIA) program had been 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."[83] Adding to troubles faced by the NRO, sources also revealed that the Misty Stealth Reconnaissance Imaging program had been cancelled due to costs, schedule delays, and poor performance.[84] The NRO is now reportedly working on a new multibillion-dollar spy satellite program called BASIC, planned to begin operations by 2011.[85] The NRO suffered another loss when it declared that the experimental spy satellite NROL-21 (US-193) launched late in 2006 failed in orbit. The satellite had not been in communication since reaching its position in LEO. It was reportedly designed to "demonstrate a new and unique blend of optical and radar imaging capabilities."[86] The NRO lost hundreds of millions of dollars on the satellite.[87] Another classified satellite referred to as NROL-24 (USA-198) was launched on 10 December 2007 and is thought to be a Satellite Data System imagery data relay satellite.[88] These events leave US military reconnaissance capabilities largely based on outdated systems. While there is not a gap in coverage, "the constellation is fragile."[89]

In a related development, the USAF Space Radar program (previously known as Space Based Radar) also showed signs of trouble in 2007. Intended to provide all-weather intelligence, surveillance, and reconnaissance using high-resolution imagery and ground movement identification, its lifecycle cost is estimated at between 20 and 25 billion dollars.[90] Classified funds were requested for the program for the FY2008 budget, which was approved in the authorization bill. Congress expressed concern about the overall approach of the program as well as its track record, however, and ordered an analysis of alternatives and a plan for expenditure of 2008 funds, authorizing only $40-million in spending until the plan has been reviewed.[91]

In the meantime, the US continues to use commercial imagery data to meet some of its data needs, as directed under the 2003 US Commercial Remote Sensing Space Policy. The first of two commercial WorldView satellites being developed by DigitalGlobe, the only commercial remote sensing satellite to provide up to 0.5-meter resolution, was launched on 20 September 2007. It is part of the National Geospatial-Intelligence Agency's (NGA's) Next View Program, to ensure accurate geospatial intelligence in support of national security. It was partially financed by the NGA, which contributed $500-million to secure imagery for specific DOD high-resolution needs.[92]

2007 Development

Russia continues to invest in military programs to maintain its space-based capabilities, with focus on revitalizing GLONASS

In 2007 Russia reconsidered its space strategy to pursue satellites with longer service lives. With its constantly aging fleet of a large number of Soviet-era satellites that have lifespans of five to six years, Russia is aiming to produce multipurpose, new-generation communications satellites with possible service lives of seven to 10 years. The new GLONASS K satellites being developed are expected to have service lives of up to 12 years.[93] Although Russia has historically launched more military satellites than the US, this higher frequency has not translated into greater capabilities because of the high replacement rate. Russia plans to spend over $200-billion on defense over the next decade and has a 10-year space budget of $10.5-billion — which is still less than what the US spends every year on space.[94]

Navigation

Completing the GLONASS satellite navigation system is the highest priority for Russia and negotiations are underway with the US and the Europe to fully integrate GLONASS with the GPS and Galileo systems.[95] Six GLONASS satellites were launched on 26 October and 25 December 2007, bringing the current constellation to 18, of which 14 are believed operational. According to Russian media sources, 20 GLONASS satellites are needed to provide complete coverage of Russia, and 24 for global coverage.[96] The budget for GLONASS has been increased significantly in order to complete the project originally begun during the Cold War: $380-million in federal funding was allocated in 2007, up from $181-million in 2006.[97] Nonetheless, fears were expressed that the system will not be completed before 2010-2011 and that ongoing problems with the ground segment may hamper its success.[98] Moreover, 12 of the current satellites are older models nearing the end of their lifespans; their loss could also affect the future success of the program.[99] The inadequacies of the GLONASS system are also becoming more apparent. Not only is it inaccurate, providing at best positional accuracy of 10-17 meters, but it is also unstable, sometimes providing no reading at all.[100]

Communications and Intelligence

Russia also launched a small number of communications, remote sensing, early warning, and intelligence satellites in 2007. The Raduga 1-8 (or 1M) communications relay satellite was launched on 9 December 2007 as part of Russia's secure system for military communications, joining Raduga 1-5 and Raduga 1-7.[101] Cosmos-2427, a Kobalt-M military optical remote sensing satellite for imaging, was launched in June. Designed to deliver a returnable film capsule, it is the third of its type launched since 2004.[102] The satellite re-entered in August 2007 after completing its mission, according to the Russian Ministry of Defense — the typical lifespan of these satellites is 60 days.[103] Meanwhile, launch of a new Persona optical remote sensing satellite was delayed to 2008.[104]

Early warning

On 23 October 2007 Cosmos-2430 satellite was launched — it is a first-generation US-KS (Oko) early warning satellite.[105] The launch did not serve to increase the capabilities of the system, which still does not provide 24-hour coverage of the US, because the Cosmos-2393 US-KS satellite launched in 2004 appears to have ended operations. The space-based portion of Russia's early warning system thus remains at just three satellites.[106] However, there are reports that Russia has commenced work on a new system, EKS (the Integrated Space System), and that tests for the program will begin in two years.[107] Russian early warning capabilities are also being upgraded with a new radar station at Armavir, which was scheduled to be ready for combat service by late 2007 but does not appear to be operating yet.[108] This radar is similar to the Voronezh-DM radar, which became combat-ready last year. Russia leases out many of its radar facilities.[109]

Launch

To maintain its high rate of military launches, Russia announced plans to build a launch facility for military and civilian satellites in the eastern Amur region of the country, near the border with China. The station is expected to begin operations is 2015.[110]

2007 Space Security Impact

The US is slowly progressing with modernization of its space systems. The focus is on meeting the bandwidth and secure communications needs of today's military and preventing gaps in next-generation capabilities, both of which are elements of secure and sustainable use of space. Troubles faced by the NRO, however, demonstrate weaknesses in its abilities to manage complex projects, research and development, and acquisitions, which may continue to hinder major system upgrades. Continued dependence on space assets increases US vulnerability in space, and it is not yet clear if efforts to protect those assets in the future will contribute to or detract from the security of outer space. The Russian focus on revitalizing GLONASS and its aging satellite fleet could also be positive for space security by providing redundancy for the US GPS, more reliable and secure early warning capabilities, and more secure satellite communications.

Trend 5.2: More actors developing military space capabilities

By the end of 2004 the US and USSR/Russia had together launched more than 2,000 military satellites, while the rest of the world had only launched between 40 and 50.[111] The UK, NATO, and China were the only other actors to launch dedicated military satellites until 1988, when Israel launched its first. In 1995 France and Chile both launched dedicated military satellites.[112] Traditionally, military satellites outside of the US and Russia have been almost exclusively intended for telecommunications and reconnaissance. Recently, however, states such as China, France, Germany, Japan, Italy, and Spain have been developing satellites with a wider range of SIGINT, navigation, and early warning functions.

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, usually relying on the launch capabilities and manufacturing services of others states or the commercial sector. Nonetheless, in the absence of their own dedicated military satellites, many actors rely on dual-use satellites, acquire existing satellites from others, or purchase data and services from satellite operators.[113]

Figure 5.4: Minimum resolutions for remote sensing target identification[114]

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. Traditionally, European states have not had separate military and civil space budgets. European military space spending has recently been estimated at $1.35-billion.[115]

While European states have pursued independent space capabilities for military support, many of these systems are also shared, in particular Earth observation. The highly classified Besoin Operationnel Commun (BOC) provides the framework for space systems cooperation between the ministries of defense of France, Germany, Italy, Spain, Belgium, and Greece.[116] France's Helios-1 and -2 military observation satellites in LEO are included under this agreement. The French Ministry of Defense procurement agency (DGA) manages the program, retaining direct control over the management of the ground segment while delegating the space segment responsibility to the French space agency, the Centre National d'Etudes Spatiales (CNES).[117] Germany's first dedicated military satellite, Sar-Lupe-1 launched in 2006, is also part of this agreement. It is the first of five all-weather synthetic aperture radar (SAR) high-resolution remote sensing satellites and will be joined by Italy's planned system of four Cosmo radar satellites, which are to be integrated with France's Pleiades high-resolution dual-use optical remote sensing satellites (2008).[118] In 2005 the UK launched an imagery microsatellite TopSat, built by Surrey Satellite Technology Ltd.

There are also several dedicated and dual-use satellite communications systems in Europe. In 2006 France completed the Syracuse III next-generation communication system with the launch of Syracuse-3B. The system has been described as "the cornerstone in a European military Satcom system."[119] France also maintains the dual-use Telecomm-2 communications satellite and the military Syracuse-2 system.[120] The UK operates a constellation of three dual-use Skynet-4 UHF and Super High Frequency (SHF) communications satellites in

GEO, with next-generation Skynet-5 satellites to follow.[121] Spain launched the dedicated military communications satellite Spainsat in 2006 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. The system, scheduled for operation in 2009, will provide the German Armed Forces with a secure information network to assist its units on deployed missions.[122] Italy's Sicral military satellite provides secure UHF, SHF, and EHF communications[123] Syracuse, Skynet, and Sicral all provide SHF capacity for NATO.

Other military space capabilities in Europe include France's constellation of four SIGINT satellites know as Essaim, launched in 2004. France also plans to launch two Spirale early warning microsatellites for a probative research and technology demonstration program by 2008.

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 joint EU and 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. It will support activities prioritized in the European Security and Defense Policy, such as natural disaster early warning, rapid damage assessment, and surveillance and support to combat forces.[124]

The Galileo satellite navigation program, initiated in 1999 and jointly funded by the EU and the ESA, will provide location, navigation, and timing capabilities.[125] Although intended for civilian use, there have been recent calls to use its dual-purpose capabilities for military applications, but all EU/ESA members do not share this view.[126] ESA, which has traditionally been restricted to working on projects designed exclusively for peaceful purposes, has begun to consider investing in dual-use, security-related research. Space surveillance, Earth observation, and data-relay satellites have been identified as priorities.[127] Moreover, potential projects such as a global, European-coordinated space-surveillance system are being described in dual-use terms, with reference to "multiple" end-users. Although end-users could potentially use ESA-developed applications for military purposes, the ESA itself would not be designing or operating military spacecraft.[128]

China

China does not maintain the same separation between civil and military space programs — officially its space program is dedicated to science and exploration.[129] Leadership of the space program is provided by the Space Leading Group, whose members include three senior officials of government bodies that oversee the defense industry in China.[130] Although the Chinese military's role in the space program is unclear, the space program is certainly governmental. Most of China's satellites are civilian or commercial, but could be used for military purposes given the nature of dual-use satellite technology.

China has advanced Earth observation capabilities. It began working on space imagery in the mid-1960s, launching its first reconnaissance intelligence satellite in 1975.[131] It successfully launched 15 recoverable film-based satellites, the last of which was reportedly decommissioned in 1996. Several of these satellites were also reported to carry "domestic and foreign commercial microgravity and biomedical experiments."[132] Today China maintains two ZY-2 series digital imagery satellites in LEO that could support tactical reconnaissance and surveillance.[133] 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.[134] More recently, in 2006 China launched the civilian SAR Remote Sensing Satellite-1 (Yaogan-1) for "scientific experiment, survey of land resources, appraisal of crops and disaster prevention and alleviation."[135] While some Western sources also give the satellite a military designation, JianBing-5,[136] there is currently no evidence to suggest that it is being used for military purposes, although it certainly has a dual-use capability.

Western experts believe that Chinese military satellite communications are provided by the DFH series satellite, officially known as 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.[137] A replacement satellite was launched in 2006.[138] China also operates four Beidou regional navigational satellites designed to augment the data received from the US GPS system and to enable China to maintain navigational capability if the US were to deny GPS services in times of conflict.[139] Beidou may also improve the accuracy of China's intercontinental ballistic missiles (ICBMs) and cruise missiles[140] It is scheduled to be operational in 2008. In 2006 China committed to building a global satellite navigation system, the Beidou-2 or "Compass" system, expanding on the regional system. The planned global system will have five satellites in GEO and 30 in MEO to provide positioning accuracy within 10 meters for military, commercial, and civilian users. The cost of the system is not known.[141]

China experimented with electronic intelligence (ELINT) satellites, called "technical experimental satellites," in the mid-1970s but these programs have since been discontinued. It relies on modern air, sea, and land platforms, not satellites, to perform SIGINT missions; however, in 2006 China launched two Shi Jian experimental satellites (SJ-6/2A and SJ-6/2B) that some Western experts believe are providing signals intelligence (SIGINT), although their official purpose is to measure the space environment.[142]

South Asia

India does not operate any dedicated military satellites, but it is undergoing a process of greater military use of outer space and its space program is certainly governmental. It 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 Organization (ISRO). It successfully launched its Satellite Launch Vehicle (SLV) to LEO in 1980, followed by the Augmented Satellite Launch Vehicle (ASLV) in 1994, the Polar Satellite Launch Vehicle (PSLV) in 1994, and the Geostationary Satellite Launch Vehicle (GSLV) in 2004.

During this time ISRO developed a series of civilian Indian Remote Sensing satellites and currently maintains a constellation of six satellites that provide imagery for the Indian military. Two in particular are suitable for reconnaissance with resolutions up to one meter — Cartosat-2 and the Technology Experiment Satellite, which provides tactical and strategic intelligence to the armed forces.[143] India's Military Surveillance and Reconnaissance System was to be launched in 2007.[144] It is intended to provide India with dedicated military satellite intelligence, including military shutter control over key satellites, through the use of the Defence Imagery Processing and Analysis Centre (DIPAC) in New Delhi and a satellite control facility in Bhopal. It would incorporate Cartosat-1 and -2, TES, as well as GLONASS. Although behind schedule, India's civilian Remote Imaging Satellite (Risat), will provide the country's first SAR remote sensing system capable of all-weather, day-and-night Earth imaging.[145] India's military also uses images from Russian and Israeli satellite feeds.[146]

India also has one of the most extensive domestic satellite communications networks in Asia, with nine satellites currently in operation.[147] Metsat-1 provides meteorological services from GEO. India is also developing GAGAN, the Indian Satellite-Based Augmentation System for US GPS (2009-2010), to be followed by the Indian Regional Navigation Satellite System (IRNSS), which will provide an independent satellite navigation capability (see Civil Space and Global Utilities Trend 3.4).[148] Although these are civilian-developed and -controlled technologies, they are used by the Indian military for their dual-purpose applications.[149] Moreover, there are indications that India's armed forces may develop a larger role in outer space in the near future. India continues to plan the creation of a military Aerospace Command, but its exact composition and function are still vague.[150] And if the US-India civilian nuclear cooperation deal is approved, sanctions will be removed that could allow for greater cooperation between ISRO and the military (see Commercial Space Trend 4.3).[151]

Pakistan's space-based capabilities are significantly less advanced than India's. China launched Pakistan's Badar-1 multipurpose satellite in 1990; in 2001 Russia launched the Badar-2 Earth observation satellite.[152] Pakistan plans to construct the Remote Sensing Satellite System (RSSS) to provide high-resolution satellite images to its military, but its status is unclear.[153] While India and Pakistan seem intent on developing space systems to support military operations, significant progress remains a longer-term objective.

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.[154] Officially called the Information Gathering Satellite series under the control of the Prime Minister's Cabinet Office, IGS 3A and 3B provide images of up to one-meter resolution to the Japanese military.[155] 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.[156] The Japanese Defense Agency also plans to construct a large-scale image communications system intended to cover East Asia, parts of the Middle East, and Africa.[157]

In December 2003 South Korea announced its intentions to increasingly use space for military purposes.[158] South Korea operates the civilian Kompsat-1 satellite with 6.6-meters resolution, which is "sufficient for [military] mapping although not for military intelligence collection."[159] It also bought 10 Hawker 800 series satellites from the US, and has operated them for signals intelligence since 1999.[160] 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.[161] South Korea also launched the Kompsat-2 high-resolution Remote Sensing Satellite for Earth mapping in 2006.[162] Although a civilian spacecraft, its one-meter resolution could allow it to serve as a reconnaissance asset.[163]

In July 2004 Thailand signed a deal with the European Aeronautic Defence and Space Company (EADS) Astrium to provide its first Earth observation satellite, which is expected to be used for intelligence and defense.[164] Taiwan has also announced plans to launch a $300-million reconnaissance satellite, but it continues to face delays. In the meantime, a Taiwanese official stated that military and security authorities will have to increase their reliance on images taken from their existing Formosa-2, with a resolution of 1.8 meters.[165]

Middle East

Israel's space program reflects an interest in exploiting space systems in support of terrestrial military operations, including operational and tactical missions. Israel operates the dedicated military Ofeq-5 system, which provides both panchromatic and color imagery at resolutions of less than one meter for reconnaissance and surveillance purposes.[166] It frequently passes over Arab territory in the region. Its capabilities are augmented by the dual-use Eros-A and B imagery satellites, the latter able to capture black-and-white images at 70-centimeter resolution.[167] Israel plans to launch a dedicated military satellite for secure communications by 2010. In the meantime it uses commercial services provided by Israel's Amos-1 and -2, Tadiran Communications Wi-Max wireless broadband, and Motorola-Israel.[168] In 2005 Israel successfully tested the latest Shavit Space Launch Vehicle, intended to give Israel independent launch capabilities.[169]

Iran launched its first satellite, the Sina-1, in 2005 with the support of a Russian launcher. It has a resolution precision of approximately 50 meters.[170] 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.[171] However, its poor resolution means that it is not very useful for military purposes. Iran also has a nascent space launch vehicle program, which some speculate is linked to its development of intercontinental-range ballistic missiles and the Shahab-4 and Shahab-5.[172]

Australia

Until recently the Australian defense forces used X-band facilities on satellites owned by the US and other allies.[173] In 2003, however, Australia launched the Defence C1 communications satellite. The satellite will be part of a new Australian Defence Satellite Communications Capability system, which will provide the country's defense forces with communications across Australia and throughout the Asia Pacific region in the X, Ka, and UHF radio frequency bands.[174]

Canada

Canada does not yet have a dedicated military satellite program, but uses commercial satellite communication, surveillance, and imaging services.[175] In June 2005, however, Canada's Department of National Defence announced the creation of Project Polar Epsilon, a $52.1-million joint space-based wide area surveillance and support capability that will provide all-weather, day/night observation of Canada's Arctic region and ocean approaches.[176] The project will link to information from RADARSAT and other sources to produce high quality imagery for military and other applications.[177] Canada will also have its first access to dedicated military satellite communications when the US AEHF satellite system becomes operational (2010).[178] A low-cost ($27-million) Joint Space Support Project (JSSP) is intended to provide surveillance information for commanders in the field via direct in-theatre download of space imagery provided by commercial satellites such as Radarsat-2, and also provide space situational awareness data gathered by the US Space Surveillance Network.[179]

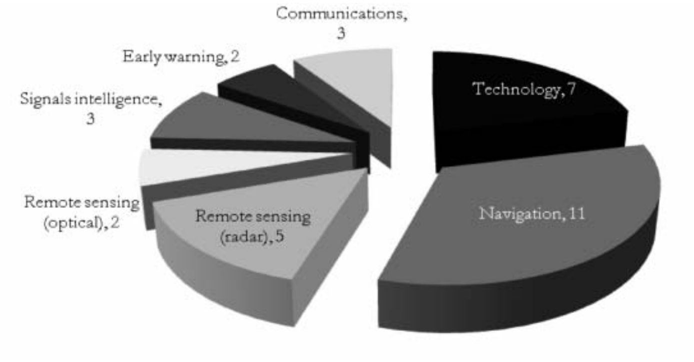
Figure 5.5: States' first dedicated military satellites and their function[180]

■ Military satellite-owning state
▨ Satellite-owning state

Year	State/Actor	Satellite	Description
1958	US	Project SCORE	Communications and experimental 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	Francec[181]	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)

* Note that other states have civil or commercial satellites that may be used for military purposes, as described in this chapter.

Figure 5.6: Dedicated military satellites launched in 2007



2007 Development

Europe developing a range of integrated military capabilities, both dedicated and dual-use

European states launched a range of communications, imaging, and intelligence capabilities to support terrestrial military operations in 2007, and the prospect of a European satellite navigation system solidified. The new European Space Policy, released in May 2007 and adopted by both the European Commission and the ESA, makes specific reference to defense and security applications, indicating a shifting focus to support increasing synergies between military and civil space programs.[182]

Communications

The Ariane-5 launched the UK's Skynet-5A and -5B military communications satellites on 11 October and 9 November 2007. Skynet-5 is a next-generation, three-satellite system to provide high-speed secure communications to the British forces.[183] Both of these X-band spacecraft were brought online later in the year. Unlike a traditional military communications system, Skynet 5 is the result of a public-private partnership between the British Ministry of Defence and Paradigm Secure Communications, which operates the satellites and provides the necessary services.[184] The UK has priority of use, with excess capacity available for sale to NATO and other UK allies. In 2007 Germany continued to develop its first military secure communications system, Satcom BW, which is scheduled for launch in 2008. This geostationary multimissions system will be fitted with payloads including super high frequency, ultra high frequency, and Ku-band transponders. Services are expected by early 2009, with an operational lifetime of 15 years.[185]

Earth Observation

Earth imaging was a major European focus in 2007. The second German SAR-Lupe synthetic aperture radar satellite was launched on 2 July 2007, followed by the third on 1 November 2007. The remaining two satellites of this dedicated military system are scheduled for launch in 2008. The system allows Earth imaging data to be gathered under any weather, light, or terrain conditions.[186] It is part of the highly classified Besoin Opérationnel Commun (BOC), which provides the framework for space systems cooperation between the ministries of defense in France, Germany, Italy, Spain, Belgium, and Greece.[187] There is a proposal to formalize this agreement into the Multinational Space-based Imaging System for Surveillance, Reconnaissance and Observation (Musis), which could be operational by 2015.[188] Italy's Cosmo-SkyMed X Band radar satellite system is also part of this agreement. The first two satellites were placed into orbit on 8 June and 9 December 2007. The system is dual-use, funded by both the Italian Ministry of Research and Ministry of Defence, and implemented by the Italian Space Agency.[189] It is intended to monitor and survey the globe to manage environmental risks, national security, and scientific and commercial use.[190] It provides high-resolution, X band, synthetic aperture radar capabilities that could be integrated with France's Pleiades optical system, now delayed until 2010.[191]

In September 2007 it was announced that Arianespace had been selected to launch the four Elisa demonstrator satellites together with the first Pleiades satellite. The demonstrator project is sponsored by the French defense procurement agency (DGA) to prepare the ground for the future ROEM (Renseignement d'Origine ElectroMagnétique) electromagnetic reconnaissance program. Its purpose is to keep databases for electronic warfare up-to-date, and to detect and monitor activities during operations.[192]

Navigation
Europe's efforts to build an independent space-based navigation system, a fully-funded EU-ESA program begun in 1999 called Galileo, almost faltered in 2007, but solidified at the end of the year. Galileo is a program of the European Commission of the EU in partnership with the ESA, which is responsible for implementing the technical aspects. After significant delays and the failure of a public-private consortium to build and operate the system, European governments agreed in 2007 to provide the necessary $5-billion to continue work on the 30-satellite space navigation system. EU budget ministers agreed to fill a €2.4-billion hole entirely with money from the EU 2007 and 2008 budgets.[193] Originally scheduled to become operational in 2008, the program is now scheduled for completion in 2013; over $1.5-billion has already been spent on the program.[194] At the end of 2007 only one experimental satellite, built by Surrey Satellite Technology Systems, was in orbit but a second is expected to be launched in 2008. Galileo is highlighted as a priority in the European Space Policy; although intended for civilian and commercial purposes, it would be a potential area for synergies with military users.

2007 Development

China investing to achieve self-reliance in space

China's announcement to replace all of its communications and broadcast satellites with indigenous models by 2010 is indicative of its efforts to achieve self-reliance in space,[195] which appears to be driven through the development of advanced dual-use capabilities. Reports emerged in 2007 that China is developing 15 different types of satellites, including Earth observation, intelligence, signals intelligence, small, and micro,[196] all of which would have dual-use capabilities.

China launched the Compass-M1 test satellite into MEO in April 2007. It is intended for system in-orbit validation and to secure the frequency filings for the Compass regional navigation system following launch of a Beidou Test System satellite into GEO on 2 February 2007.[197] The Beidou Test System for China's satellite navigation plans is currently active and provides service to navigation terminals in China. Unlike other navigation systems, Beidou is composed of four satellites in GEO. The Compass system is intended to build on the Beidou Test System, first by providing regional service either in 2008 or 2009. Plans for a global system of 30 satellites in MEO and five in GEO are currently conceptual, but entail 24-hour all-weather coverage to provide precise time and orbit information on L-band frequencies. Although Compass falls under China's defense ministry, it is intended to provide both an Open Service with position accuracy of 20 meters and an Authorized Service that will be "highly reliable even in complex situations."[198] Concerns have been expressed that Compass will use the same radio frequencies as Galileo and possibly GPS (see Space Environment Trend 1.4); however, China maintains that this is still under negotiation. Some analysts have suggested that using the same radio frequencies would make it more difficult for the Compass system to be jammed.[199]

China also launched Yaogan-3 (Remote Sensing Satellite-3) on 11 November 2007. A civilian satellite intended to monitor Earth resources, estimate crop yields, and assist with natural disasters, this SAR satellite is also described by some unsourced Western reports as having a military designation, Jian Bing-6, and as funded by the People's Liberation Army.[200] SAR provides a wide range of powerful civilian and military applications. Like other SAR satellites launched in 2007, including Italy's Cosmo-SkyMed and Canada's Radarsat-2, it is possible that Yaogan-3 will be used for both civilian and military purposes. Yaogan-3 and an optical imaging satellite, Yaogan-2, were both launched secretly and little information has been provided on their uses, aside from the generic description of China's remote sensing program.[201]

China also launched the civilian China-Brazil Earth Resources Satellite (CBERS-2B) developed with Brazil. Unlike previous satellites launched through this partnership, the CBERS-2B carries a high-resolution camera capable of providing black-and-white images with a resolution of 2.5 meters, which could support some military applications.[202] Brazil has plans to boost its military spending by over 50 percent in 2008. The amount is pegged at $5-billion; however, it is unclear how much of it will be directed to military space infrastructure. Brazil has pointed out that it plans to overhaul all areas of its armed forces.[203] Its space activities are under the authority of the Brazilian Air Force.

2007 Development

Focus on remote sensing capabilities in the Middle East and Asia

On 11 June 2007 Israel launched the military optical remote sensing Ofeq-7 satellite, which became operational later that year. Ofeq-7 is the most advanced Earth imaging satellite launched from the Middle East, and significantly increases Israel's reconnaissance capabilities in the region. Its digital high-resolution camera can identify objects as small as approximately 0.5 meter.[204] The lifespan of the satellite is expected to be four to six years.[205] This enhanced optical imaging capability is expected to be complemented by the launch of Israel's TecSat (Polaris) SAR imaging satellite by ISRO in early 2008. The classified satellite encountered technical difficulties in 2007, pushing back its launch date.[206] It is anticipated that its SAR technology will be capable of providing sharp pictures of sub-meter resolution, in all-day, all-weather, all-terrain conditions. Choosing India's launch service is thought to demonstrate a new era of significant military space cooperation between Israel and India.[207]

As competition for military space dominance increases in the Middle East, the Israeli Ministry of Defense is also developing the Ofeq-8 and the Ofeq-Next satellites. As well, in 2007 Israel signed a deal with state-owned Israel Aerospace Industries (IAI) to develop the next-generation Amos-4 communications satellite, which will be available to commercial customers as well as Israeli political-military users. However, the satellite is not expected to be operational until 2012.[208]

Egypt's civilian Egyptsat-1 microsatellite, jointly built by Egypt's National Authority for Remote Sensing and Space Sciences and the Yuzhnoye Design Bureau in Ukraine, was launched onboard a Dnepr-1 launch vehicle on 17 April 2007. Weighing just 100 kilograms, it has an infrared imaging sensor and a high-resolution multispectral imager to transmit black-and-white, color, and infrared images. It is intended to support construction, cultivation, and to fight desertification (see Civil Space and Global Utilities Trend 3.2).[209] Egypt has not released public details about the resolution or clarity of the images it provides. An Israeli source has made an unconfirmed claim that it can detect objects as small as 4 meters and accuses it of gathering intelligence on Middle Eastern countries.[210] Whatever the case, the use of outer space resources appears to be affecting perceptions of terrestrial security in the Middle East.

After several years of anticipation, Turkey awarded a $250-million contract for its first military optical reconnaissance satellite GOKTURK in 2007. It is intended to have an 80-centimeter resolution, and the launch is planned for 2011.[211]

Japan successfully launched a fourth Earth observation satellite of the Information Gathering Satellites (IGS) program on 24 February 2007, along with an experimental optical satellite. The program is under the control of a special Cabinet Intelligence and Research Office of the Cabinet Secretariat, rather than the Ministry of Defense, and provides intelligence support to the government.[212] The launch completed Japan's four-satellite constellation, giving it an all-weather, daily, global observation capability based on two optical and two radar satellites with up to one-meter resolution.[213] However, this capability was diminished when one of the satellites, launched in 2003, failed in orbit in March 2007.[214] Moreover, there are concerns that despite the size of the program, higher-quality images can be obtained from the US, or even commercial sources.

India's Cartosat-2A was planned for launch in 2007, but delayed until 2008 for technical reasons. The original satellite Cartosat-2 was launched on 10 January 2007, but suffered problems once in orbit that affected the quality of its images.[215] Cartosat-2A, intended for cartographic purposes, was built and will be operated by ISRO, but has dual-use military applications. Secretary of the Department of Space and Chairman of ISRO, G Madhavan Nair has explained that "[[w]e don't put a restriction on anybody using it,"[216] confirming beliefs that India's civil space program is available for military use. Indeed, earlier reports indicated that the Military Surveillance and Reconnaissance System to provide India with dedicated military satellite intelligence was to become operational by the end of 2007, but its current status is not clear.[217] Cartosat-2A, like the original satellite, will carry a powerful panoramic camera and is intended to provide images with a resolution of one meter.[218]

Plans for the establishment of the much talked about Indian Aerospace Command (as part of the Indian Air Force) were again announced by the Indian Air Chief Marshal in 2007.[219] However, instead of a fully fledged aerospace command, a space cell has been established under the Air Vice Marshal,[220] and a dialogue on the shape of the eventual aerospace command is expected to take place between the three branches of the Indian armed forces. A core group of people has also begun training to staff the future command. These developments occurred in the wake of reported revisions to India's defense doctrine to support the use of space to enhance the functional effectiveness of its armed forces (Laws, Policies, and Doctrines Trend 2.4).

Finally, India signed an agreement with Russia in January 2007 to jointly use the GLONASS global navigation system, which supports both military and civilian users.[221]

A plan to replace and upgrade Taiwan's civilian-classified Formosat-2 optical remote sensing satellite was blocked, at least temporarily, when a classified budget for an optro-electronic remote sensing satellite was cancelled in January 2007. Formosat-2 is anticipated to stop operating by 2009. Although a civilian satellite, it is suspected of providing support to Taiwan's military, and the budget for the upgraded spacecraft was part of a secret budget for Taiwan's National Security Bureau.[222] Formosat-2 has a resolution of 1.8 meters.

Figure 5.7: Dedicated military payloads launched in 2007

COSPAR	Launch Date	Launch Vehicle	Satellite Name	Launch State	State	Primary Function	Primary Manufacturer	Orbit Type
2007-006A	3/8/07	Atlas V 401	ASTRO (orbital express)	US	US	Technology	Boeing	LEO
2007-003A	2/3/07	Chang Zheng 3A	Beidou 4	China	China	Navigation	CAST	GEO
2007-011A	4/14/07	Chang Zheng 3A	Beidou 5	China	China	Navigation	CAST	MEO
2007-030A	7/2/07	Soyuz	SAR-Lupe 2	Russia	Germany	Remote sensing (Radar)	OHB	SSO
2007-053A	11/1/07	Kosmos-11K65M	SAR-Lupe 3	Russia	Germany	Remote sensing (Radar)	OHB	SSO
2007-025A	6/11/07	Shavit 1	'Ofeq-7	Israel	Israel	Remote sensing (Optical)	IAI	LEO
2007-005A	2/24/07	H-IIA 2024	IGS 4A	Japan	Japan	Remote sensing (Optical)	MELCO	SSO
2007-005B	2/24/07	H-IIA 2024	IGS 4B	Japan	Japan	Remote sensing (Radar)	MELCO	SSO
2007-022A	6/7/07	Soyuz-U	Kosmos-2427	Russia	Russia	Remote sensing (Optical)	Arsenal	LEO
2007-029A	6/29/07	Zenit-2M	Kosmos-2428	Russia	Russia	Signals intelligence	KBYu	LEO
2007-038A	9/11/07	Kosmos-11K65M	Kosmos-2429	Russia	Russia	Navigation, data relay	Polyot	LEO
2007-049A	10/23/07	Molniya 8K78M	Kosmos-2430	Russia	Russia	Early warning	Lavochkin	HEO
2007-052A	10/26/07	Proton-K/DM-2	Kosmos-2431	Russia	Russia	Navigation	Polyot	MEO
2007-052B	10/26/07	Proton-K/DM-2	Kosmos-2432	Russia	Russia	Navigation	Polyot	MEO
2007-052C	10/26/07	Proton-K/DM-2	Kosmos-2433	Russia	Russia	Navigation	Polyot	MEO
2007-058A	12/9/07	Proton-M/Briz-M	Kosmos-2434	Russia	Russia	Communication	NPO PM	GEO
2007-065A	12/25/07	Proton-M/DM-2	Kosmos-2435	Russia	Russia	Navigation	Polyot	MEO
2007-065B	12/25/07	Proton-M/DM-2	Kosmos-2436	Russia	Russia	Navigation	Polyot	MEO
2007-065C	12/25/07	Proton-M/DM-2	Kosmos-2437	Russia	Russia	Navigation	Polyot	MEO
2007-007B	3/11/07	Ariane 5ECA	Skynet 5A	France	UK	Communication	Astrium	GEO
2007-056C	11/14/07	Ariane 5ECA	Skynet 5B	France	UK	Communication	Astrium	GEO
2007-006	3/9/07	Atlas V 401	MEPSI Picosat	US	US	Technology	AFRL	LEO
2007-006B	3/9/07	Atlas V 401	Midstar 1	US	US	Technology	USNA	LEO
2007-006C	3/9/07	Atlas V 401	Nextsat (orbital express)	US	US	Technology	Boeing	LEO
2007-006D	3/9/07	Atlas V 401	STPSat-1	US	US	Technology	AertoAstro	LEO

COSPAR	Launch Date	Launch Vehicle	Satellite Name	Launch State	State	Primary Function	Primary Manufacturer	Orbit Type
2007-006E	3/9/07	Atlas V 401	Falconsat-3	US	US	Technology	USAFA	LEO
2007-006F	3/9/07	Atlas V 401	CFESat	US	US	Technology	SSTL/LANL	LEO
2007-027A	3/09/07	Atlas V 401	USA 194 (NROL-30)	US	US	Signals intelligence	LMA	LEO
2007-027C	3/09/07	Atlas V 401	USA 194 P/L 2	US	US	Signals intelligence	LMA	LEO
2007-046A	10/11/07	Atlas V 421	WGS SV-1	US	US	Communication	Boeing	HEO
2007-047A	10/7/07	Delta 7925-9.5	Navstar GPS IIR-M4	US	US	Navigation	LMMS/VF	MEO
2007-054A	11/10/07	Delta 4H	DSP F23 (USA 197)	US	US	Early warning	TRW	GEO
2007-060A	12/10/07	Atlas V 401	USA 198 NROL-23	US	US	Comsat, relay, early warning	LMA	HEO
2007-062A	12/20/07	Delta 7925-9.5	Navstar GPS IIR-M5	US	US	Navigation	LMMS/VF	MEO
2007-014A	4/24/07	Minotaur 1	NFIRE	US	US	Research	GD/Gilbert	LEO
2007-023	6/07/07	Delsta 7420-10C	Cosmo-1	US	Italy	Remote sensing (radar)	Alenia Spazio	LEO
2007-059A	12/9/07	Delta 7420-10	Cosmo-2	US	Italy	Imaging (radar)	Alenia Spazio	LEO

2007 Development

Canada to use dual-use satellites to monitor the Arctic, develop military support capabilities

Canada's Radarsat-2 was launched on 14 December 2007 aboard a Russian Soyuz launch vehicle.[223] Although a commercial satellite providing 3-meter, all-weather, all-day, all-terrain satellite images, it was primarily financed by the Canadian Space Agency, and includes an experimental Ground Moving Target Indication (GMTI) mode known as Moving Object Detection Experiment (MODEx). This mode will support experiments and demonstrations on the use of space based synthetic aperture radar for detecting, measuring and monitoring vehicles. This mode is wholly owned and funded by Defence Research and Development Canada (DRDC), however it is expected to provide an important tool for both military and civil users.[224] Germany's commercial TerraSar-X and Italy's Cosmos-SkyMed-1, both launched in 2007, include similar technology experiments. The Canadian government has declared that Radarsat-2 will help assert its sovereignty over the Arctic by providing enhanced land and sea surveillance capabilities for the Canadian Forces.[225]

In a related project, the Canadian Department of National Defence is moving forward with project Polar Epsilon, expected to reach initial operating capacity on the country's west coast by 2010. It is a $52.1-million joint project features a space-based wide area surveillance and support capability that will provide all weather, day/night observation of Canada's Arctic region and ocean approaches.[226] The project will link to information from Radarsat and other sources to produce high quality imagery for the military.[227]

Canada's DRDC is also investigating the use of microsatellites to meet the needs of the Canadian forces deployed on missions.[228] Currently, the Canadian Forces rely entirely on the US DOD and the commercial sector for space support. A responsive space effort has been established by the Space Systems Group at the DRDC to develop an indigenous military space capability, influence Canada's space strategy, and contribute to allied space effort. Two examples are the Near Earth Object Surveillance Satellite (NEOSSat) and the Maritime Monitoring and Messaging Microsatellite (M3MSat). Both missions are jointly managed and funded by the DRDC and the Canadian Space Agency and cost less than $12-million.

2007 Development

Potential use of space for military purposes in Nigeria

In 2007 the Nigerian Space Agency supported the need to integrate space technology with that of the Nigerian Armed Forces. Suggestions were made to establish a space command to monitor the progress of this integration.[229] Even though Nigeria is a new entrant into space, its ambitions to be a regional player are becoming more apparent. Nigeria is developing its second imaging satellite, which is expected to be launched in 2008.[230]

2007 Space Security Impact

The continued drive for more states to develop and deploy both dedicated military and dual-use space systems was reflected in 2007 along with a growing emergence of strategic partnerships. While an increase in the use of space for military purposes demonstrates the continued accessibility of the space environment and greater access to space technologies, states continue to operate and develop their space programs with considerable secrecy, reducing transparency of space operations. There are indications that these developments are affecting perceptions of security on Earth; how this in turns affects the security of space will depend on how states react to perceived threats from and in space. As more states become dependent on space systems for military operations and national security, mutual vulnerability may provide incentives to enhance the security of outer space or to develop capabilities to quickly negate space systems. The growing diversity of space systems for global navigation and positioning and communications may enhance the security of space operations by providing redundancy, particularly if they are interoperational.

CHAPTER SIX

6. Space Systems Protection

This chapter assesses trends and developments related to the research, development, testing, and deployment of physical capabilities to better protect space systems from potential negation efforts, which are examined in more detail in the Space Systems Negation chapter. Physical protection capabilities are designed to mitigate the vulnerabilities of the ground-based components of space systems, launch systems, communications links to and from satellites, and satellites themselves.

While physical capabilities can provide a certain degree of protection from potential negation efforts, they cannot make satellite systems invulnerable. Consequently, initiatives to prevent the proliferation and use of negation capabilities covered in the chapters on Laws, Policies and Doctrines and Commercial Space are also critical for protection, as is the achievement of collective space security as defined by the Space Security Index.

Both active and passive means can be used to provide three main types of space systems protection: 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. While attacks on the space negation capabilities of others, such as suspected anti-satellite (ASAT) systems, are considered protection measures by some, they are indistinguishable from other ASAT systems and are thus addressed in the Space Systems Negation chapter.

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, since it is important to know whether the failure of a space system is being caused by technical or environmental factors or by the deliberate actions of an attacker. Detection of an actual attack is often a precondition for effective protection measures such as electronic countermeasures or simply maneuvering a satellite out of the path of an attacker. The ability to detect an attacker is also a prerequisite for deterrence.

Protecting satellites, satellite ground stations, and communications links depends on the nature of the space negation threat that such systems face, but in general terms they 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.

A more advanced space systems protection capability is 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 rebuild space-based systems are much more difficult to develop. Capabilities to protect systems against environmental hazards such as space debris are examined in the Space Environment chapter.

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).[1] Other potential threats include radiofrequency weapons, high-powered microwaves, and "heat-to-kill" ground-based laser ASATs. Growing awareness of the vulnerabilities of space systems has led actors to develop space systems protection capabilities to better detect, withstand, and/or recover from an attack. Nonetheless, there are no effective protections against the most direct and destructive types of negation such as the use of kinetic or high-powered energy force against satellites aside from preventing proliferation and use of such capabilities.

These 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. The ability to detect and survive an attack could also help to deter negation attempts. Actors may refrain from attacks on well protected space systems if such attacks would seem to be both futile and costly.

However, the space security dynamics of space negation and protection are closely related. The use of protective measures to address system vulnerabilities could offer a viable alternative to offensive means to defend space assets. Given the concerns surrounding space debris, passive defensive measures may offer more sustainable approaches.

Because it is currently difficult to distinguish between satellite failures caused by environmental factors and deliberate attacks, some experts argue that greater space situational awareness (SSA) is critical to improvements in space security.[2] However, SSA raises dual-use concerns as it can also be used to track and target foreign satellites and is part of US space control programs.

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 an actor's fear of retaliation, reducing the threshold for using space negation capabilities. Finally, protection, which often increases the mass of the space system, can have cost implications that affect space access and use, and can thereby reduce the number of actors with secure use of space.

Trend 6.1: US and Russia lead in general capabilities to detect rocket launches, while US leads in the development of advanced technologies to detect direct attacks on satellites

The ability to distinguish space negation attacks from technical failures or environmental disruptions is critical to maintaining international stability in space. Early warning also enables the mounting of physical protection efforts, although the type of protection available may be limited. Detecting attacks on satellite ground stations is not addressed in any detail in this trend assessment since this capability is available to almost all actors with a conventional military capability.

Detecting rocket launches

During the Cold War the USSR and the US developed significant space-based early warning systems to detect ballistic missile and space rocket launches. These systems also provided some ability to detect the ground-based launch of an ASAT by monitoring the trajectory of the launch to see if it could place its payload into the same area as that of an existing satellite. Only the US and Russia currently have a space-based early-warning capability, although France is due to launch two early warning demonstrator satellites, Spirale-1 and Spirale-2, in 2008.[3]

The USSR launched its first space-based early warning Oko satellite in 1972 and had fully deployed the system by 1982. To maintain a continuous capability to detect the launch of US land-based ballistic missiles, the system had a minimum of four satellites in Highly Elliptical Orbits (HEO). 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 at the minimum possible level of four HEO satellites, which have since been lost and replaced by two satellites in HEO. The Oko system now provides coverage of US intercontinental ballistic missile fields about 12 hours a day, but with reduced reliability — capable of detecting massive attacks but not individual missile launches.[4]

The Oko system is complemented by an additional early-warning satellite in Geosynchronous Orbit (GEO), which is believed to be a next-generation US-KMO or Prognoz satellite capable of detecting missiles against the background of the Earth.[5] Russia began launching Prognoz in 1991. There have been up to six launches, but the program has been plagued by satellite malfunctions. Despite setbacks Russia completed construction of a new command and control station in 1998.[6] The complete system would be composed of up to seven GEO satellites and provide global coverage; only one is currently active. A new system is being planned for 2009.[7] Plans have also been announced to restore the space-based component of its missile attack warning system (MAWS), for which funding has been increased.[8]

Russia’s early warning capabilities also include nine 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.[9]

The US military has always emphasized space protection as one of the key pillars of its space doctrine.[10] First launched in 1970 US Defense Support Program (DSP) early warning satellites have 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.[11]

The US Air Force (USAF) initiated the Space Based Infrared System (SBIRS) and the Space Tracking and Surveillance Systems (STSS) to replace the DSP satellites in 1994; however, both face ongoing delays, funding shortfalls, and cost overruns.[12] When completed, these systems will be capable of detecting and tracking ballistic missiles and potential ground-based kinetic-kill ASATs. The SBIRS constellation will consist of three GEO satellites, but four are needed for global coverage. It will also include a spare satellite and additional sensors on two classified HEO satellites. By 2005 the total system cost had grown to an estimated $10.64-billion from $4.15-billion in 1995.[13] The first infrared sensor was launched in 2006 and the first GEO satellite was scheduled for launch in 2008.[14] Escalating costs led to the initiation of a parallel program in 2006: the Alternative Infrared Satellite System (AIRSS), supposedly designed to provide DSP-like functions with a simpler and cheaper design than that of SBIRS.[15]

The STSS system under development by the US Missile Defense Agency (MDA) aims 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 to 30 sensor-satellites in low Earth orbit (LEO). The program has been restructured and renamed several times since 2001, and has experienced significant cost growth.[16] Two STSS experimental satellites are scheduled for launch in 2008.[17] STSS has dual-use applications for space systems negation efforts and space-based strike capabilities.

Sea-based and terrestrial assets perform ballistic missile launch detection and tracking for China, France, and the UK. China's four Yuan Wang tracking ships are used for satellite tracking as well as missile detection and tracking. China is also believed to have one Large Phased-Array Radar for missile launch detection near Xuanhua in the west.[18] France employs the Monge tracking ship with ARMOR radars to track ballistic missiles, primarily for its missile testing program. On the Monge ship there are two C-band ARMOR radars with 10-meter receiver dishes capable of viewing objects up to 4,000 kilometers.[19] Royal Air Force Fylingdales in North Yorkshire, UK is a major space surveillance site with a Large Phased-Array Radar operating in the UHF frequency range. Fylingdales is one of three radars in the Ballistic Missile Early Warning System, which performs missile launch detection for Europe and the US. The radar also acts as a collaborative sensor for the US Space Surveillance Network (SSN) and is currently being updated to play a role in the US ballistic missile defense program.[20] Another early warning system has been proposed for the Czech Republic.

Detecting ASAT attacks

Most actors 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 actors 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 actors operating a satellite have some capability to detect spoofing (feeding a false signal), since basic electronic error code checking routines are relatively simple to implement. However, early warning for 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.[21] Only US satellites are known to have such capabilities, and only Russia, France, Germany, and perhaps China have reconnaissance satellites that might employ such capabilities.

Space-based conventional ASATs can be detected through the tracking of satellite maneuvers to monitor whether a satellite is in an orbit that could allow it to intercept or attack another satellite. Both the US and Russia have a limited ability to do this through their space surveillance capabilities. The US has been slowly augmenting this capability with the development of the Space Surveillance Telescope (SST), the Deep View radar, and the Large Millimeter Telescope and SBSS; however, these programs are generally under-funded and behind schedule. EU states have also discussed the feasibility of developing an independent space surveillance system (see Space Environment Trend 1.3). In 2004 the US began moderating access to satellite orbital information from its SSN because such data can also be used to support negation efforts.[22] While the ability to constantly monitor all satellites to detect hostile maneuvers would constitute a significant protection capability, no space actor currently has this ability.

Another approach to detection would be to place sensors on every satellite to allow the detection of nearby satellites and negation efforts. While no actor has fully developed these capabilities, the ongoing US Radio Frequency Threat Warning and Attack Reporting (RFTWARS) program aims to develop a lightweight, low-power radio frequency sensor suite to attach to individual satellites to provide situational awareness.[23] The US is also developing capabilities to detect electromagnetic interference on satellites through its Rapid Attack Identification Detection and Reporting System (RAIDRS) program. This largely classified program is defined by the US as a defensive counterspace system designed to identify, locate, and report attacks on US space systems, thus enabling timely deployment of defensive responses.[24] The system has been operating since 2005 with six fixed ground stations and three deployable ground segments.[25] Finally, the USAF is developing the Autonomous Nanosatellite Guardian for Evaluating Local Space (ANGELS) to shadow a space asset and provide local, on-orbit space situational awareness and anomaly characterization.[26] The first ANGELS launch is currently expected in 2009.

A high altitude nuclear detonation (HAND) can be detected by using gamma ray/X-ray/neutron flux detectors in orbit. Only the US and Russia are known to have such capabilities, and no other actors are known to be developing them. The US developed and launched 12 Vela series satellites, which would detect nuclear tests, to monitor compliance with the 1963 Limited Test Ban Treaty. Subsequently such instruments were integrated with DSP early warning satellites and Global Positioning System (GPS) satellites.[27] Russia integrates nuclear detonation warning sensors onto its GLONASS satellites. Actors in direct line of sight could also detect a HAND.

2007 Development

Russia upgrades its early-warning systems, but results are limited

On 23 October 2007 Cosmos 2430, a first-generation US-KS (Oko) early-warning satellite, was launched into HEO.[28] However, this did not serve to increase the capabilities of the system, which only provides 12-hour coverage of the US, as a similar satellite launched in 2004 appears to have ended operations, leaving Russia with an eight-month capability gap. The space-based portion of Russia's early warning system thus remains at just three satellites — two in HEO and one next-generation UK-KMO satellite in GEO.[29] However, there are reports that Russia has begun work on a new system called EKS (the Integrated Space System) and that on-orbit tests for the program will begin in 2009–2010.[30]

Russia also maintained efforts to end its dependence on foreign, ground-based early-warning radar stations as some of its current capabilities are based outside of Russian territory. According to the head of the Russian Space Force, Colonel-General Vladimir Popovkin, Russia intends to use systems only within its own territory and is likely to end usage of radars at Gabala, Azerbaijan, and Balkhash, Kazakhstan.[31] In July 2007 Russia withdrew its treaty with Ukraine for the use of two Soviet-era radars located at Mukachevo and Sevastopol, terminating it as of January 2008.[32] Russia has a program to build six new Voronezh-M phased array radars along its west, south-west, and southern borders, beginning with radars located in Lekhtusi and Armavir.[33] The Lekhtusi radar system began operations in December 2006 while construction of the Armavir facility was completed in May 2007. Although Armavir was expected to come online by December 2007 testing delays pushed the date into 2008.[34] The Southward facing Armavir radar provides roughly the same coverage as the Soviet-era early warning radar in Azerbaijan, and will be able to track rocket launches from the Middle East.[35] The Lekhtusi Voronezh-M radar is estimated to cost $80-million, while the remainder stations are estimated at $60-million each.[36] Despite this costly effort Russian early-warning capabilities will not be significantly increased, as systems are largely replacements for existing ones.

In additional to the new radars the Don-2N radar of the Moscow anti-ballistic missile system received an upgrade to its computational hardware and software in 2007.[37]

2007 Development

US early-warning upgrade efforts continue to face challenges, but also some success

The 23rd and final US DSP satellite was launched into GEO on 10 November 2007 onboard a Delta-4 Heavy rocket.[38] As the service life of the remaining DSP satellites comes to an end, the DSP function will be shifted to the USAF's next-generation SBIRS. The SBIRS system is currently planned to include three satellites in GEO and two sensor payloads piggybacking on classified reconnaissance satellites in HEO. However, the constellation is not expected to provide global coverage without a fourth GEO satellite.[39]

Several advances were made in 2007 toward launch of the first SBIRS GEO satellite in 2008, including testing of the infrared sensor used for detection, delivery of software for the launch, and testing of the ground segment.[40] In October 2007, however, a classified GEO satellite with a design similar to that of the SBIRS model suffered a failure, causing its mission to be terminated. Changes to correct a similar problem with the SBIRS satellite are expected to delay the program by one year and add $1-billion to the cost.[41] The first SBIRS GEO satellite is now expected to be launched in 2009.[42] The SBIRS program is estimated to cost $11-billion and is seven years behind schedule. The program is expected to receive $587-million in FY 2008.[43]

Due to the numerous delays and cost overruns of SBIRS the Alternative Infrared Satellite System, now renamed Third Generation Infrared Surveillance Program, (3GIRS),[44] was initiated by the USAF in December 2006 as a less complex alternative using existing technologies. Contracts were awarded to Raytheon, General Dynamics, and SAIC to begin work on the program in 2007.[45] However, in 2007 the objective of the AIRSS program changed from competing with SBIRS to becoming a SBIRS follow-on as the Air Force tries to determine how many SBIRS GEO satellites to purchase to provide global coverage.[46] The AIRSS program is estimated to cost $3.3-billion from FY2007 to FY2013. But Congressional support for the program faltered in 2007 when Congress approved only $75.9-million of the Air Force's $230.887-million request for FY2008. This decision reflects the fact that AIRSS is now no longer envisioned as a backup for SBIRS, but as a potential follow-on. The Air Force will decide whether to purchase the fourth SBIRS GEO satellite or opt for 3GIRS in the FY2010 budget.[47]

The second layer of US next-generation space-based ballistic missile detection and tracking, the MDA's STSS, is also significantly over cost and behind schedule. The US Congress cut the FY2008 budget for the program by $100-million (see Space Based Strike Capabilities).[48]

2007 Development

US focus on space situational awareness and space protection

Following the Chinese satellite intercept on 11 January 2007 US President Bush sent a classified memo to relevant government agencies calling for improved space situational awareness capabilities (SSA).[49] At least nine tasks related to improving US SSA were listed in the memo. The State Department and the Department of Defense (DOD) were directed to find ways to prevent future anti-satellite launches and to manage the consequences should one occur. One potential approach being investigated is to share SSA data among nations with space surveillance capabilities.

In a related development, funding for SSA efforts was increased by more than $100-million by the US Congress in the FY2008 budget authorization.[50] Programs that received additional funds include a variety of SSA and also potential space control functions including the Space Fence, RAIDRS, ORS, the Maui Space Surveillance System, Panoramic Survey Telescope and Rapid Response System, Space Situation Awareness research, the High Accuracy Network Discrimination System, Space Control, testing capabilities, and awareness.[51] The Maui Space Surveillance System, which tracks satellites, is scheduled to receive $42-million, up from $5-million in FY2007. RAIDRS received an $11-million increase to $64-million. An initial cut in funding for the Space Fence was reversed and overall SSA operations spending was increased from $187-million to $197-million.[52]

The US Congress also directed the Secretary of Defense and Director of National Intelligence to create a Space Protection Strategy that establishes “the priority within the Nation’s space programs on the protection of national security space systems,” highlighting the growing vulnerability of space systems demonstrated by the Chinese satellite intercept. It claimed that protection and SSA capabilities could together help to mitigate that vulnerability and called for better coordination between the two.[53]

2007 Development

Global development of space surveillance capabilities

Following years of debate over a potential European system[54], in 2007 the European Space Agency proposed creation of an agency to provide space weather forecasting and space surveillance services. The scope, budget, and source of funding of the proposed agency, as well as the potential contribution of data by various ESA member states will be discussed at a scheduled ESA ministers meeting in November 2008.

Also in 2007 the head of Ukraine’s Pivdenne Design Bureau claimed in an interview that the country has an independent ability to detect and monitor objects in orbit, but this capability has not been verified by outside sources. The Ukrainian system was apparently used to monitor three of the country’s Earth observation satellites along with Egyptsat-1. The interview also indicated that a similar system is being built for Egypt, and that negotiations are underway between Ukraine and Kazakhstan for cooperation on a similar deal.[55]

In Canada MacDonald, Dettwiler and Associates Ltd. was awarded a $65-million contract by the Department of National Defence to develop the information system for the SAPPHIRE program. SAPPHIRE will be Canada’s first space-based space surveillance satellite and is designed to monitor natural and manmade objects in GEO from altitudes of 6,000 km to 40,000 km. Data gathered will be integrated with the US Space Surveillance Network and used to update the US Satellite Catalog.[56] The spacecraft is expected to be launched in 2010 and cost $96.4-million, which includes the launch and two years of operating expenses.[57]

2007 Space Security Impact

As space actors seek to improve their launch detection and space surveillance capabilities, space security could be enhanced through greater transparency of space activities, more accurate threat detection, and greater redundancy, which can support protective responses and overall confidence. The benefits of space surveillance could be increased with data sharing among different actors. Yet the continued drive for independent space tracking systems indicate broader mistrust that could reduce space security, particularly as many aspects of these capabilities are enablers for space system negation. In this context, as demonstrated by the US focus on the space protection/negation elements of space situational awareness, greater transparency may not make actors feel more secure in space.

Trend 6.2: The protection of satellite ground stations is a concern, while the protection of satellite communications links is poor but improving

Protection of satellite ground stations

Satellite ground stations and communications links are the likeliest targets for space negation efforts since they are vulnerable to a range of widely available conventional and electronic weapons. Military satellite ground stations and communications links are generally well protected, whereas 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.[58] Satellite communications can usually be restored, however, 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,[59] leaving them potentially vulnerable to some of the most basic attacks, such as car bombs. As a notable example, the US GPS was operational for five years before a second primary ground station was completed.[60] Responding to such concerns, in 2002 the US General Accounting Office recommended that "commercial satellites be identified as critical infrastructure" (see Commercial Space Trend 4.3).[61] In the event of an attack the use of standardized protocols and communications equipment could allow alternative commercial ground stations to be brought online.

Electronic protection

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, although they may not elect to do so. Thus this chapter focuses on the increasingly critical area of the protection of satellite communications links. This is also an area in which space negation efforts have recently been undertaken, during times of peace and of conflict (see Space Systems Negation Trend 7.1).

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.[62]

Sophisticated electronic protection measures are generally unique to the military communications systems of technologically advanced states. 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 radio frequencies, to keep adversaries from “locking-on” to signals to jam or intercept them; (3) antenna side-lobe reduction designs that mitigate jamming or interception vulnerabilities by providing more focused main communication beams and reducing interference from jamming in the side-lobe regions; and (4) nulling antenna systems (adaptive interference cancellation), which monitor interference and combine antenna elements designed to nullify or cancel the interference.[63] This last technique is considered the most comprehensive anti-jamming technique in existence.[64]

During the Cold War the US and the USSR led in the development of satellite communications protection systems. The US currently appears to be the leader in developing advanced satellite communications protection. 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.[65] Through its Global Positioning Experiments project, the US has demonstrated the ability of GPS airborne pseudo-satellites to relay and amplify GPS signals to counter signal jamming.[66] The US and several other countries are currently developing laser-based communication systems, which could provide a degree of immunity from conventional jamming techniques in addition to more rapid communication; however, they continue to face technological challenges.[67] The US has also initiated a Cyberspace Command responsible for the military’s Internet and other computer networks, as well as the electromagnetic spectrum, which could cover satellite protection from directed energy weapons and communications jamming.[68] Technologies to protect against electronic jamming are increasingly available commercially.

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.[69] China is also reportedly upgrading its Xi’an Satellite Monitoring Center to monitor and diagnose satellite malfunctions, eliminate harmful interference, and prevent purposeful damage to satellite communications links.[70]

2007 Development

Slow but steady progress on laser satellite communication links

The US and Europe are slowly moving to the use of optical satellite communication links, which could provide both a degree of immunity from conventional jamming techniques and more rapid communications, but technological challenges remain.[71] In 2007 the US MDA tested a laser communication terminal developed by Tesat Spacecom of Germany and carried aboard the MDA’s NFIRE satellite.[72] The German laser terminal was added after the removal of the "kill vehicle" that was originally part of NFIRE. The experiments focused on satellite-to-ground communication; the data will be used to characterize the laser module's performance. Both Boeing and Lockheed Martin, which are competing to build the Transformational Satellite Communications (TSAT) space segment, validated their laser communications technology, developed for the Risk Reduction and System Definition phase.[73] A decision between the two systems was expected in 2007 but was not made.

France's Astrium Satellites and its subsidiary Tesat Spacecom in Germany launched a civil-military laser communication program in 2007.[74] The program will have four main applications: intersatellite communication; satellite-to-ground communication; links with deep space missions; and transmissions between low flying aircraft, low earth orbit satellites, and GEO satellites. Astrium has previously demonstrated satellite-to-aircraft laser communication with the Lola system, while Tesat Spacecom has laser terminals onboard the US NFIRE satellite and the German TerraSAR-X, also launched in 2007. The ESA is set to decide whether to include a laser terminal onboard the Sentinel series of Earth observation spacecraft for the Global Monitoring for Environment and Security (GMES) program. Tesat Spacecom and Oerlikon Space AG signed an agreement in June 2007 to collaborate on the development and manufacture of laser communication terminals for the GMES satellites if approved.[75] The companies will base their terminals on the system developed for Tandem-X, which has a data rate of 3–5 Gbits/s over 40,000 km. In November 2007 Oerlikon simulated laser transmission over a distance of 1.5-million km.[76]

2007 Development

US RAIDRS Unit becomes operational

Although the system has been operating since 2005, in May 2007 the USAF officially activated the 16th Space Control Squadron, which will be responsible for RAIDRS. The new unit will eventually be based at the Peterson Air Force Base in Colorado. The RAIDRS program received a funding boost in FY 2008 from $53-million to $64-million following concerns raised by the Chinese satellite interception.

2007 Development

Renewed focus on protecting commercial satellites

A call in 2007 for more protection measures for commercial satellites used by the US military was followed by willingness on behalf of commercial satellite operators to invest in special anti-jamming antennas and other defensive measures on the condition that the government's procurement strategy shift to encourage such long-term investments.[77] Currently the Defense Information System Agency awards contacts strictly based on the lowest bid, and satellite service providers are unwilling to shoulder the extra cost of expensive defensive measures. Anti-jamming systems used by the US military were put on the market for commercial satellites by EMS Technologies in 2007. It anticipates that 25 percent of the commercial satellite market will be interested in purchasing the system.[78]

Developments in 2007 had a mixed impact on space security. While some progress has been made toward securing ground-to-satellite communications through the use of laser links, progress remains slow due to major technological challenges and communication links remain vulnerable. In the meantime, a greater ability by the US to identify and respond to sources of interference might enhance the security of some systems, but efforts to better protect commercial satellites will only be effective if market incentives are in place.

Trend 6.3: Protection of satellites against some direct threats is improving but remains limited

After attacks on satellite ground stations and communications links the most significant space systems protection challenge is the defense of satellites from direct attack by conventional, nuclear, or directed energy weapons. In this case, the primary source of protection for satellites is derived from the difficulties associated with launching an attack of conventional weapons into and through the unique space environment to specific locations. Directed energy weapons must overcome atmospheric challenges and be effectively targeted at satellites, which orbit at great distances and move at very high speeds.

Twenty-eight actors are assessed to have a suborbital launch capability that allows them to launch a conventional or nuclear payload into LEO attitudes for a few minutes before it descends back into the Earth's atmosphere. Ten actors have developed an orbital launch capability; eight of these actors have demonstrated the capability to reach GEO. The fact that LEO can be reached in a matter of minutes, while GEO takes about a half-day to reach by completing a Hohmann transfer orbit, illustrates the unique protection dynamics associated with different orbits.[79] Some military systems are being placed into higher orbits such as Medium Earth Orbit (MEO) or GEO, but orbits are largely dictated by function. Russia leads in use of HEO applications.

There are defender advantages in space: for example, the distances and speeds involved in satellite engagements can be exploited to enhance satellite 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. 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 kilometers the predictability of orbits is limited to an error of approximately one kilometer for a prediction 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 kilometers. Surface finishes and designs optimized for heat dissipation and radar absorption can also reduce the observation signatures of a satellite, further complicating negation targeting efforts. Nonetheless, if an actor has the ability to overcome these natural defenses, there are few options available for physically protecting 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 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 opportunities when the longitude of the interceptor launch site matched that of the target satellite, which only occurred twice per day. 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 valuable fuel mass 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 only be large enough to avoid the weapons effects or target acquisition range of the interceptor,[80] but the extra fuel required might represent more than 10–20 percent of the satellite cost.[81]

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.[82]

Dispersion is a well established practice in terrestrial conflict that can be applied to satellite operations. 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. Over the longer term, on-orbit repair and robotic servicing capabilities will likely further improve the survivability of space systems. While signature reduction has been developed, particularly in the context of reconnaissance satellites, costs are significant. The US National Reconnaissance Office, for example, developed a stealth satellite program referred to as Misty, which was cancelled in 2007 following enormous cost overruns.[83]

In general, 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. But commercial satellites are increasingly exploiting slack in the commercial telecommunications systems to allow for distribution and redundancy.

Greater dependence on space systems is increasing the motivation for redundancy. China, the European Space Agency (ESA) and the EU (in partnership with others), and Japan are developing satellite navigation systems that will increase the redundancy of such systems on two levels. First, constellations of satellites such as the GPS and the proposed EU Galileo system are inherently protected by redundancy, since the loss of one satellite might reduce service reliability but not destroy the entire system. Second, different but often interoperable systems could create redundancy of entire navigation systems, as the US and EU agreed to do in 2004 with the GPS and Galileo systems (see Civil Space Programs and Global Utilities Trend 3.4).[84]

Higher orbits can also be utilized to take advantage of longer warning times and greater access difficulties. To some extent, Russia has led in the use of higher orbits by using HEO applications. The use of this orbit allows Russia to obtain better coverage of the US for a longer duration. Increasingly the US is recognizing the benefits of higher orbits and using them; other space actors are slowly following suit.

Technology development such as that by the Defense Advanced Research Projects Agency (DARPA) and the National Aeronautics and Space Administration (NASA) for the Orbital Express program may enable space-based defenses for kinetic attacks by developing architecture for future automated on-orbit spacecraft servicing. If successful, future on-orbit servicing could enable greater maneuverability for defensive purposes and extend the life of satellites, although it would also have notable dual-use capabilities.[85] On the other hand, more active space-based defensive systems may be indistinguishable from ASATs, particularly because many space-based kinetic threats in space cannot be countered except with a preemptive attack.[86] Moreover, more active measures to counter kinetic threats to satellites could create large amounts of space debris, doing more harm than good.

Protection against nuclear attack

Since all current nuclear weapon states also have suborbital space access, the capability to carry out a HAND attack is within the capability of at least these states. While unhardened satellites are quite vulnerable to the effects of nuclear weapons, there are three general measures that can be used to protect them: (1) radiation hardening, (2) electromagnetic pulse (EMP) shielding, and (3) scintillation and blackout avoidance.[87]

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.

EMP shielding protects sensitive satellite components from the voltage surges generated by nuclear detonations reacting with the environment and the internal voltages and currents generated when X-rays from a nuclear detonation penetrate a satellite.[88] 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 protection 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.

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 DSP early warning, 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. Both the US and Russia maintain hardening to protect against a HAND on their military assets, as do the UK and France. It is not clear from open sources whether China, India, and Israel employ such measures.

Most commercial spacecraft must install radiation-hardening to guarantee lifespan (typically 15 years) 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 are radiation-hardened by using materials developed for military specifications, which may provide some limited protection. Any physical protection normally creates an increased cost and it seems unlikely that the space industry will harden its satellites without significant prompting and subsidization from governments.[89] Protection measures vary in cost; for example, hardening against the radiation effects of a nuclear detonation is estimated to be about two to five percent of satellite costs, while hardening against the EMP effects of a nuclear detonation can be up to 10 percent of satellite costs.[90]

The US is pursuing technologies other than hardening to reduce the damaging long-term radiation belts caused by a HAND. The US High Frequency Active Auroral Research Program includes research on active measures to reduce the concentration of ionic particles in the upper atmosphere following a HAND.[91] Such measures would reduce the probability of satellite malfunction in the aftermath of a HAND.

Protection against a directed energy attack

The simplest form of directed energy weapon makes use of a ground-based laser directed at a satellite to temporarily dazzle or disrupt sensitive optics. Optical imaging systems on a reconnaissance 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. Because the attacker must be in the line of sight of the instrument, opportunities for attack are limited to the available territory below the satellite. A more advanced directed energy attack designed to degrade or damage sensitive optical or thermal imaging sensors requires higher laser powers (see Space Systems Negation). 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.[92] The use of higher orbits 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.[93] 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.

The US currently leads the way in both systems protection policy and technology to protect from directed energy attack. But commercial satellites typically lack protection from laser or microwave attack. Besides the US, only France and Russia are assessed to employ means such as higher orbits or spectral filtering on reconnaissance satellites to provide protection from directed energy attacks.

2007 Development

US continues to pursue space-based satellite protection

In 2007 the USAF awarded a $29.5-million contract to Orbital Sciences Corporation to upgrade the ANGELS program.[94] They are to be launched into space attached to a host satellite and detach once in orbit. The ANGELS satellite, designed to have a three-year lifespan, would have the ability to autonomously navigate around the host and perform inspections, detect and characterize unknown objects approaching the "keep out zones" around the host, and detect jamming. The FY2008 budget approved for the program includes funds for on-orbit testing and identification of technological options for incorporating the ANGELS satellite into LEO and GEO satellites.[95] Launch of the first satellite is anticipated in 2008. While the ANGELS satellites are intended to provide localized threat assessments, it is not clear what responses could be anticipated; the ANGELS program is intended to develop tools for "high value satellite defense."[96] While there are concerns about its potential use for space systems negation, information in open literature does not indicate that it will have the capacity to significantly change orbit to target foreign satellites.

In a different approach to space-based systems protection, two spacecraft for the Orbital Express program, ASTRO and NextSat, were launched into LEO on 5 March 2007 onboard an Atlas-5 launch vehicle.[97] Developed by prime contractor Boeing with DARPA and NASA, Orbital Express aims to develop architecture for future automated on-orbit spacecraft servicing.[98] The two spacecraft launched in 2007 completed a number of missions, testing automated approach and docking, fuel transfer, and component exchange. The results of these experiments demonstrated the feasibility of conducting automated satellite refueling and repair, which could extend the life of satellites and enable greater maneuverability for defense against threats. However, long- and short-range autonomous approach of a non-cooperative target was also demonstrated, raising the prospect that the technology could also support space-based negation capabilities. At the end of July 2007, after completion of the tests, ASTRO and NextSat were decommissioned.[99]

Another program exploring technologies for space-based protection from direct threats is the DARPA Tiny, Independent, Coordinating Spacecraft (TICS) program, which would involve small 10-pound satellites that could be quickly air launched by fighter jets to form protective formations shielding larger satellites from direct attacks. At $6-million in FY2008, the program is small, but one of its key objectives is to make TICS satellites relatively cheap.[100] The program could have an inherent anti-satellite capability, however, if used to swarm non-cooperative aircraft (see Space Systems Negation Trend 7.4).

2007 Space Security Impact

The development of autonomous on-orbit servicing satellites and nanosatellites for local space surveillance has the potential to improve space security for the actors employing those technologies by providing better on-orbit threat identification and response options to protect the space-based components of satellite systems. However, the basic technologies involved are also applicable for spacecraft negation and raise questions about the implications of more active space-based protection systems for the security of other actors in space. The overall impact on space security will depend greatly on how the relevant technologies are used and how transparent the usage is. Moreover, space-based protection capabilities themselves could be defeated by a determined attacker.

Trend 6.4: US leads in developing capabilities to rapidly rebuild space systems following direct attacks on satellites

The capability to rapidly rebuild space systems in the wake of a space negation attack could reduce vulnerabilities in space and increase the ability to recover from an attack. It is assumed that actors capable of operating a satellite are also able to recover from an electronic attack since such attacks do not, in most cases, cause permanent damage. It is also assumed that space actors have the capability to rebuild satellite ground stations. This assessment examines capabilities to rebuild space systems by launching new satellites into orbit in a timely manner to replace satellites damaged or destroyed by a space negation attack. Although efforts are underway 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 rapidly launching new satellites as a means 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.[101] 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. Indeed 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.[102] A significant number of Russia's current launches, however, are of other nations' satellites; Russia continues to struggle to maintain existing military systems in operational condition. Thus little redundancy is actually leveraged through this launch capability.[103]

The US leads in the development of next-generation responsive space capabilities. Since 2003 the USAF has promoted Operationally Responsive Space, with 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's *Strategic Master Plan FY06 and Beyond* notes, "An operationally responsive spacelift capability is critical to place timely missions on orbit assuring our access to space."[104] Several programs, including Falcon, address this concern.[105] Initial steps include a Small Launch Vehicle (SLV) subprogram for a rocket capable of placing 100 to 1,000 kg into LEO on 24-hours notice for under $5-million; however, the program is ultimately linked to a long-term prompt global strike capability.[106] Under this program AirLaunch LLC is developing the QuickReach air-launch rocket and SpaceX is working on the Falcon-1 to fulfill the SLV requirements.[107] 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."[108] A full ORS capability could allow the US to replace satellites on short notice,[109] enabling rapid recover from space negation attacks and reducing general space system vulnerabilities, but it remains in the distant future.

The concept for a US Space Maneuver Vehicle (SMV) 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.[110] Two technology demonstrators have been built, including the X-40 (USAF) and the X-37A (NASA/DARPA).[111] India is working on a similar design, the Reusable Launch Vehicle, but it is not anticipated before 2015.[112] The commercial space industry is contributing to responsive launch technology development through advancements with small launch vehicles, such as the Falcon-1 developed by Space Exploration Technologies (see Commercial Space Trend 4.2).

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.[113] 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.[114] More recently plans have been announced by Kazakhstan.[115] The US has been using 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.[116] Other efforts include the China Aerospace Science and Technology Corporation (CASC) plan to launch small payloads released from a modified H-6 bomber.[117]

2007 Development

US increases efforts for Operationally Responsive Space

Since 2003 the USAF has promoted the concept of Operationally Responsive Space. This vision was given renewed emphasis in April 2007 with the release of a US congressional report on ORS. The report laid out the motivations and requirements of ORS, as well as a roadmap for implementation. In May a DOD Operationally Responsive Space Office was opened at the Kirkland Air Force Base in New Mexico to coordinate the development of hardware and doctrine in support of ORS across the various agencies, with personnel drawn from across the Army, Air Force, Navy, DARPA, National Reconnaissance Office, and NASA. Funding officially began on 1 October 2007 and the budget for FY2008–2013 is estimated to be around $400-million.[118]

The ORS report recommended a three-tier approach to achieve operationally responsive space. Tier 1 would make use of existing satellites and re-task them as required, with a response timeframe of minutes to days after the initial request. Tier 2 involves building and launching small satellites on short notice to begin operations within weeks of a request. Tier 3 is similar to Tier 2, except that cutting edge technologies would be incorporated, extending the timeframe to a year from the date of request. According to the ORS report, Tier-1 capability is expected to be available in FY2007, while Tier-2 and -3 capabilities are expected to be available in late FY2008.

A key component of the ORS program is the TacSat series of experimental small satellites intended to test the ability of small satellites to carry militarily useful payloads, falling under Tiers 2 and 3 of the ORS report. TacSat-2, managed by the USAF Research Lab, was launched in December 2006 and successfully completed its mission in 2007. The 814-pound spacecraft carried instruments, including a one-meter-resolution optical telescope and a signals intelligence package.[119] The Air Force Research Lab is also managing the TacSat-3 program. The satellite will carry a hyperspectral imager in its payload, which

Alliant Technologies delivered in September 2007, and is scheduled for launch in June 2008.

Responsive launch capabilities are also essential for ORS. In 2007 SpaceX declared the Falcon-1 rocket operational, despite a premature second-stage shutdown during its second test flight on 20 March 2007. The next flight of the rocket is scheduled to carry Malaysia's RazakSAT Earth observation satellite into orbit.[120] Falcon-1 is part of the SLV portion of the DARPA/USAF Falcon project that seeks to develop launch vehicles that can send a 450-kg payload into LEO on 24-hours notice for less than $5-million. AirLaunch LLC is developing the QuickReach rocket and SpaceX is working on the Falcon-1 to fulfill the Falcon requirements.[121] In 2007 AirLaunch LLC was granted clearance by USAF and DARPA to begin the next development phase of the QuickReach rocket. The company plans to focus this phase on the liquid-oxygen-propane vapor pressurization propulsion system. The ORS Office also intends to provide funding for the development of low-cost responsive launch vehicles and is monitoring the results of the DARPA/USAF Falcon SLV program.[122]

A full ORS capability could allow the US to replace satellites on short notice, enabling rapid recover from space negation attacks and reducing general space system vulnerabilities.

2007 Development

Small and nanosatellite research may contribute to passive protection in space

Several developments took place in the US in 2007 to support the operational use of small satellites. NASA announced that it had developed a low-cost, 200-pound satellite with no moving parts or propellants.[123] The first FASTSAT prototype was developed in less than 11 months at a cost of less than $4-million. The satellite can have a payload of up to 110 pounds and can be launched by either SpaceX's Falcon-1 or Rocketplane Kistler's K-1 rockets, both of which were designed for responsive, affordable space launch. Boeing developed and launched the CubeSat Testbed-1 on 17 April.[124] The satellite weighs less than two pounds and is intended to demonstrate several software and hardware technologies for nanosatellites. ATK won a $3.3-million USAF contract, with an option for an additional $4.7-million, to develop a small satellite propulsion system combining both chemical and electrical methods.[125] DARPA released a Call for Proposal for System F6, which seeks to research, develop, and test a satellite architecture where the functionality of a single satellite is replaced by a cluster of free-fly subsatellites that wirelessly communicate with each other.[126] Each subsatellite of the system can perform a separate function or duplicate the function of another module. The use of smaller and smaller satellites to provide operational requirements in outer space, as well as the use of defensive clusters of satellites or the inclusion of space-based backup systems, could contribute to space systems protection strategies, including ORS..

Other actors that are seeking to develop more advanced microsatellites include China, ESA, Israel, Russia, the UK, Canada, and India.

2007 Space Security Impact

Whether efforts on more responsive space launch and flexible deployment of microsatellites will enhance the secure use of space systems remains unclear. The formal definition of the US ORS concept and the continued development of small satellites and launch vehicles are steps toward a rapid replacement capability, but an operational ORS capacity remains fairly distant. Further studies are also needed to determine the survivability of small satellites against potential threats. Nonetheless, the use of small and relatively low-cost satellites for a greater range of applications potentially allows actors to replace outdated, malfunctioned, or attacked satellites more often and quickly. Constellations of smaller satellites can also provide enhanced protection through redundancy, but because they are difficult to detect and track, transparency of and confidence in space activities could be reduced.

7. Space Systems Negation

This chapter assesses trends and developments related to the research, development, testing, and deployment of capabilities designed to negate the use of space systems. It also assesses the development of space situational awareness capabilities, including space surveillance, which is a key enabling technology for space systems negation since tracking and identifying targeted objects in orbit are prerequisites to most negation techniques. The development of technologies and capabilities that may be used to negate space systems is not necessarily linked to policies to use them.

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 United States as the five Ds: deception, disruption, denial, degradation, and destruction.

Many space negation capabilities apply to widely proliferated 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.[1] Conventional anti-satellite weapons include precision-guided kinetic-kill 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 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).[2]

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 likely succeed in the face of weak protection measures. Like other offense-defense relationships in military affairs, this space security negation-protection dynamic raises concerns about an arms race and instability as actors compete for the strategic advantages that space negation capabilities appear to offer. Different negation activities are likely to stimulate different responses.[3] While interruption of communication links would probably not be viewed as very provocative, physical destruction of satellites would be liklier 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 (see Laws, Policies, and Doctrines). Recent 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.[4]

These security concerns are compounded by the fact that many key space capabilities are inherently dual-use. For example, space launchers are required for many ASAT systems; microsatellites offer great advantages as space-based kinetic-kill vehicles; and space surveillance capabilities can support space debris collision avoidance strategies as well as targeting for ASAT weapons.

It is noteworthy that the application of some destructive space negation capabilities, such as kinetic-kill ASATs, would generate space debris that could potentially inflict widespread damage on other space systems and undermine the sustainability of space security. Similarly, a HAND is indiscriminate in its effects and would generate long-term negative impacts on space security. These concerns have led some experts to argue that carefully targeted space negation efforts may have a positive impact on space security if such efforts prevent the targeted actor from using space systems to inflict widespread, long-term damage to the space environment or otherwise prevent access to space.

Trend 7.1: Proliferation of 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 widely accessible weapons and technologies. An attack on the ground segments of space systems with conventional military force is the most likely space negation scenario. System sabotage; physical attack on the ground facility by armed invaders, vehicles, or missiles; and interference with power sources would require modest military means.

The US leads in developing advanced technologies to temporarily negate space systems by disrupting or denying access to satellite communications. The 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."[5] In 2004 the mobile CounterCom system, designed to provide temporary and reversible disruption of satellite communications signals, was declared operational.[6] 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."[7] 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."[8] The 2004 *Presidential Directive on Space-Based Positioning, Navigation and Timing Systems* calls for development of capabilities to selectively deny, as necessary, GPS and other navigation services.[9]

Electronic and information warfare techniques, including hacking into computer networks and electronic jamming of satellite communications links, are negation capabilities that are becoming increasingly available to both state and non-state actors. Incidents of electronically jammed media broadcasts have been reported in recent years, including interruptions to US broadcasts to Iran,[10] Kurdish news broadcasts,[11] and Chinese television (allegedly by the Falun Gong).[12] Iraq's acquisition of GPS-jamming equipment for use against US GPS-guided munitions during Operation Iraqi Freedom in 2003 suggests that jamming capabilities are proliferating the equipment was reportedly acquired commercially from a Russian company, Aviaconversiya Ltd..[13] The US CounterCom system is largely based on commercially available components.[14]

2007 Development

Tamil Tigers illegally broadcast radio and television on Intelsat signals

Following complaints by the Sri Lankan government reports emerged in 2007 that the Tamil Tigers were illegally using an Intelsat signal to broadcast radio and television.[15] Although Intelsat took steps to correct the problem, the event raises questions about the vulnerability of commercial satellites to external threats. The Tamil Tigers indicated that they had been using the Intelsat-12 satellite since May 2005, uplinking their programming from secret locations in Tamil-controlled regions of Sri Lanka.[16] While Intelsat maintains that the Tamil Tigers illegally used the free satellite transponders, the Tigers claim to have been using the service legally. Questions such as how the Tamil Tigers managed to accomplish the feat and why it took Intelsat so long to correct the situation remain unanswered. After Intelsat discontinued the Tamil Tiger's broadcast, the group tried to launch a second satellite television channel, TTN. Arrangements were made with Globecast, a subsidiary of France Telecom to uplink the programming to the Hotbird satellite.[17] Protests by the Sri Lankan government and the subsequent investigation into TTN revealed that the station was operating without a license from the French *Conseil supérieur de l'audiovisuel*, and the station faces closure.[18]

2007 Development

Mysterious jamming incidents demonstrate continued ease of jamming satellite communications

In September 2007 reports of satellite TV interruptions spread across Israel and Lebanon.[19] The source of the interference was not positively identified, but started at the same time as an Israeli air strike on a facility in Syria.[20] Originally thought to have been caused by the jamming tactics used by the Israeli force to disrupt air defense radars, an official Israeli investigation pointed to a different source of the interference: a Dutch ship operating as part of the United Nations Interim Force in Lebanon (UNIFIL) in the Mediterranean.[21] The Dutch government has since denied the claim and the investigation continues, with Russian and German vessels raised as potential causes.[22] The interference has disrupted the finances of the Israeli Yes satellite television company, resulting in thousands of cancelled viewer contracts and the launching of a class-action lawsuit against the company.[23] Eutelsat also investigated an unidentified source of interference in January 2007.[24] While unintentional satellite interference is an ongoing problem that relates to constraints on space resources such as frequencies and orbital slots, it also demonstrates the ease with which satellite signals, if not adequately protected, can be jammed by relatively low-grade technology.

2007 Development

Intrusion of secure computer networks in China, UK, Germany, France, and the US

Government computer networks in the UK, Germany, France, and the US reported incidents of hacking in 2007.[25] Networks affected include those belonging to the office of the German

Chancellor, the French Ministry of Defense, and the US Department of Defense.[26] The German Federal Office of Information Security discovered Trojan software installed on computers in the Chancellor's office and Pentagon officials acknowledged that some computers on a network serving the Office of the Secretary of Defense were shut down due to the intrusions. The attacks were thought to have originated from China, although the identities of those involved are unknown.[27] The purpose of the intrusions is thought to be information gathering and probing of network defenses.[28] According to a senior Chinese government official, Chinese computer networks were also under attack in 2007.[29] These attacks illustrate the weaknesses of even supposedly secured networks against computer invasions.

2007 Development

US and China upgrade capabilities for cyber attacks, jamming

The USAF initiated an upgrade of the CounterCom satellite jamming system it first deployed in 2004. The CounterCom system is a "mobile, ground-based antenna that can jam the signals from a single satellite in geosynchronous orbit."[30] The upgrade aims to fully equip two squadrons with seven jamming systems, up from the current two. USAF also started pre-acquisition work for next-generation jammers, which will have "enhanced capabilities for SATCOM denial" using largely commercially available components.[31] The USAF also intends to reduce the number of authorization steps and shorten the decision time to launch offensive cyber attacks against enemy networks. The goal is to provide lower-ranking officers with the authority to launch attacks so that they could take place within minutes.[32] Currently the only authority rests with the President and the Secretary of. Electronic jamming is in keeping with the USAF preference for temporary and reversible means of space systems negation. In 2007 the US Army reported that it had deployed and is using a "wildly successful"[33] ground-based system that is complementary to the USAF CounterCom to deny US enemies the ability to use commercial space capabilities.

Reports emerged in November 2007 that China had deployed advanced GPS jamming systems on vans throughout the country. Given the relatively weak signals of GPS, incidents of jamming are not new — for example, Russian systems have been used in Iraq and North Korea — but these have been easily defeated by the US military. Efforts to protect against the Chinese jammers may be more difficult.[34]

2007 Space Security Impact

Incidents of both deliberate and unintentional satellite interference in 2007 demonstrate the vulnerability of satellite communications and computer networks to external attacks. Moreover, the significant security and financial costs that result from interference show the debilitating effect that relatively low-cost, low-technology threats can have on the security of space operations. Facilitating and dispersing authorization for attacks could also create greater instability. It should be noted, however, that interference with satellite communications and ground stations is generally temporary and reversible and is less provocative and escalatory than other types of space system negation.

Trend 7.2: US leads in the development of space situational awareness capabilities to support space negation

Driven by Cold War security concerns the US and 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. Although the US remains dominant, Russia maintains 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 reportedly upgrading its Xi'an Satellite Monitoring Center, which is the primary control center for China's network of 13 monitoring stations. Upgrades include increased orbit determination and tracking capabilities of domestic and foreign satellites, which could be used to target negation activities against space-based assets.[35] The satellite intercepted by China on 11 January 2007 was tracked and targeted from this center.[36] Canada, France, Germany, and Japan are all actively expanding their ground- and space-based space surveillance capabilities (see Space Environment Trend 1.3).

The US explicitly links space surveillance with its space control doctrine and desire to achieve "space situational awareness." The 2001 *Quadrennial Defense Review Report* stated that the US would "pursue modernization of the aging space surveillance infrastructure, enhance the command and control structure, and evolve the system from a cataloging and tracking capability to a system providing space situational awareness."[37] Space Control is defined by the US Air Force (USAF) as "combat, combat support, and combat service support operations to ensure freedom of action in space for the United States and its allies, and when directed, deny an adversary freedom of action in space."[38][i]

The US Space Surveillance Network is the primary provider of space surveillance data. It has limited capabilities to provide real-time data collection, however, and restrictions were placed on the distribution of the data in the 2004 Defense Authorization Act.[39] The Space Situational Awareness Integration Office was created in 2002 within USAF Space Command, with responsibilities to oversee the integration of space surveillance to achieve space situational awareness.[40] Space-based surveillance, demonstrated by the US in the late 1990s through the Space Visible Sensor experiment,[41] is being pursued through the Space-Based Surveillance System (SBSS), described in the 2003 *Transformation Flight Plan* as "a constellation of optical sensing satellites to track and identify space forces in deep space to enable defensive and offensive counterspace operations."[42] A pathfinder SBSS satellite is set for launch in 2009.[43] But funding issues have bedeviled efforts to improve US space surveillance. In 2006 the US DOD cancelled the Orbital Deep Space Imager program, intended to develop satellites that would "provide a predictive, near real-time operating picture of space to enable space control operations" in GEO, citing budgetary constraints.[44] Traditional US willingness to provide space surveillance data to other governments and commercial firms has been challenged over the past several years — both for cost reasons and because of concerns about satellite security[45] (see Space Environment Trend 1.3).

2007 Development

Space surveillance capabilities highlight vulnerability of satellites to detection

During its first 16 months of operations the French space surveillance radar GRAVES detected between 20 and 30 satellites in LEO that are not listed in the official US Defense Department satellite catalog. These satellites are assumed to belong to the US, as the DOD catalogue excludes information on sensitive US satellites. French officials are planning to use the GRAVES radar data in negotiations with the US to remove sensitive French satellites from the catalog, but are waiting for more data from German space surveillance radars. French officials have claimed that they have enough information to determine the size, location, orbit, and transmitting frequency of the unlisted satellites.[46]

The GRAVES space surveillance radar is operated by the French Air Force. The radar is a bistatic design, with an emitter located near the Dijon Air Base in eastern France and a receiver located 400 km away on the Plateau d'Albion in Provence. The system, overflying France at an altitude between 400 km and 1000 km, is capable of detecting spacecraft as small as one meter in diameter.[47] More than 2,200 objects have been detected and categorized since GRAVES became operational at the end of 2005. The GRAVES system, together with similar systems in Germany and the UK, may contribute to a European Space Surveillance system.[48] Governments of the European Space Agency will be asked to approve this project in a meeting in 2008 (see Space Systems Protection Trend 6.1).

Funding for US space situational awareness (SSA) efforts was increased by more than $100-million by the US Congress in the FY2008 budget authorization.[49] This followed a classified memo by President Bush to relevant government agencies calling for improved SSA capabilities.[50] Also in 2007 the head of Ukraine's Pivdenne Design Bureau claimed in an interview that the country has an independent ability to detect and monitor objects in orbit, linked with its ability to control space; however, this capability has not been verified by outside sources[51] (see Space Systems Protection Trend 6.1).

2007 Development

Orbital Express satellite demonstrates automated approach using Space Situational Awareness data

In 2007 the DARPA/NASA Orbital Express program demonstrated the potential use of SSA data to support an automated approach to foreign satellites. Tracking data from the US Space Surveillance Network (SSN) were used by the Astro spacecraft in the initial stages of its approach to NextSat in the final experiment of the program.[52] During the experiment the two spacecraft were initially separated by more than 300 km. After the sensors onboard Astro lost track of NextSat at a distance of 310 km, the ground controllers used data from the SSN to provid Astro with a location fix for NextSat. Astro then maneuvered toward the predicted location of NextSat and its optical and infrared sensors were able to reacquire the satellite (see Space Systems Protection Trend 6.3).

2007 Space Security Impact

Space surveillance can support both protection and negation activities. Efforts to develop and enhance space surveillance systems can have a positive impact on space security by increasing the ability of actors to safely operate in space, enhancing transparency of outer space activities, and providing a redundancy of capabilities. But the potential for such capabilities to support deliberate attacks against satellites and other space objects is demonstrated through the centrality of space surveillance in identifying foreign satellites, space control efforts, and close proximity operations, depending on the extent to which the capability were integrated into military command systems. Transparency in the collection and use of space surveillance data would enhance its positive contribution to the security of outer space.

Trend 7.3: Ongoing proliferation of ground-based capabilities to attack satellites

As noted in Figure 7.1 a variety of American and Soviet/Russian programs during the Cold War and into the 1990s sought to develop ground-based ASAT weapons employing conventional, nuclear, or directed energy capabilities.

Figure 7.1: History of ground-based ASAT programs[53]

System	Actor	Dates	No. 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 recognized as an ASAT test	1	Megawatt-class chemical laser fired at satellite to disable electronic sensors
Ground-Based Kinetic Energy ASAT Medium-range ballistic missile-based kinetic energy ASAT	US (US Army) China (PLA)	1990-2004 2007-	0 1	Kinetic-kill vehicle launched from the ground to intercept and destroy a satellite Destroyed the Feng Yun 1C weather satellite

Conventional (kinetic hit-to-kill) weapons

Launching a payload to coincide with the passage of a satellite in orbit is the fundamental requirement for a conventional ASAT capability. Twenty-eight actors have demonstrated suborbital launch capabilities; 10 of this number have demonstrated an orbital launch ability (see Civil Space and Global Utilities Trend 3.1). With tracking capabilities, a payload of metal pellets or gravel could be launched into the path of a satellite by suborbital rockets or missiles (such as a SCUD missile).[54] Kinetic hit-to-kill technology requires more advanced sensors to home in on the target. Targeting satellites from the ground using any of these methods would likely be more cost-effective and reliable than space-based options.[55]

USAF *Counterspace Operations* Doctrine 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."[56] It describes the planning for and execution of such operations, including legal considerations and targets, which include satellites; communications links; ground stations; launch facilities; command, control, communication, computer, intelligence, surveillance, and reconnaissance systems (C4ISR); and third-party providers. 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 (KE) ASAT program was terminated in 1993 but was later granted funding by Congress in FY 1996 through FY2005.[57] Congress appropriated $14-million for the KE ASAT for FY2005 through the Missile Defense Agency's (MDA) Ballistic Missile Defense Products budget.[58] It is part of the Army Counterspace Technology testbed at Redstone Arsenal.[59] However, the US has not conducted a kinetic energy ASAT demonstration since 1985.

The US has deployed a limited number of ground-based exoatmospheric kill vehicle (EKV) interceptors for ballistic missile defense purposes.[60] EKVs use infrared sensors to detect ballistic missiles in midcourse and maneuver into the trajectory of the missile to ensure a hit to kill.[61] With limited modification, the EKV could act as an ASAT against satellites in LEO.[62] Russia has developed a long-range (350 kilometer) exoatmospheric missile, the Gorgon, for its A-135 anti-ballistic missile system.[63] Russia continues to observe a voluntary ASAT test moratorium. The precise status of its ASAT system is not known, but it is most likely no longer operational.[64] China has developed an advanced kinetic ASAT capability, demonstrated by tests in 2005 and 2006 that culminated in the destruction of a Chinese weather satellite on 11 January 2007.[65] The UK, Israel, and India are also exploring techniques for exoatmospheric interceptors.[66]

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.[67] Given the current global dependence on the use of 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.[68]

China, the member states of ESA, India, Israel, Japan, Russia, Ukraine, and the US possess space launch vehicles capable of launching a nuclear warhead into orbit, although placing weapons of mass destruction in outer space is prohibited by the Outer Space Treaty. North Korea, Iran, 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 assessed 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.[69] Iran reportedly ended its nuclear weapons program in 2003, but the International Atomic Energy Agency continues to investigate potential illegal uranium enrichment activities.[70] Iran also has an active long-range missile program.

Directed energy weapons

The ASAT potential of high-energy lasers has been extensively explored by the US the USSR/Russia and China. All states have access to low-powered lasers, which could be used to "dazzle" unhardened satellites in LEO, and many may already have the capability to use low-power lasers to degrade unhardened sensors on satellites in LEO.[71] In 1997 the US Mid-Infrared Advanced Chemical Laser (MIRACL) was test fired against a satellite in a 420-km orbit, damaging the satellite's sensors. Reportedly, it was a 30-watt laser used for alignment that actually damaged the target satellite's sensors,[72] suggesting that even a commercially available low-watt laser functioning from the ground could be used to "dazzle" or temporarily disrupt a satellite.[73] The megawatt class MIRACL laser system is able to dazzle and blind sensors in GEO and heat to kill electronics on satellites in LEO — a significant ASAT capability. Similarly the USAF Starfire Optical Range at Kirtland Air Force Base in New Mexico is undertaking laser experiments under the Advanced Weapons Technology program that was characterized as "experiments for application including antisatellite weapons" and called for a demonstration of "fully compensated beam propagation to Low-Earth orbit satellites" in the FY2007 budget request. Funding was only authorized after the USAF denied any intent to test Starfire as an ASAT.[74] Until 2004 the US was developing a Counter Surveillance Reconnaissance System (CSRS) that employed lasers to temporarily disrupt surveillance satellites by dazzling their sensors.[75]

The Airborne Laser currently under development in the US is central to plans for future Boost Phase Ballistic Missile Defense.[76] The project achieved "first light" in 2004 in a ground-based test of the chemical oxygen iodine laser.[77] This technology is assessed by some experts to have ASAT capabilities; however, the Airborne Laser continues to suffer from serious technology challenges, schedule delays, and cost concerns within Congress.[78] Other US High Energy Laser projects include the Joint High Power Solid State Laser (JHPSSL).[79]

China operated a high-power laser program as early as 1986 and is now believed to have multiple hundred-megawatt lasers.[80] Chinese researchers are also studying adaptive optics to maintain beam quality over long distances and the use of solid state lasers in space; both technologies could apply to ASAT applications.[81] In 2006 China reportedly used a ground-based laser to illuminate an American reconnaissance satellite flying over Chinese territory.[82] It is difficult to verify from public sources the nature of the laser beam, the physical effects on the spacecraft, or the intent behind the illumination.[83]

A summary of the technologies that are required to support the development of ground-based capabilities to attack satellites is provided in Figure 7.2 below.

Figure 7.2: Technologies required for the development of ground-based capabilities to attack satellites

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

Key: ■ = Enabling capability

2007 Development

China tests direct ascent missile against its own satellite, triggers protective response

Previously unreported attempts by China to intercept a satellite with a missile on 7 July 2005 and 6 February 2006 culminated in a successful intercept on 11 January 2007.[84] The target was the retired Feng Yun 1C (FY-1C) weather satellite, launched in 1999 into a Sun-Synchronous orbit with an altitude of 850 km.[85] Reports indicate that the missile was launched from a mobile launcher at the Xichang Space Launch Center, or a site close to it. The FY-1C was moving south when the kill vehicle collided with it at high velocity. The booster that delivered the kinetic kill vehicle is believed to be based on a medium-range, two-stage, solid-fuelled ballistic missile, possibly the DF-21.[86] A significant amount of large and small debris was ejected into popular LEO, GEO, and sun-synchronous orbits. China is the second country to successfully carry out a kinetic hit-to-kill intercept of a satellite, and this is the first instance of a ground-launched intercept. It demonstrates the country's advanced tracking, targeting, and precision guidance capabilities in space, as well as its ability to use those technologies for space negation purposes. Despite the test 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.[87] The intention of the satellite intercept is not clear. In response to concerns expressed by many states Chinese authorities maintain that the test was "not targeted at any country and will not threaten any country."[88] Both the US and Russia ceased testing kinetic anti-satellite systems during the Cold War (see Space Environment Trend 1.1 and Laws, Policies and Doctrines Trend 2.2).

Demonstrating the sensitive negation-protection dynamics of space, the US response appears to focus on increasing its ability to detect future attacks on its space assets and to replace lost capabilities should an attack or equipment failure occur. US President George W. Bush sent a classified memo to relevant government agencies calling for improved situational awareness capabilities and directing the US State Department and the US Department of Defense (DoD) to look for ways to prevent future ASAT launches and to manage the consequences. The FY2008 National Defense Authorization Act contains a provision that requires the

Secretary of Defense to develop a Space Protection Strategy for periods beginning in 2008 and continueing through to 2025.[89] The first report on the strategy is due six months after the bill's enactment. Previously announced funding cuts to US SSA efforts were reversed and the various programs received an overall funding boost in the FY2008 budget.[90] The US Operationally Responsive Space program also received $20-million above the original $87-million requested for a total of $107-million.

Efforts are ongoing to develop High Altitude Airships and long endurance unmanned air vehicles to supplement US space capabilities.

In 2007 India also focus on protecting its satellites, renewing plans to create an aerospace defense command, although such a capability remains several years away.[91]

2007 Development

US continues development of ballistic missile defense systems and considers use against a de-orbiting satellite

US BMD programs achieved several milestones in 2007, including nine launches that met basic testing objectives.[92] These intercepts included five by the Aegis BMD system (short- to medium-range) and one by the Ground-based Midcourse Defense (GMD) System (long-range), which have the capability of reaching LEO. The GMD system has only completed two end-to-end tests of engagement sequences since 2002, however, and some sensor elements such as the Forward Based X-band-Transportable Radar (FBX-T) have yet to show that they can pass tracking and surveillance data to the GMD system in real time.[93] Interceptors on the Aegis BMD system and the GMD system both use infrared sensors to detect ballistic missiles in midcourse and maneuver into the trajectory of the missile to ensure a hit to kill.[94] Some experts assess that, with limited modification, these systems could act as ASATs.[95] In December 2007 MDA was asked by the National Reconnaissance Office (NRO) if it would be possible to intercept its failed US-193 reconnaissance satellite that had de-orbited and would reenter the Earth's atmosphere in 2008.[96]

The US also continued to pursue boost-phase BMD capabilities, which could potentially be used to prevent an actor from launching a satellite. The Kinetic Energy Interceptor (KEI) program has spent almost $1-billion over the past five years, with requests for large increases over the next few years.[97] While the KEI aims to provide boost-phase missile defense through "a fast-burn, high velocity, mobile interceptor," the program is plagued with technological challenges.[98] Still, the KEI completed several development tests in 2007, including "booster hypersonic wind tunnel tests," and it acquired "Facilities and Range support services for first booster flight."[99]

In addition to the KEI program, Raytheon and the MDA are modifying the AIM-120 Advanced Medium Range Air-to-Air Missile (AMRAAM) under the Network Centric Airborne Defense Element (NCADE) program to develop an air to air missile suitable for boost phase intercepts. The program completed several tests in 2007, including the imaging of an Orion sounding rocket at close range by a NCADE seeker mounted on an AIM-9X missile, but is quite small, with a budget of only $6-million in FY2008.[100]

The Airborne Laser (ABL) also achieved several hardware and performance advances in 2007. Mounted on a modified Boeing 747 jet, the ABL is a high-powered chemical laser to be used as a direct energy interceptor for short-range ballistic missiles in boost phase. In 2007 the illuminator laser was successfully fired more than 50 times during in-flight tests and the chemical main laser was integrated into the ABL aircraft. Integration will continue in 2008, with missile interception flight tests currently planned for 2009.[101] The ABL aircraft, which is equipped with the Surrogate High Energy Laser, also demonstrated one full engagement sequence in flight on 24 July 2007. The test involves detecting and tracking a target board carried by a modified KC-135 using the Target Illuminator Laser (TILL), illuminating the target with the Beacon Illuminator Laser (BILL) and adjusting for atmospheric distortions using BILL reflections, and finally illuminating the target board using the surrogate laser.[102] The Airborne Laser program had a budget of $598-million in FY2007, and $513-million was approved for FY2008, a reduction of $35-million, although both the House and Senate initially opted to cut the program by at least $200-million.[103]

Funding for the program comes despite its being "a high risk technology development and demonstration program"; it has "suffered numerous delays and cost increases since its inception in 1996, and it is currently estimated that it will cost $5.1-billion from inception to the completion of the first test to shoot down a target missile, currently scheduled for 2009. The original cost estimate to complete the first shoot-down test was $1-billion." Even if successful, "the first shoot-down test will not determine whether the ABL could be made operationally effective or affordable. There are inherent operational constraints in the ABL concept that would have to be overcome. Additional testing would be required to demonstrate operational capability and military utility. Furthermore, even if the follow-on testing were successful, the system would likely not provide an operational capability until 2018 or later."[104] While it is developing and testing advanced laser applications that could form the basis of directed energy anti-satellite capabilities, technical challenges to the program remain daunting.

2007 Development

Ballistic missile defense efforts in Japan, and India could lay the foundation for potential ground-based ASAT capabilities

As the desire for a BMD capability spreads, so too do the technical capabilities, which could be modified for the purposes of space systems negation. Japan is the largest international BMD partner with the US. On 17 December 2007 the destroyer JS KONGO became the first Japanese ship to successfully perform a sea-based mid-course intercept against a ballistic missile target during the Japan Flight Test Mission-1.[105] JS KONGO is an Aegis-class destroyer equipped with the Aegis Missile Defense System. During the flight test an Aegis SM-3 missile detected, tracked, and intercepted an exoatmospheric target missile launched from the US Navy's Pacific Missile Range Facility in Hawaii. The ship also previously participated in two earlier tracking exercises where its radar detected and tracked target missiles launched from the Pacific Missile Range Facility. The Aegis SM-3 is a fairly mature technology that could be modified for use against satellites in LEO. But current Japanese policy prohibits ASAT activities and changing this policy requires an amendment to the Japanese constitution.

India is attempting to build its own indigenous BMD system and achieved several successes in 2007, although the program is not yet capable of threatening satellites and there are no plans to pursue exoatmospheric capabilities. India reportedly tested a hypersonic Advanced Air Defense interceptor missile against a modified Prithvi target missile.[106] The missile was tracked using the long-range tracking radar, developed with the help of Israel, and the intercept occurred at an altitude of 15 km. A few days earlier there was a similar test of an intercept at an altitude of 50 km.[107] Many technological challenges still face India's BMD efforts, but it continues to progress.

Figure 7.3: Ballistic missiles with a range over 1000 km by country[108]

Country	System Name	Status	Range (km)	Payload (kg)
Asia				
China	CSS-2 (DF-3/3A)	Operational	2,650/2,900	2,150
	CSS-3 (DF-4)	Operational	5,500	2,200
	CSS-4 (DF-5/5A)	Operational	12,000/13,000	
	CSS-5 (DF-21)	Operational	1,800	600
	DF-25	Operational	1,700	2,000
	CSS-9 (DF-31)	Operational*	8,000	700
	DF-31A	Operational**	12,000	800
	CSS-N-3 (JL-1) (SLBM)	Operational	2,500	500
	CSS-NX-5 (JL-2) (SLBM)	Operational ■	2,000-8,000	1050-2,800
India	Agni-II	Operational	2,000/2,500	1,000
North Korea	Nodong	Operational	1,300	700-1,000
	Taepodong I	Testbed ■	1,500-2,000	1,000
Pakistan	Ghauri I (Hatf V/Nodong)	Operational	1,300	500-750
	Ghauri II	Operational	1,500-2,000	700
	Shaheen II	Operational	2,000/2,500	750-1,000
Russia and United States				
Russia	SS-18 (Satan)	Operational	9,000-11,000	8,800
	SS-19 (Stiletto)	Operational	10,000	4,350
	SS-24 (Scalpel)	Operational	9,000-11,000	8,800
	SS-25 (Sickle)	Operational	10,500	1,000-1,200
	SS-27 (Topol-M)	Operational	10,500	1,000-1,200
	SS-N-18 (Stingray) (SLBM)	Operational	6,500	1,600
	SS-N-23 (Skiff) (SLBM)	Operational	8,300	2,800
United States	Minuteman III (MK-12/12A)	Operational	9,650+	1,150
	MX Peacekeeper	Operational	9,650+	3,950
	Trident II (D5) (SLBM)	Operational	7,360+	2,800
Europe				
France	M-45 (SLBM)	Operational	6,000	?
United Kingdom	Trident II (D5) (SLBM)	Operational	7,360+	2,800
Middle East				
Iran	Shahab III	Operational	1,300	750-800
	Ashoura	Operational ■	2,000 ■	■
Israel	Jericho III	Operational ■ ‡	3,000-6,500	1,000-1,300
Saudi Arabia	Dong Feng-3 (CSS-2)Ω	Operational	2,600	2,150

* Limited deployment according to DOD Report to Congress on PRC military power

** Limited deployment according to DOD Report to Congress on PRC military power

■ Possible testbed for multistage missile technologies. Involved in the satellite launch attempt in 1998

‡ Not explicitly mentioned in newspaper article http://www.haaretz.com/hasen/spages/945859.html

Ω Imported from China

2007 Development

Ongoing development of high-energy lasers and adaptive optics

Several actors are developing ground-based lasers, adaptive optics, and tracking systems that 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 a number of industrial countries such as Canada, China, Japan, Russia, the US, and India are involved.[109] Actors that are developing laser satellite communication systems, such as France, Germany, and Japan, also inherently have the ability to track and direct a laser beam at a satellite. Several actors have demonstrated the technical ability to generate relatively high-powered laser beams. Both Israel and the United States have developed prototypes of laser systems that are capable of destroying artillery shells and rockets at short ranges.

Following background information denying any intent to test the system as an ASAT, the USAF Starfire Optical Range requested $5.7-million in FY2007 to test fire a laser at a satellite in LEO.[110] There is no public information emerged that such a test took place in 2007, but the US DOD received $44-million in funding for Starfire in the FY2008 budget.[111] The Chinese government is devoting resources to high-power solid state laser research.[112] As of 2007 power outputs in the single-digit kilowatt range have been achieved. While this output is much lower than the 100 kW considered necessary for a weapon, the 1997 MIRACL test demonstrated that even low-power lasers can damage satellites. South Korea is also interested in developing laser systems for use against North Korean missiles and artillery shells, and hopes to deploy a system starting in 2010.[113] Japan is interested in developing an air- and ground-based laser system for BMD. The Japanese Ministry of Defense plans to request funding for research and development for a ground-based system in its FY2008 budget and it is also interested in participating in the US ABL program.[114] Indian defense scientists are also reportedly experimenting with "high-power laser weapons."[115]

2007 Space Security Impact

The Chinese satellite intercept in January 2007 ended a 20-year pause in known ASAT testing and demonstrated a current capability to destroy LEO satellites. The successful destruction of FY-1C and the debris cloud created are both negative developments in space security, compounded by a potential spiral of capabilities and tests — indicated by US anti-ballistic missile activities — as well as other protective responses. The continued development of high energy lasers combined with adaptive optics could have a negative impact on space security as it has the potential to cause permanent damage to a satellite. The same technologies could also be applied to satellite tracking and identification. The development of theater-level ABM capabilities by the various actors, although not a direct threat to space objects, is cause for concern, because most of the necessary technologies, such as target detection, tracking, homing, command and control networks, and boosters, are also applicable to ASAT roles.

Trend 7.4: Increasing access to space-based negation-enabling capabilities

Deploying space-based ASATs, whether using kinetic-kill, directed energy, or conventional explosive techniques, would require somewhat more advanced enabling technologies beyond the fundamental requirements for orbital launch. Many of these technologies could be advantageous for a variety of civil, commercial, or non-negation military programs, but microsatellites, maneuverability, and other autonomous proximity operations are essential building blocks for a space-based negation system. 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 7.4.

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. Relatively inexpensive to develop and launch and with a long lifespan, microsatellite technology serves many useful purposes. A microsatellite's purpose would be difficult to determine until detonation and, because of its small size, a space-mine microsatellite would be hard to detect, particularly if launched discreetly.

The proliferation of microsatellite technology has involved a wide array of new state, commercial, and academic actors engaging in satellite research and development. At least 30 states have at some time employed microsatellites (see Civil Space Programs and Global Utilities Trend 3.1). In 2000 the partnership between China and Surrey Satellite Technology Ltd. of the UK saw the launch of the Tingshua-1 microsatellite and companion Surrey Nanosatellite Application Platform to test on-orbit rendezvous capabilities.[116]

A variety of ongoing US programs are developing advanced technologies that would be foundational for a space-based conventional ASAT 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 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. However, in 2005 MDA cancelled the kill vehicle experiment after Congress expressed concerns about its applicability to ASAT development.[117] In 2006 the US launched a pair of Microsatellite Technology Experiments (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 US Air Force and the US Navy. A major goal of the MiTEx demonstrations is to assess the potential of small satellites in GEO for defense applications.[118] Another missile defense technology that could enable space systems negation would be the space-based interceptor (SBI) (see Space-Based Strike Capabilities Trend 8.1).[119]

Figure 7.4: 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[120]	X	X	X		X	X	X	X	X	X
Land – Mobile[121]	L		L	L	L	L		X	L	X[122]
Sea	L[123]							X[124,125]	X[126]	X[127]
Air								D[128]		X[129]
Space tracking (uncooperative)										
Optical (passive)	X[130]	X	X[131]	X[132]			X[133]	X[134]		X[135]
Radar	X[136]		X[137]	X[138]			X[139]	X[140]		X[141]
Laser[142]	X	X	X	X		X	X	X	X	X
Autonomous rendezvous										
Cooperative		D[143]						X[144]		D[145]
Uncooperative		D[146]						F[147]		D
Proximity operations										
Cooperative		D[148]								X[149]
Uncooperative		D[150]								X[151]
High-g, large-ΔV 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 capabiity 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.

Autonomous rendezvous capacity was also the objective of NASA's Demonstration of Autonomous Rendezvous Technology (DART) spacecraft, relying on the Advanced Video Guidance Sensor and GPS to locate its target.[152] In 2005 the ASAT capability of maneuverable microsatellites was demonstrated when the DART unexpectedly collided with the target satellite and bumped it into a higher orbit.[153]

The DARPA Orbital Express program will develop on-orbit refueling and reconfiguring — servicing necessary to maneuver a space-based ASAT.[154] These programs use smaller, lighter components and are consistent with a growing US emphasis on responsive space programs (see Space Systems Protection Trend 6.3).

On-orbit servicing is also a key research priority for German and Canadian civil space programs and supporting commercial companies. The joint German-Russian-Canadian on-orbit servicing program, Technology Satellite for Demonstration and Verification of Space Systems, is testing proximity operations and on-orbit maintenance of satellites. It will explore "in-orbit qualification of the key robotics elements (both hardware and software) for advanced space maintenance and servicing systems, especially with regard to docking and robot-based capturing procedures." Germany's Spacecraft Life Extension System project plans a satellite "tugboat" to keep satellites in orbit beyond their intended lifespans.[155] The ConeXpress Orbital Life Extension Vehicle being developed by Orbital Recovery is set to be the first commercial satellite that is specifically designed to rendezvous with a target satellite in GEO. There is no evidence to suggest that these programs are intended to support space systems negation purposes, but the technologies could conceivably be modified for such an application.

Researchers at Chinese universities are analyzing on-orbit homing and rendezvous methods, although it is unclear whether the research is original and Chinese-initiated or merely a review of previously conducted foreign research.[156]

2007 Development

US and European states testing space-based technologies with potential negation capabilities

The USAF's XSS-11 program uses microsatellites to test proximity operations, including autonomous rendezvous, maneuvering, and close-up inspection of a target in LEO. It was launched in 2005 and funding for a follow-on XSS mission was requested. The FY2007 budget included $26.6-million to complete the bus and payload for the next XSS satellite, to perform environmental testing, and to begin integration with the launch vehicle.[157] The program received $28.9-million in FY2008.[158] The budget request indicated that XSS-11 remained in orbit in 2007 and that another launch is planned for 2009. The fact that the program is linked to the Advanced Weapons Technology element of the budget suggests that it could evolve into an ASAT program.[159]

A smaller program aimed at developing similar technologies, the Microsatellite Demonstration Science and Technology Experiment Program (MiDSTEP) sponsored by DARPA, the USAF, and the US Navy, integrates a variety of advanced technologies into microsatellites that can operate as high as GEO orbits. These technologies include lightweight optical space situation awareness sensors, lightweight power, chemical and electrical propulsion systems, and active radio frequency sensor technologies. They are being demonstrated in space through Microsatellite Technology Experiments (MiTEx) satellites launched in 2007.[160] The project received $8-million in FY2007 and requested $10-million in 2008 to study the results of the MiTEX experiments. While there is little public information available to verify the intent of the MiDSTEP program, the stated technologies could have ASAT applications.[161] The experimental Naval Research Laboratory (NRL) upper-stage motor has solar panels, high performance delta-V motors, long lifetime attitude control thrusters, a high performance star tracker, and large capacity fuel tanks.[162] It is thought to possess greater capability and have a longer lifespan than is required to transfer a pair of microsatellites to GEO and could potentially be designed to maneuver for close proximity operations with other satellites. Potential uses include passive reconnaissance missions or more hostile negation efforts to interfere with or even damage satellites. These activities could be done discreetly, as such small satellites are difficult to reliably detect and track, particularly in GEO.[163]

Other US programs developing a range of space-based, dual-use maneuvering, autonomous approach, and docking capabilities include the DARPA/NASA Orbital Express program, which demonstrated the feasibility of conducting automated satellite refueling and repair in 2007; and the Autonomous Nanosatellite Guardian for Evaluating Local Space (ANGELS) program, intended to shadow a space asset and provide local, on-orbit space situational awareness and anomaly characterization, with first launch planned for 2009.[164] These programs are covered in more detail in Space Systems Protection Trend 6.3. DARPA and the NRL are also developing a space tug capable of physically maneuvering another satellite in orbit under a program called Front-End Robotic Enabling Near-Term Demonstrations (FREND). It is "designed to allow interaction with geosynchronous orbit (GEO)-based military and commercial spacecraft, extending their service lives and permitting satellite repositioning or retirement."[165] In August 2007 the Alliance Spacesystem LLC delivered a prototype robotic arm to the NRL for FREND, while a second arm built to spaceflight requirements is scheduled to be delivered in July 2008.[166]

The NRL has developed and ground tested the guidance and control algorithms to enable a spacecraft-mounted robotic arm to autonomously grapple another satellite not designed for docking.[167] Although not the intention of the program, the capabilities being developed could have applications for space-based systems negation, particularly because the docking and maneuvering capabilities are being designed for use against satellites that could be non-cooperative. Program funding remains modest, however, at $14.4-million for FY 2008.

Another program exploring technologies for space-based protection from direct threats is the DARPA Tiny Independent Coordinated Spacecraft (TICS) program, which would create small (10-pound) satellites that could be quickly air launched by fighter jets to form protective formations shielding larger satellites from direct attacks (see Space Systems Protection Trend 6.3).[168] The program objective to create small satellites that are "hard to detect," can be inserted into "any common operational orbit," with "little or no warning," and include "advanced robotic technologies" could potentially be used against non-cooperative spacecraft.[169]

Advanced space-based technologies with dual-use characteristics are also being developed elsewhere. Sweden is developing Europe's first automated rendezvous and proximity operation mission.[170] The PRISMA mission is to demonstrate technologies for autonomous formation flying, approach and rendezvous, proximity operations, and final approach and recede operations.[171] The mission is funded by the Swedish National Space Board; the Swedish Space Corporation is the main contractor. Project partners include the German Aerospace Center (DLR), the French Centre National d'Études Spatiales (CNES), and the Technical University of Denmark (DTU). Similar to the US Orbital Express mission, the PRISMA mission will launch two small satellites into orbit. The 140 kg MAIN satellite is fully maneuverable and will perform all the maneuvering. The 50 kg TARGET will be the reference spacecraft that MAIN will approach using GPS and RF sensors. MAIN and TARGET passed their Critical Design Review in February 2007 and the main propulsion of MAIN was delivered in September of that year. The mission is scheduled to be launched in the second half of 2008 and the total development cost is just under 230-million SEK ($38.64-million).[172]

2007 Space Security Impact

The emergence of advanced space-based capabilities is likely to complicate space security because of the range of passive protection and more active negation functions that they can serve, with the line between these types of activities unclear. These technologies could be used to enhance knowledge of local space and gather information on other, potentially hostile, satellites or to support on-orbit servicing of satellites to extend their lifespans or recover from negation efforts. But all of the capabilities described have clear space negation applications. Currently, however, these programs are still experimental and their funding levels are relatively low. The more immediate consequence is the challenge posed by not knowing what the threats are, largely because of the secrecy of many technology programs.

8. Space-Based Strike Systems

This chapter assesses trends and developments related to the research, development, testing, and deployment of space-based strike capabilities and 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 the Space Systems Negation chapter. Space systems that support Earth-based strike capabilities, such as reconnaissance satellites, are addressed in 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 of an energy-to-target SBSS 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 Missile Defense Agency (MDA) canceled the SBL program in 2000, although some classified work on the concept may be ongoing.[1]

While no space-based strike systems have yet been tested or deployed, the US and the former USSR devoted considerable resources to the development of key space-based strike capabilities during the Cold War. The US continues to develop SBI enabling technologies within the context of its missile defense program. 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. It is generally accepted that only the most advanced spacefaring states could overcome the technical hurdles to deploy effective space-based strike systems in the foreseeable future.

Space Security Impact

Space-based strike systems can have a direct impact on all 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 and may generate additional space debris or electromagnetic interference.

The deployment of a space-based strike system would enable an actor to threaten and even attack actors on Earth with very little warning and would constitute a departure from current practice regarding the military use of space. The psychological effects of such a "Sword of Damocles" could be far-reaching. It would also 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.[2] 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 ASAT weapons and legitimize attacks on space assets in self-defense. Certain normative restrictions and moratoria upon such attacks could be undermined. For rapid response times, strike systems would have to be placed in low earth orbit, making them vulnerable to attack.[3] Further, the testing and deployment of ASAT systems in response to space-based strike installations could generate space debris, undermining the sustainable use of space for all actors over the longer term (see Space Environment).

Some argue that space-based strike capabilities may be necessary to protect space systems from attack.[4] Indeed, 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 Space Systems Negation, it is argued that 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 8.1: While no space-based strike systems have been tested or deployed, the US continues to consider a space-based interceptor for its missile defense system

No known integrated space-based strike systems have been tested or deployed.[5] The most advanced space-based strike effort during the Cold War primarily focused 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 135-150 kilometers in altitude; it would de-orbit after flying only a fraction of one orbit, destroying an Earth-based target.[6] 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 the USSR FOBS system.[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 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 (SDI), although the effort proved unsuccessful and was abandoned. The US also performed a Relay Mirror Experiment in 1990, 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 of continuing work on space-based directed energy technologies.[13]

Under SDI in the 1980s the US invested several billion dollars in research and development of a space-based strike concept called Brilliant Pebbles. While the SDI never developed or deployed a fully operational system, the US did test some propulsion and targeting subsystems for Brilliant Pebbles. Research and development efforts in the US for space-based strike capabilities declined in the 1990s, but have been revived since 2000 through the SBI. SBI continues to be the most substantial space-based strike research and development program. The current SBI concept was developed to contribute to missile defense by providing a capability to intercept missiles as they pass through space. As with ground-based ASAT systems, SBI capabilities could conceivably be used for offensive attacks on satellites.

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] It has been succeeded by the US Air Force's Experimental Spacecraft System (XSS) with the objective to develop and demonstrate the capabilities of various microsatellite technologies, although the program has no direct relationship to MDA's SBI program (see Space Systems Negation Trend 7.4). 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] There is ongoing debate within the US Congress on whether the NFIRE system should be allowed to launch an independent "kill vehicle" to intercept a missile. This mission has been revised several times.[16] Under none of these revisions has the kill vehicle included the propulsion unit required for homing in on a missile, so it cannot be called an integrated space-based strike system. Revival of the interceptor is listed as justification for a second NFIRE mission in the FY2007 budget request "in response to congressional encouragement in the FY 06 Defense Appropriations bill to complete development of the Kill Vehicle."[17] However, MDA has repeatedly stated that it has no plans to revive it. 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.[18]

Longer-term US plans include the deployment of an SBI testbed.[19] While such a system would have limited operational utility, it could constitute the first deployment of a space-based strike system. A summary of completed and planned US space-based strike-related missions is provided in Figure 8.1.

Figure 8.1: Recent and planned US space missions testing SBI technologies or integrated systems

Mission	Stage	Launch	Agency	Description
Clementine	Complete	1994	DOD & NASA	Tested lightweight sensors at realistic closing velocities using the moon and asteroids as targets
NFIRE	Ongoing	2007	MDA	Testing space-based plume detection and early-warning and tracking capabilities, and missile defense models and simulations[20]
MPX	Planned	N/A	MDA	Two two-stage anti-missile propulsion units
SBI testbed	Planned	2010-2012	MDA	Three to six integrated SBIs as a testbed for a full SBI system

Since its first appearance on the budget in FY2004 under the Ballistic Missile Defense Interceptor Program, the allocation for Space Test Bed has 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 has dropped sharply, from $1.5-billion for FY2003–2007 to $290-million through FY2013, but goals and timelines have remained stable in recent years.[21] The meaning of these budget cuts is not clear. It is possible that Space Test Bed is receiving more funds from classified accounts, or funding is being diverted to other classified programs. While the program remains on the books, the FY2007 authorization bill restricted 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, "an analysis of implication on foreign policy and national security, as well as probable responses from other countries."[22]

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 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.[23] 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.[24] 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.[25]

In summary, there have been no space-based strike systems tested or deployed to date, although Cold War-era programs did support considerable development and testing of key technologies. Prohibitive costs and reduced perceived needs led Russia and, to a lesser degree, the US to drastically cut funding for space-based strike programs, particularly the energy-to-target types. More recently the US has pursued the development of SBI in the context of its ballistic missile defense program, although both political and financial challenges to its completion remain.

2007 Development

NFIRE successfully tests sensor system in space for missile defense

The US Missile Defense Agency (MDA) NFIRE satellite was launched on 24 April 2007 on a US Air Force Minotaur rocket from NASA's Wallops facility off the coast of Virginia.[26] The primary Track Sensor Payload (TSP) is designed to collect both high- and low-resolution imagery from a missile plume using long-, medium-, and short-wave infrared.[27] It is intended to test a sensor system to observe and differentiate a missile plume from its rocket, a critical piece of data to enable space-based missile defense interception. The first test of the system took place on 23 August 2007 when a modified Minuteman II Intercontinental Ballistic Missile (ICBM) was launched from Vandenberg Air Force Base in California. The NFIRE satellite observed the missile plume as the Minuteman passed within 3.5 km at its closest point — the test cost approximately $25-million. The total program cost $300-million.[28]

A second sensor originally planned to fly on a “kill vehicle” in close proximity to the target missile was cancelled in 2004, removing any potential weapons component to the system. Nonetheless, the test was an important milestone in the development of the enabling technology for space-based boost phase missile defense. While some analysts cite concerns that it could be used to support future space-based interceptors or to target satellites, MDA officials contend that there are currently no plans to develop such systems.[29]

2007 Development

Multiple Kill Vehicle received boost in FY2008 budget allocation

Citing concern over loss of focus, the US Congress eliminated all funding for the Multiple Engagement Payload (MEP) in the FY2008 Defense Authorization bill and instead directed MDA to focus its efforts on the Multiple Kill Vehicle (MKV) development. Congress cut $40-million from MDA's requested program budget, authorizing $231.2-million.[30]

In contrast to the MEP, which was being developed for the US Navy's Standard Missile-3, the MKV is proposed to be used for both the mid-course Ground-Based Interceptor (GBI) and boost-phase Kinetic Energy Interceptor (KEI). While the MKV is not a direct component of a space-based strike system, MDA officials in the past have acknowledged that it would be a technology enabler for SBI.[31]

2007 Development

Congress cuts funding for the Space Test Bed

The follow-on program to the NFIRE is the Space Test Bed, an MDA program with the goal of developing the infrastructure for space-based missile interceptors.[32] In opposition to the President's budget request of $10-million, the US Congress allocated no funds for this program in 2007,[33] although requests for funds are expected to continue in the future.

2007 Space Security Impact

The ongoing absence of space-based strike systems and infrastructure continued to support the security of outer space in 2007. While precursor technology development continued through the NFIRE test and MKV program, restraint exercised by US policymakers is positive and indicates concern for space security and the challenge of balancing terrestrial missile defense requirements with the need to maintain freedom from space-based threats.

Trend 8.2: A growing number of countries are developing more advanced space-based strike-enabling technologies through other civil, commercial, and military programs

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. The enabling technologies described below are dual-use. None are related to dedicated space-based strike programs, but are part of other 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, the dual-use applications of these advances do bring actors technologically closer to such a strike capability.

The advanced enabling technologies listed in Figure 8.2 are those required for each of the major space-based strike concepts over and above 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 widely described in open source literature.[34]

Figure 8.2: Advanced space-based strike enabling capabilities*

	SBI	Hypervelocity rod bundle	SB munitions delivery	SB munitions delivery	SBL	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 re-entry technology		■	■	■		
Nuclear weapons				■		

Key: ■ = Required □ = Needed but not necessarily on the primary SBSW crat(s)

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

A *precision position maneuverability* capability to ensure that an object can be moved to a specific location with an accuracy of less than 10 meters 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 will dock at the International Space Station in 2008. The Chinese manned spacecraft, the Shenzhou series, is also equipped with a docking mechanism.[35]

High-G thrusters that provide the large acceleration required for final stages of missile homing are under development by the US for the SBI. No other state is currently assessed to have such a capability. A *large delta (Δ)-V thruster* capability that enables a change in velocity required to maneuver in orbit or de-orbit to reach the target is fundamental for several space-based strike concepts. This is a relatively common capability that has been demonstrated by all actors with rocket technology, including the 29 states that have demonstrated orbital or suborbital space access.

Accurate *global positioning* capabilities required for all space-based strike concepts are possessed primarily by the US (GPS) and Russia (GLONASS), although the GLONASS system is not fully operational at present. All other actors with space access are involved to some degree in the development of navigation systems — for example, the planned EU Galileo system, the Chinese Beidou constellation, and the Japanese Quazi-Zenith Satellite System (see Civil Space Programs and Global Utilities Trend 3.4). 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 required for the SBI concept, 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. India and Japan are also developing this capability.[36]

Relatively extensive *global missile warning and missile tracking* capabilities, required for the SBI and SBL concepts, were developed by the US and the USSR during the Cold War (see Space Systems Protection Trend 6.1). Early warning of missile launches is currently 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-High and Space Tracking and Surveillance System are being designed to be more advanced in this regard, although both systems are behind schedule.[37] No other states currently have space-based early-warning capabilities, but France is developing two early-warning satellites, Spirale-1 and -2, to launch in 2008.[38]

Launch-on-demand capabilities to maintain an effective global space-based strike system are provided by rockets with an operational readiness of less than one week. Russia currently leads with 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.[39] Some commercial actors, in particular Space-X, are aiming to provide more responsive and less expensive space launches (see Space Systems Protection Trend 6.4).[40] Although US concepts for a military space plane envision launch-on-demand capabilities, physical constraints would limit its utility.[41]

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 all developed microsatellites.

High-power laser systems envisioned for an SBL have only been developed to any 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 Space Systems Negation Trend 7.3). None of those efforts have reached fruition due to continuing technical challenges. China has also operated a high-power laser program since 1986 and it now has multiple hundred-megawatt lasers.[42] The technology does not exist to build a high-power space-based laser.[43]

High-power generation systems for space, necessary for powering the SBL concept and for high thrust propellants for kinetic strike capabilities, have been developed and deployed both by the US and former Soviet Union, particularly through the use of nuclear power. For example, the US System for Nuclear Auxiliary Power-10A mission launched in 1965 had a 45-kilowatt thermonuclear reactor. NASA is working on several nuclear projects under Project Prometheus.[44] Between 1967 and 1988 the USSR launched 31 low-powered reactors in Radar Ocean Reconnaissance Satellites.[45] 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 the SBL concept, and the latter applicable for all space-based strike concepts — have been developed by a number of actors, including China, ESA, France, Japan, Russia, and the US, for military reconnaissance or civil astronomical telescope missions.[46] India and Israel are currently developing such capabilities (see Civil Space Programs and Global Space Utilities). China has announced plans for a civilian telescope that will demonstrate precision attitude control capabilities.[47]i

Precision reentry technology, needed to prevent burn-up and lateral lift caused by atmospheric for kinetic space-to-Earth strike concepts has been developed by states with a human spaceflight capability, namely China, Russia, and the US. ESA has this capability under development with its Applied Re-entry Technology program and through the joint NASA-ESA Crew Return Vehicle (X-38).[48] France's Centre National d'Etudes Spatiales (CNES) has announced the development of a new reentry vehicle program for civil space purposes.[49] The Japan Aerospace Exploration Agency has some experimental reentry vehicle programs.[50] States with nuclear weapons have also developed precision reentry technologies for their nuclear warhead reentry vehicles. The capabilities needed for a rapid strike from space are more advanced, however, due to the higher speed at which reentry would occur.[51]

Figure 8.4 provides a schematic overview of the space-based strike enabling technologies possessed or under development by key space actors, as discussed above. Only actors that have developed orbital space access are included, since this is a prerequisite for all space-based strike systems.

Figure 8.3: Space-based strike enabling capabilities of key space actors[52]

Advanced Capability	China	EU/ESA	France	UK	India	Israel	Japan	Russia	Ukraine	US
Precision position maneuverability	■	□						■		■
High-G thrusters										□
Large Δ-V thrusters	■	■	■	■	■	■	■	■	■	■
Accurate global positioning[53]	□	□			□	□	□	□	□	■
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	■		■	■	■	■	■	■	■	■
SBSW										
Space-based laser								(□)		(□)
Space-based interceptors								(□)		□
Hypervelocity rod bundle										
SB munitions delivery (conventional)										
Neutral particle beam								(□)		(□)

Key: ■ = Some capability[54] □ = Capability under development (□) = Past development (■) = Past capability

2007 Development

Prompt Global Strike program authorized by the US Congress

Following Congressional testimony by the then Commander of USSTRATCOM, General Cartwright,[55] the US Congress has refocused development efforts for a US prompt global strike capability. The FY2008 Defense Authorization bill provided $100-million for a new Prompt Global Strike program, combining funds from the US Navy Conventional Trident Modification Program and US Air Force Common Aero Vehicle (CAV – part of the Falcon program). It is unlikely that this program will result in the development of a space-based weapon system. The US Congress has issued explicit instructions to the Department of Defense about the areas to which funding can be applied and asked for a report on the future roadmap within 90 days of the bill's implementation.[56] Still, several advanced enabling technologies will be developed, including "advanced propulsion, payload delivery and dispensing mechanisms, weapon system command and control, and advanced non-nuclear, kinetic, and other enabling capabilities,"[57] which would be required to support a space-based strike system.[58]

The latest phase of the DARPA/USAF Falcon program is the HTV-3X (formerly CAV, described above), which motivated a new USAF/DARPA program called Blackswift in

2007.[59] Originally, HTV-3 was supposed to be boosted by a rocket; the HTV-3X is conceptualized to fly at Mach-6 using a combined cycle engine, and is planned to take-off and land like a conventional airplane. Blackswift is a flight test program aimed at developing the concepts of HTV-3X.[60] The USAF signed a Memorandum of Understanding on the project with DARPA in September 2007 and will contribute roughly $800-million dollars US towards the program.[61] Details of the program are vague. "…it could be part of the global strike mission or a reconnaissance strike aircraft…"[62] Nonetheless, the Blackswift project seems to be part of the new Prompt Global Strike program, along with the CAV/HTV.

2007 Development

Report outlines the potential costs to deploy space-based weapons

The Center for Strategic and Budgetary Assessments released a preliminary assessment outlining a "rough order of magnitude estimates" of the potential costs of acquiring and supporting various space-based weapon systems, including space-based missile defense, space-based ASATs, and space-based weapons that can target the Earth.[63] In all three cases the report concluded that other options, primarily terrestrial, were more cost-effective; however, there is wide variance in costs, technological demands, and effectiveness across different options.

Overall, the report found space-based boost-phase ballistic missile defense to be the least feasible both in terms of technology and cost.[64] An optimistic Congressional Budget Office (CBO) study indicates that such a system is estimated to need a minimum of 368 satellites to cover potential threats from only North Korea and Iran, assuming intercept speeds of 4 km/second with at least two satellite in range of the threat area at any given time. This resulted in a 99.5 percent absentee rate, meaning that each satellite would only be over the threat area for 0.5 percent of the time.[65] A smaller number of interceptors could potentially be used if there were a "technological leap" in kill vehicle miniaturization.[66] The potential 20-year cost of such a system is estimated at between $29- and $290-billion, depending on technology levels and capability, but even the most advanced system would have modest capabilities that could be easily overcome.

The report found the potential of space-based weapons to be greatest for a terrestrial strike or prompt global strike capability, but high costs and technology challenges still apply.[67] CBO and RAND studies indicate that a system of 30 satellites with 40 maneuverable reentry vehicles (common aero vehicles) carrying conventional munitions, plus spares, could cost $12-billion in acquisitions over 30 years. A similar cost is estimated for a 'Rods from God' system.[68] For both missile defense and terrestrial strike, laser systems are deemed to be much more expensive and technologically inferior.

2007 Development

Upgrades in US global missile tracking and warning

Both satellites for the Space Tracking and Surveillance System (STSS) completed acceptance testing; after significant delays they are scheduled for launch in November 2008 as part of the MDA sensor network[69] (see Space Systems Protection Trend 6.1 and Space Systems Negation Trend 7.1). The second layer of US next-generation space-based ballistic missile detection and tracking, the STSS is designed as a constellation of satellites in low Earth orbit intended to detect and track ballistic missiles, with specific focus on the mid-course phase; differentiate the missile warheads from decoys and debris; and provide targeting data to the missile defence network. It is also testing sensor performance against ground-based and airborne targets.[70] It is significantly over cost and behind schedule. Construction of the STSS is now near completion and prime contractor Northrop Grumman completed thermal vacuum testing of two STSS demonstration satellites in 2007.[71] The two satellites are scheduled to be launched in tandem from Cape Canaveral in 2008 and will be linked to MDA's Missile Defense Space Experimentation Center.[72] The STSS ground segment also passed its final test and operational readiness demonstration in 2007.[73] However, the House cut the FY2008 budget for the program by $100-million.[74]

The US also conducted talks with the Czech Republic over the course of 2007, during which the two nations agreed to pursue installation of a missile defense radar near the Czech town of Misov.[75] The agreement proposed to move an existing mid-course tracking radar from the Kwajalein test range to the Czech Republic.[76]

2007 Development

The US, Europe, China, and Russia continue research and development of global positioning systems

China added its first Medium Earth Orbit global positioning satellite on 13 April 2007. The Compass-M1 was successfully launched onboard a Long March 3A booster from Xichang Launch Center.[77] The previous four Beidou satellites were all placed in geostationary orbit over Asia (see Space for Terrestrial Military Operations Trend 5.2).

Although the Galileo satellite navigation system was initially proposed as a public-private partnership, the European Transport Council voted on 8 June 2007 to fund it using solely public money.[78] Another agreement on 29 November 2007 opened the procurement process to competitive bidding[79] (see Civil Space and Global Utilities Trend 3.3).

Russia launched nine Global Navigation Satellite System (GLONASS) satellites in 2007 on three dates to bring its navigation constellation to 13 operational satellites, still short of the 24 satellites needed for full operation.[80] India also announced in 2007 that it will be partnering with Russia on the GLONASS constellation after discussing the possibility of joining with the US GPS system[81] (see Space for Terrestrial Military Operations Trend 5.1).

2007 Development

Continued progress in air-based laser technology

The Airborne Laser (ABL) program had a series of successive tests to bring it closer to operational reality. These included the first in-flight firing of the laser through ABL's turret, first active tracking of a non-cooperative airborne target, and the first successful tracking of a vertically dynamic target in the form of a climbing F-16[82] The ABL would be a high-powered chemical laser mounted on a modified Boeing 747 jet to be used as a direct energy interceptor for short-range ballistic missiles in boost-phase. Despite progress, however, it remains "a high risk technology development and demonstration program" which has "suffered numerous delays and cost increases since its inception in 1996, and it is currently estimated that it will cost $5.1-billion from inception to the completion of the first test to shoot down a target missile, currently scheduled for 2009"[83] and significant technological challenges remain (see Space Systems Negation Trend 7.3).

2007 Space Security Impact

Space-based weapons designed to strike terrestrial targets will require sophisticated technological developments that, at present, few spacefaring states seem able to exploit. The development of dual-use capabilities that also provide enabling technologies for space-based strike systems continued in 2007, although there is no evidence that states are developing such capabilities for strike purposes. Nonetheless, the potential for space-to-Earth strike systems will continue to pose a challenge to the international community as advanced space-based technologies continue to be developed. While some enabling technologies for space-based strike are specific to that purpose and include significant technology barriers, many are advanced technologies associated with other space applications and have been developed for a variety of purposes by several different actors; this means that if one actor were to pursue a space-based strike capability, others could follow.

Space Security Working Group Meeting

Institute of Air and Space Law, McGill University
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Satellite name	Launch vehicle	Launching state	Function	Orbit	Launch date
Chile					
Fasat-Bravo	Zenit-2	Russia	Imaging	LEO	10/07/1998
China					
Zhongxing-22A	Chang Zheng 3A	China	Communications	GEO	12/09/2006
Zhongxing-20 (Feng Huo)	Chang Zheng 3A	China	Communications	HEO	14/11/2003
Feng Huo 1	Chang Zheng 3A	China	Communications	GEO	25/01/2000
Yaogan 3	Chang Zheng 4B	China	Imaging	LEO	11/11/2007
Yaogan 2	Chang Zheng 2D	China	Imaging	LEO	25/05/2007
Yaogan 1	Chang Zheng 4B	China	Imaging	LEO	26/04/2006
Zi Yuan 2C	Chang Zheng 4B	China	Imaging	LEO	06/11/2004
Zi Yuan 2	Chang Zheng 4B	China	Imaging	LEO	27/10/2002
Beidou 5	Chang Zheng 3A	China	Navigation	MEO	13/04/2007
Beidou 4	Chang Zheng 3A	China	Navigation	GEO	02/02/2007
Beidou 3	Chang Zheng 3A	China	Navigation	GEO	24/05/2003
Beidou	Chang Zheng 3A	China	Navigation	GEO	20/12/2000
Beidou	Chang Zheng 3A	China	Navigation	HEO	30/10/2000
France					
Syracuse 3A	Ariane 5GS	France	Communications	GEO	13/10/2005
Syracuse 3B	Ariane 5ECA	France	Communications	GEO	08/11/2006
Helios 2A	Ariane 5G+	France	Imaging	LEO	18/12/2004
Helios 1A	Ariane 40	France	Imaging	LEO*	07/07/1995
Clementine	Ariane 40	France	Signals Intelligence	LEO	03/12/1999
Essaim 4	Ariane 5G+	France	Signals Intelligence	LEO	18/12/2004
Essaim 3	Ariane 5G+	France	Signals Intelligence	LEO	18/12/2004
Essaim 2	Ariane 5G+	France	Signals Intelligence	LEO	18/12/2004
Essaim 1	Ariane 5G+	France	Signals Intelligence	LEO	18/12/2004
Germany					
SAR-Lupe 3	Kosmos-11K65M	Russia	Imaging	LEO	01/11/2007
SAR-Lupe 2	Kosmos-11K65M	Russia	Imaging	LEO	02/07/2007
SAR-Lupe 1	Kosmos-11K65M	Russia	Imaging	LEO	12/19/2006
Israel					
Ofeq-7	Shavyit 1	Israel	Imaging	LEO	10/06/2007

Based on Jonathan McDowell's Satellite Database (1 January 2008). Due to the nature of some military satellites, it is not always known when a satellite changes its status from operational and operational to in orbit but no longer operational. This list only discounts satellites which are publicly known to be inactive and as such is likely to overestimate the number of active satellites in some cases.

Satellite name	Launch vehicle	Launching state	Function	Orbit	Launch date
Ofeq-5	Shaviyt 1	Israel	Imaging	LEO	28/05/2002
Italy					
COSMO 2	Delta 7420-10	France	Imaging	LEO	09/12/2007
COSMO 1	Delta 7420-10C	France	Imaging	LEO	08/06/2007
Sicral	Ariane 44L	France	Communications	GEO	07/02/2001
Japan					
IGS Radar-2	H-IIA 2024	Japan	Imaging	LEO	24/02/2007
IGS Optical-3 Verification	H-IIA 2024	Japan	Imaging	LEO	24/02/2007
IGS Opitcal-2	H-IIA 202	Japan	Imaging	LEO	11/09/2006
IGS-1b	H-IIA 2024	Japan	Imaging	LEO	28/03/2003
IGS-1a	H-IIA 2024	Japan	Imaging	LEO	28/03/2003
Russia					
Raduga-1M	Proton-M/Briz-M	Russia	Communications	GEO	09/12/2007
Meridian No. 1	Soyuz-2-1A	Russia	Communications	HEO	24/12/2006
Gonets-D1	Kosmos-11K65M	Russia	Communications	LEO	21/12/2005
Kosmos-2409	Kosmos 11K65M	Russia	Communications	LEO	23/09/2004
Kosmos-2408	Kosmos 11K65M	Russia	Communications	LEO	23/09/2004
Raduga-1	Proton-K/DM-2	Russia	Communications	GEO	27/03/2004
Kosmos-2401	Kosmos 11K65M	Russia	Communications	LEO	19/08/2003
Kosmos-2400	Kosmos 11K65M	Russia	Communications	LEO	19/08/2003
Molniya-1T	Molniya 8K78M	Russia	Communications	HEO	02/04/2003
Molniya-1T	Molniya 8K78M	Russia	Communication	HEO	18/02/2004
Kosmos-2391	Kosmos 11K65M	Russia	Communications	LEO	08/07/2002
Kosmos-2390	Kosmos 11K65M	Russia	Communications	LEO	08/07/2002
Kosmos-2386	Tsiklon-3	Russia	Communications	LEO	28/12/2001
Kosmos-2385	Tsiklon-3	Russia	Communications	LEO	28/12/2001
Kosmos-2384	Tsiklon-3	Russia	Communications	LEO	28/12/2001
Raduga-1	Proton-K/DM-2	Russia	Communications	GEO	28/08/2000
Kosmos-2371	Proton-K/DM-2	Russia	Communications	GEO	04/07/2000
Kosmos-2352	Tsiklon-3	Russia	Communications	MEO	15/06/1998
Molniya-1T	Molniya 8K78M	Russia	Communications	HEO	24/09/1997
Kosmos-2339	Tsiklon-3	Russia	Communications	LEO	14/02/1997

Key: * Older than 10 years ** Older than 15 years (or suspected of being dead)

Satellite name	Launch vehicle	Launching state	Function	Orbit	Launch date
Kosmos-2338	Tsiklon-3	Russia	Communications	LEO	14/02/1997
Kosmos-2337	Tsiklon-3	Russia	Communications	LEO	14/02/1997
Molniya-1T	Molniya 8K78M	Russia	Communications	HEO	28/09/1998
Raduga	Proton-K/DM-2	Russia	Communications	GEO*	30/09/1993
Kosmos-2430	Molniya 8K78M	Russia	Early Warning	HEO	23/10/2007
Kosmos-2422	Molniya 8K78M	Russia	Early Warning	HEO	21/07/2006
Kosmos-2393	Molniya 8K78M	Russia	Early Warning	HEO	24/12/2002
Kosmos-2379	Proton-K/DM-2	Russia	Early Warning	GEO	24/08/2001
Kosmos-2368	Molniya 8K78M	Russia	Early Warning	HEO	27/12/1999
Kosmos-2427	Soyuz-U	Russia	Imaging	LEO	07/06/2007
Kosmos-2392	Proton-K/17S40	Russia	Imaging	MEO	25/07/2002
Kosmos-2436	Proton-K/DM-2	Russia	Navigation	MEO	25/12/2007
Kosmos-2435	Proton-K/DM-2	Russia	Navigation	MEO	25/12/2007
Kosmos-2434	Proton-K/DM-2	Russia	Navigation	MEO	25/12/2007
Kosmos-2433	Proton-K/DM-2	Russia	Navigation	MEO	26/10/2007
Kosmos-2432	Proton-K/DM-2	Russia	Navigation	MEO	26/10/2007
Kosmos-2431	Proton-K/DM-2	Russia	Navigation	MEO	26/10/2007
Kosmos-2429	Kosmos-11K65M	Russia	Navigation	LEO	11/09/2007
Kosmos-2425	Proton-K/DM-2	Russia	Navigation	MEO	25/12/2006
Kosmos-2426	Proton-K/DM-2	Russia	Navigation	MEO	25/12/2006
Kosmos-2424	Proton-K/DM-2	Russia	Navigation	MEO	25/12/2006
Kosmos-2419	Proton-K/DM-2	Russia	Navigation	MEO	25/12/2005
Kosmos-2418	Proton-K/DM-2	Russia	Navigation	MEO	25/12/2005
Kosmos-2417	Proton-K/DM-2	Russia	Navigation	MEO	25/12/2005
Kosmos-2414	Kosmos-11K65M	Russia	Navigation	LEO	20/01/2005
Kosmos-2413	Proton-K/DM-2	Russia	Navigation	MEO	26/12/2004
Kosmos-2412	Proton-K/DM-2	Russia	Navigation	MEO	26/12/2004
Kosmos-2411	Proton-K/DM-2	Russia	Navigation	MEO	26/12/2004
Kosmos-2407	Kosmos 11K65M	Russia	Navigation	LEO	22/07/2004
Kosmos-2404	Proton-K/Briz-M	Russia	Navigation	MEO	10/12/2003
Kosmos-2403	Proton-K/Briz-M	Russia	Navigation	MEO	10/12/2003
Kosmos-2402	Proton-K/Briz-M	Russia	Navigation	MEO	10/12/2003
Kosmos-2398	Kosmos 11K65M	Russia	Navigation	LEO	04/06/2003

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Satellite name	Launch vehicle	Launching state	Function	Orbit	Launch date
Kosmos-2396	Proton-K/DM-2M	Russia	Navigation	MEO	25/12/2002
Kosmos-2395	Proton-K/DM-2M	Russia	Navigation	MEO	25/12/2002
Kosmos-2394	Proton-K/DM-2M	Russia	Navigation	MEO	25/12/2002
Kosmos-2381	Proton-K/DM-2	Russia	Navigation	MEO	01/12/2001
Kosmos-2382	Proton-K/DM-2	Russia	Navigation	MEO	01/12/2001
Kosmos-2378	Kosmos 11K65M	Russia	Navigation	LEO	08/06/2001
Kosmos-2375	Proton-K/DM-2	Russia	Navigation	MEO	13/10/2000
Kosmos-2374	Proton-K/DM-2	Russia	Navigation	MEO	13/10/2000
Kosmos-2361	Kosmos 11K65M	Russia	Navigation	LEO	24/12/1998
Kosmos-2428	Zenit-2M	Russia	Signals Intelligence	LEO	29/06/2007
Kosmos-2421	Tsiklon-2	Russia	Signals Intelligence	LEO	25/06/2006
Kosmos-2406	Zenit-2	Russia	Signals Intelligence	LEO	10/06/2004
Kosmos-2369	Zenit-2	Russia	Signals Intelligence	LEO	03/02/2000
Kosmos-2360	Zenit-2	Russia	Signals Intelligence	LEO	28/07/1998
South Korea					
Koreasat 5	Zenit-3SL	France	Communications	GEO	22/08/2006
Spain					
XTAR-EUR	Ariane 5ECA	France	Communications	HEO	12/02/2005
Spainsat	Ariane 5ECA	France	Communications	GEO	11/03/2006
UK					
Skynet 5B	Ariane 5ECA	France	Communications	GEO	14/11/2007
Skynet 5A	Ariane 5ECA	France	Communications	GEO	11//03/2007
Skynet 4F	Ariane 44L	France	Communications	GEO	07/02/2001
Skynet 4E	Ariane 44L	France	Communications	GEO	26/02/1999
Skynet 4D	Delta 7925-9.5	US	Communications	GEO	10/01/1998
Skynet 4C	Ariane 44LP	France	Communications	GEO**	30/08/1990
Topsat	Kosmos 11K65M	Russia	Imaging	LEO	27/10/2005
US					
USA 198	Atlas V 421	US	Communications	HEO	10/12/2007
WGS SV-1	Atlas V 421	US	Communications	GEO	11/10/2007
NMARS	Space Shuttle	US	Communications	LEO	10/12/2006
USA 169 (Milstar 6)	Titan 401B/Centaur	US	Communications	GEO	08/04/2003
DSCS III A-3	Delta 4M	US	Communications	GEO	11/03/2003

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Satellite name	Launch vehicle	Launching state	Function	Orbit	Launch date
USA 164	Titan 401B/Centaur	US	Communications	GEO	16/01/2002
USA 162	Atlas IIAS	US	Communications	HEO	11/10/2001
USA 157	Titan 401B/Centaur	US	Communications	GEO	27/02/2001
USA 155	Atlas IIAS	US	Communications	HEO	06/12/2000
USA 153	Atlas IIA	US	Communications	GEO	20/10/2000
USA 179	Atlas IIAS	US	Communications	HEO	31/08/2004
UHF F/O F11 (USA 174)	Atlas 3B	US	Communications	GEO	18/12/2003
DSCS III B-6	Delta 4M	US	Communications	GEO	29/08/2003
USA 148	Atlas IIA	US	Communications	GEO	21/01/2000
UHF F/O F10	Atlas IIA	US	Communications	GEO	23/11/1999
MUBLCOM	Pegasus XL/HAPS	US	Communications	LEO	18/05/1999
UHF F/O F9	Atlas IIA	US	Communications	GEO	20/10/1998
UHF F/O F8	Atlas II	US	Communications	GEO	16/03/1998
CAPRICORN	Atlas IIA	US	Communications	HEO	29/01/1998
USA 135	Atlas IIA	US	Communications	GEO	25/10/1997
UFO F7 (UHF F/O F7)	Atlas II	US	Communications	GEO*	25/07/1996
USA 125	Titan 405A	US	Communications	LEO*	03/07/1996
Milstar DFS 2	Titan 401A/Centaur	US	Communications	GEO*	06/11/1995
UFO F6 (UHF F/O F6)	Atlas II	US	Communications	GEO*	22/10/1995
USA 113	Atlas IIA	US	Communications	GEO*	31/07/1995
UFO 5 (UHF F/O F5)	Atlas II	US	Communications	GEO*	31/05/1995
Milstar DFS 1	Titan 401A/Centaur	US	Communications	GEO*	07/02/1994
NATO 4B	Delta 7925	US	Communications	GEO*	08/12/1993
USA 97	Atlas II	US	Communications	GEO*	28/11/1993
UHF F/O F2	Atlas I	US	Communications	GEO*	03/09/1993
USA 93	Atlas II	US	Communications	GEO*	19/07/1993
USA 82	Atlas II	US	Communications	GEO*	02/07/1992
USA 78	Atlas II	US	Communications	GEO*	11/02/1992
NATO 4A	Delta 7925	US	Communications	GEO**	08/01/1991
LES 9	Titan IIIC	US	Communications	GEO**	15/03/1976
DSP F23 (USA 197)	Delta 4H	US	Early Warning	GEO	11/11/2007
DSP F21 (USA 159)	Titan 402B/IUS	US	Early Warning	GEO	06/08/2001

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Satellite name	Launch vehicle	Launching state	Function	Orbit	Launch date
DSP F20 (USA 149)	Titan 402B/IUS	US	Early Warning	GEO	08/05/2000
DSP F22	Titan 402B/IUS	US	Early Warning	GEO	14/02/2004
DSP F18	Titan 402B/IUS	US	Early Warning	GEO	23/02/1997
DSP F17	Titan 402A/IUS	US	Early Warning	GEO*	22/12/1994
DSP F13	Titan 34D/Transtage	US	Early Warning	GEO**	29/11/1987
Tacsat 2	Minotaur	US	Imaging	LEO	16/12/2006
USA 186	Titan 404B	US	Imaging	LEO	19/10/2005
USA 182	Titan 405B	US	Imaging	LEO	30/04/2005
USA 161	Titan 404B	US	Imaging	LEO	05/10/2001
USA 152	Titan 403B	US	Imaging	LEO	17/08/2000
USA 144	Titan 404B	US	Imaging	LEO	22/05/1999
DMSP 5D-3 F-16	Titan II SLV	US	Imaging	LEO	18/10/2003
DMSP 5D-3 F-15	Titan II SLV	US	Imaging	LEO	12/12/1999
USA 133	Titan 403A	US	Imaging	LEO	24/10/1997
USA 129	Titan 404A	US	Imaging	LEO*	20/12/1996
USA 69	Titan 403A	US	Imaging	LEO**	08/03/1991
Navstar GPS IIR-M5 (USA 199)	Delta 7925-9.5	US	Navigation	HEO	20/12/2007
Navstar GPS IIR-M4	Delta 7925-9.5	US	Navigation	MEO	17/10/2007
Navstar GPS IIR-M3	Delta 7925-9.5	US	Navigation	MEO	17/11/2006
Navstar GPS IIR-M2	Delta 7925-9.5	US	Navigation	HEO	25/09/2006
Navstar GPS IIR-M1	Delta 7925-9.5	US	Navigation	MEO	26/09/2005
Navstar GPS IIR-13	Delta 7925-9.5	US	Navigation	HEO	06/11/2004
Navstar GPS IIR-12	Delta 7925-9.5	US	Navigation	MEO	23/06/2004
Navstar GPS IIR-11	Delta 7925-9.5	US	Navigation	MEO	20/03/2004
Navstar GPS IIR-10 (USA 175)	Delta 7925-9.5	US	Navigation	MEO	21/12/2003
Navstar GPS IIR-9 (USA 168)	Delta 7925-9.5	US	Navigation	MEO	31/03/2003
Navstar GPS IIR-8 (USA 166)	Delta 7925-9.5	US	Navigation	MEO	29/01/2003
GPS IIR-7	Delta 7925-9.5	US	Navigation	MEO	30/01/2001
GPS IIR-6	Delta 7925-9.5	US	Navigation	MEO	10/11/2000
GPS IIR-5	Delta 7925-9.5	US	Navigation	MEO	16/07/2000

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Satellite name	Launch vehicle	Launching state	Function	Orbit	Launch date
GPS IIR-4	Delta 7925-9.5	US	Navigation	MEO	11/05/2000
GPS SVN 46	Delta 7925-9.5	US	Navigation	MEO	07/10/1999
GPS SVN 38	Delta 7925	US	Navigation	MEO	06/11/1997
GPS SVN 43	Delta 7925	US	Navigation	MEO	23/07/1997
Navstar SVN 30	Delta 7925	US	Navigation	MEO*	12/09/1996
Navstar SVN 40	Delta 7925	US	Navigation	MEO	16/07/1996
Navstar GPS 33	Delta 7925	US	Navigation	MEO	28/03/1996
Navstar GPS 36	Delta 7925	US	Navigation	MEO*	10/03/1994
Navstar GPS 34	Delta 7925	US	Navigation	MEO*	26/10/1993
Navstar GPS 35	Delta 7925	US	Navigation	MEO*	30/08/1993
Navstar GPS 39	Delta 7925	US	Navigation	MEO*	26/06/1993
Navstar GPS 37	Delta 7925	US	Navigation	MEO*	13/05/1993
Navstar GPS 29	Delta 7925	US	Navigation	MEO*	18/12/1992
Navstar GPS 32	Delta 7925	US	Navigation	MEO*	22/11/1992
Navstar GPS 27	Delta 7925	US	Navigation	MEO*	09/09/1992
Navstar GPS 26	Delta 7925	US	Navigation	MEO*	07/07/1992
Navstar GPS 28	Delta 7925	US	Navigation	MEO*	10/04/1992
Navstar GPS 25	Delta 7925	US	Navigation	MEO*	23/02/1992
Navstar GPS 24	Delta 7925	US	Navigation	MEO**	04/07/1991
Navstar GPS 23	Delta 7925	US	Navigation	MEO**	26/11/1990
Navstar GPS 15	Delta 6925	US	Navigation	MEO**	01/10/1990
NNS O-23	Scout G-1	US	Navigation	LEO**	
NNS O-25	Scout G-1	US	Navigation	LEO**	
NNS O-31	Scout G-1	US	Navigation	LEO**	25/08/1988
NNS O-32	Scout G-1	US	Navigation	LEO**	26/04/1988
USA 194 P/L 2	Atlas V 401	US	Signals Intelligence	LEO	15/06/2007
USA 194 (NROL-30	Atlas V 401	US	Signals Intelligence	LEO	15/06/2007
USA 184	Delta 4M+(4,2)	US	Signals Intelligence	HEO	28/06/2006
USA-181 P/L 2	Atlas 3B	US	Signals Intelligence	LEO	03/02/2005
USA 181	Atlas 3B	US	Signals Intelligence	LEO	03/02/2005
USA 173 P/L 2	Atlas IIAS	US	Signals Intelligence	LEO	02/12/2003
USA 173	Atlas IIAS	US	Signals Intelligence	LEO	02/12/2003
USA 171	Titan 401B/Centaur	US	Signals Intelligence	GEO	09/09/2003

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Satellite name	Launch vehicle	Launching state	Function	Orbit	Launch date
USA 160 P/L 2	Atlas IIAS	US	Signals Intelligence	LEO	08/09/2001
USA 160	Atlas IIAS	US	Signals Intelligence	LEO	08/09/2001
USA 139	Titan 401B/Centaur	US	Signals Intelligence	GEO	09/05/1998
USA 136	Titan 401A/Centaur	US	Signals Intelligence	HEO	08/11/1997
USA 122	Titan 403A	US	Signals Intelligence	LEO	12/05/1996
USA 121	Titan 403A	US	Signals Intelligence	LEO*	12/05/1996
USA 120	Titan 403A	US	Signals Intelligence	LEO*	12/05/1996
USA 119	Titan 403A	US	Signals Intelligence	LEO*	12/05/1996
USA 118	Titan 401A/Centaur	US	Signals Intelligence	GEO*	24/04/1996
USA 116	Titan 404A	US	Signals Intelligence	LEO*	05/12/1995
USA 112	Titan 401A/Centaur	US	Signals Intelligence	HEO*	10/07/1995
USA 103	Titan 401A/Centaur	US	Signals Intelligence	HEO*	03/05/1994
ANDE-FCAL	Space Shuttle	US	Calibration	LEO	10/12/2006
RAFT1	Space Shuttle	US	Calibration	LEO	10/12/2006
RADCAL	Scout G-1	US	Calibration	LEO*	25/06/1993
DMSP 5D-3 F-17 (USA 191)	Delta 4M	US	Meteorology	LEO	04/11/2006
DMSP 5D-2 F-14	Titan II SLV	US	Meteorology	LEO	04/04/1997
DMSP 24547	Atlas E	US	Meteorology	LEO**	24/03/1995
DMSP 23545	Atlas E	US	Meteorology	LEO*	29/08/1994
ANDE-MAA	Space Shuttle	US	Science	LEO	10/12/2006
MTI	Taurus 1110	US	Science	LEO	12/03/2000
NFIRE	Minotaur 1	US	Technology	LEO	24/04/2007
CFESat	Atlas V 401	US	Technology	LEO	9/03/2007
Falconsat-3	Atlas V 401	US	Technology	LEO	9/03/2007
STPSat-1	Atlas V 401	US	Technology	LEO	9/03/2007
Nextsat	Atlas V 401	US	Technology	LEO	9/03/2007
MidStar 1	Atlas V 401	US	Technology	LEO	9/03/2007
ASTRO	Atlas V 401	US	Technology	LEO	9/03/2007
MEPSI 2A/2B	Space Shuttle	US	Technology	LEO	10/12/2006
USA 189	Delta 7925-9.5	US	Technology	GEO	21/06/2006
USA 188	Delta 7925-9.5	US	Technology	GEO	21/06/2006
USA 187	Delta 7925-9.5	US	Technology	GEO	21/06/2006
XSS-11 (USA 165)	Minotaur	US	Technology	LEO	11/04/2005
GeoLITE	Delta 7925-9.5	US	Technology	GEO	18/05/2001
TSX-5	Pegasus XL	US	Technology	LEO	07/06/2000
MSX	Delta 7920-10	US	Technology	LEO*	24/04/1996

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Chapter One Endnotes

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Chapter Three Endnotes

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