The Space Environment

Growing debris threats to spacecraft

Traveling at speeds of 7.5 kilometers per second, space debris poses a significant threat to spacecraft. The number of objects in Earth orbit have increased steadily; today there are an estimated 35 million pieces of space debris. Approximately 13,000 of the objects in orbit that are large enough to seriously damage or destroy a spacecraft – over 90 percent of which are space debris – are being tracked. The annual growth rate of tracked debris began to decrease in the 1990s, largely due to national debris mitigation efforts, but this trend was reversed in 2004.

Previously unreported Chinese attempts to intercept a satellite with a ballistic missile in 2005 and 2006 culminated with the hit-to-kill explosion of an aging Chinese weather satellite on 11 January 2007. It is considered to be one of the worst manmade debris-creating events in history. Over 1,300 pieces of large debris from the event have been catalogued by the US Space Surveillance Network, many of which are expected to remain in orbit for years or decades. Eight incidents of accidental satellite fragmentation also took place in 2006 – the highest number of incidents since 1993 – including the unexpected breakup of a US Delta-4 second stage.

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

Significant on-orbit collisions and tracking efforts have encouraged the recognition of space debris as a growing threat. Since the mid-1990s, many space-faring states, including China, Japan, Russia, and the US, and the European Space Agency have developed debris mitigation standards.

In 2006 the Space Debris Working Group of the UN Committee on the Peaceful Uses of Outer Space drafted non-binding international space debris mitigation guidelines that significantly include avoiding intentional destruction and other harmful activities in space.

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. The US Space Surveillance Network uses 30 sensors worldwide to monitor over 13,000 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.

In 2006 US efforts to expand its space surveillance capabilities in GEO suffered from funding cuts and program delays. Launch of the first Space-Based Surveillance System (SBSS) satellite was delayed until 2009 and the Orbital Deep Space Imager program was cut. There were also indications that funding will be cut for future upgrades to the Space Fence radar portion of the Space Surveillance Network. Russia and the UK announced plans to improve their space surveillance capabilities.

Growing demand for radio frequencies

Expanding satellite applications are driving demand for limited resources in space, including radio frequency spectrum. More satellites are operating in the frequency bands that are commonly used by GEO satellites and are causing increasing frequency interference. Satellite operators now 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.

The growing demand for radio frequencies was managed in 2006; there were fewer reported cases of satellite radio frequency interference. Nonetheless, growing military demand created challenges. Key technologies to increase available military bandwidth experienced delays, while use by applications, including unmanned aerial vehicles, increased. Moreover, China announced that its proposed Compass navigation system may use the military frequencies reserved for the EU's Galileo encrypted service and the US military GPS signal.

Growing demand for orbital slots

There are more than 800 operational satellites in orbit today: about 46 percent in LEO, 6 percent in MEO, 42 percent in GEO, and 6 percent in HEO. 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.

Implications of growing demand for GEO orbital slots were demonstrated in 2006. The US Federal Communications Commission granted EchoStar's application to operate in the 86.5o West Latitude orbital location against opposition from Telesat Canada. Telesat claimed that the EchoStar satellite positioning would violate the standard nine degrees of separation for Direct Broadcast Satellites, resulting in interference. There are no clear rules in the US for smaller DBS satellite spacing.

Space Laws, Policies, and Doctrines

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 (1975), 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 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.

Events related to the intentional Chinese destruction of a satellite in 2006 and early 2007 raised questions about the spirit with which the OST is being implemented internationally. Meanwhile, in the Committee on the Peaceful Uses of Outer Space (COPUOS) Legal Subcommittee states disagreed over the adequacy of the existing international regime to prevent the weaponization of outer space, with the US arguing that no new legal tools are needed.

COPUOS remains active, but the CD has been deadlocked on space weapons issues 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; however, the CD has been deadlocked without an agreed plan of work since 1998 and so has been unable to move forward on the PAROS mandate to develop an instrument relating to space security and the weaponization of space.

The CD remained deadlocked in 2006, although several informal discussion sessions were organized. The Space Debris Working Group of the Scientific and Technical Subcommittee of COPUOS drafted space debris mitigation guidelines consistent with those of the Inter-Agency Debris Coordination Committee and recommended voluntary implementation by all member states.

Space-faring states' national space policies consistently emphasize international cooperation and the peaceful uses of outer space

All space-faring states emphasize the importance of cooperation and the peaceful uses of space, but often 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.

The US and China adopted new space policies in 2006 that emphasize both international cooperation and national security. The US released an unclassified version of a new National Space Policy similar to the 1996 version but with notable emphasis on US freedom of action in space and opposition to new legal regimes or other restrictions on US access to, or use of, space. It maintains the tradition of US cooperation on peaceful uses of outer space. China released a White Paper on Space Activities that stresses the importance of international cooperation and exchanges, while linking China's space activities to its national interests and strengths.

Growing focus within national military doctrine 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 also begun to focus 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.

Security uses of outer space continued to figure prominently in 2006. The new US National Space Policy declared freedom of action in space as important to the US as air and sea power. China's White Paper, "China's National Defense," stressed "informationization" as a key strategy in the modernization of the People's Liberation Army, although there is no express mention of the use of outer space for national defense. The ruling Liberal Democratic Party in Japan formulated a bill that would allow the Japanese government to carry out space activities expressly for non-aggressive military and/or defense purposes. India continued to consider the creation of an integrated Aerospace Command.

Civil Space Programs and Global Utilities

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 2006 10 actors had demonstrated independent orbital launch capacity and 47 states had launched civil satellites, either independently or in collaboration with others. China recently joined Russia and the US as the only space powers with demonstrated manned spaceflight capabilities.

The year 2006 saw the launch of 47 civil spacecraft, including the first satellite owned by Kazakhstan, which became the 47th state to access space. Although launch vehicle technology continued to develop, the failure of the Indian Space Research Organization's Geo-Synchronous Satellite Launch Vehicle hindered its efforts to become one of the few states with the capability to launch heavy payloads into GEO.

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, 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.

There was a marked focus on lunar exploration and human spaceflight in statements by civil space agencies in 2006. NASA, Russia, China, and India announced plans for future lunar missions and the ESA successfully completed its SMART mission, which crashed a spacecraft onto the lunar surface. Both the US and China referred to future human missions to the moon and lunar bases. Moreover, India announced its intention to proceed with a human spaceflight program. In the US, this focus appeared to come at the expense of NASA's space science budget. Despite these long-term policy announcements, civil space budgets generally increased only modestly in 2006.

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 International Space Station (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.

By 2006 China had signed 16 international space cooperation agreements with 13 different countries, space agencies, and international organizations. Major international cooperation initiatives in 2006 included an India/NASA agreement for technology exchange, a deal between India and Russia to jointly use Russia's GLONASS navigation system, and an agreement for the EU's EUMETSAT and the US NOAA to share meteorological information during times of crisis or war. Although NASA Chief Administrator Michael Griffin visited China in September 2006, there is no evidence that there will be substantial cooperation between the two countries in the near future.

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 economies are heavily dependent on these space-based systems. Currently China, the EU, India, Japan, Russia, and the US are developing satellite-based navigation capabilities; there are now approximately 48 navigation satellites in operation. The strategic value of satellite navigation was underscored by the conflict over frequencies for Galileo and GPS, resolved in 2004.

Expansion of space-based global utilities continued in 2006. The US moved forward with initial steps to modernize its GPS system, while Russia launched three more GLONASS satellites, bringing the system closer to full operational status. States continued to seek independent capabilities: India announced that it will create an independent Regional Navigation Satellite System and China indicated that it will extend its Beidou regional system into a global system called Compass. Meanwhile, the operational date of the EU Galileo satellite navigation system has been rescheduled from 2008 to 2011. Security concerns encroached on the use of global utilities when the EU agreed with the US NOAA to create a "data denial list" restricting certain agencies from accessing weather data from EUMETSAT.

Commercial Space

Continued 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 to account for 60 percent of the $88.8-billion commercial satellite sector in 2005. 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 while US companies have led in the satellite manufacturing sector.

Satellite services continued to dominate the commercial space market in 2006, accounting for 60 percent of satellite industry revenues. The market was in a period of growth – there were 21 commercial launches in 2006 – nine of these by Russia – compared to 17 in 2005. US companies produced 59 percent of all satellites launched in 2006. Major corporate consolidations in the commercial communications industry indicated market efficiencies and expanding business opportunities; however, mergers in the US launch industry suggest market weakness.

Declining commercial launch costs support 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, Energia in Russia, Lockheed Martin and Boeing Launch Services in the US, and two international consortia – Sea Launch and International Launch Service. With the launch of Mojave Aerospace Ventures' SpaceShipOne in 2004, the private sector entered the sub-orbital manned spaceflight sector.

The US continued to lose commercial launch market share to Europe and Russia in 2006, while corporate consolidations between Boeing and Lockheed Martin (United Launch Alliance) and Rocketplane Ltd. and Kistler Aerospace Corporation (Rocketplane-Kistler) suggest a struggling US launch market. Moreover, the malfunction of the SpaceX Falcon-1 temporarily dashed hopes for a new, low-cost American commercial space launcher. The space tourism industry received a boost from new business and investment initiatives in 2006, but continued to face challenges posed by a lack of international legal safety standards, high launch costs, and export regulations. There was evidence of increasing space launch costs as market overcapacity diminished.

Government subsidies and national security concerns continue to play important roles in the commercial space sector

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, including insurance costs. The US and European space industry also receive important space contracts from government programs. The 1987 Missile Technology Control Regime (MTCR), designed to restrict the proliferation of missile technology, has encouraged actors outside the regime to develop space systems using components that are restricted by the regime itself. 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.

At a cost of $1-billion per year, the US Department of Defense continued to be the single largest consumer of commercial satellite services. National security concerns placed ongoing restrictions on the commercial space industry in 2006, particularly for satellite imagery service providers, which faced additional government resistance to the public availability of images covering what are described as strategic locations. The close relationship between governments, militaries, and space industries was re-established in the US and China, with national policies that link domestic space industries to national security.

Space Support for Terrestrial Military Operations

The US and Russia continue to lead in developing 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 2006 the US and USSR/Russia had launched more than 4,800 military satellites, while the rest of the world had launched only 80 to 90.

The US has dominated the military space arena since the end of the Cold War and currently accounts for roughly 95 percent of total global military space expenditures with approximately 130 operational military-related satellites – over half of all military satellites in orbit. Russia is believed to have some 60 dedicated military and 18 multipurpose satellites in orbit. The US is, by all major indicators, the actor most dependent on its space capabilities. The *2001 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.

In 2006 the US launched 14 military satellites, maintaining dominance in military space. However, a report issued by the Government Accountability Office called attention to ongoing cost overruns and delays of several high-profile space acquisition programs, including the Space Based Infrared System, the Wideband Global SATCOM, and the Advanced Extremely High Frequency programs.

While Russia's military space budget increased by about one-third in 2006, it was still dwarfed by US spending. Russia launched eight military satellites in an attempt to maintain the capacity of its aging reconnaissance, early warning, and communications system, and to bring its constellation of GLOSNASS navigation satellites closer to completion.

More states 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 three reconnaissance satellites – two optical and one radar. Thailand operates a military communications satellite and is developing its first intelligence and defense satellite.

Ongoing regional tensions continued to drive military space developments in 2006. Although China did not launch any dedicated military satellites, the launch of spacecraft with dual-use applications, including communications and radar imaging, potentially expanded its access to military space capabilities. Japan launched its third reconnaissance satellite and, following a series of missile tests by North Korea, tabled a bill to relax restrictions on military space applications. South Korea launched its first military satellite, Koreasat 5, which will provide military and commercial communications. India continued to work on the Military Surveillance and Reconnaissance System and to consider an integrated Aerospace Command.

Germany launched its first dedicated military satellite – SAR-Lupe – a radar reconnaissance satellite that will join France's Helios A and Italy's Cosmos Skymed (2007) to provide France, Germany, Italy, Spain, Belgium, and Greece with reconnaissance capabilities. Debate continued over the potential dual-use of European space capabilities, as the Galileo navigation system progressed and the European Space Agency considered investing in dual-use, security-related research. Canada took steps to increase its access to military space applications, including the future US Advanced Extremely High Frequency satellite system and imagery from Radarsat-2 through a new Joint Space Support Project.

Space Systems Protection

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

The timely detection and warning of attacks are key for enabling defensive responses in space. 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.

US efforts to upgrade its missile early-warning system progressed in 2006 with the launch of a Space Based Infrared System sensor; however, the program was over budget, behind schedule, and risked replacement by the newly initiated Alternative Infrared Satellite System. Russia closed a seven-year coverage gap in its northwestern region when its new Voronezh meter-band early warning radar was put online in 2006. Russia also brought its space-based Oko early-warning constellation back up to minimum operational status with the launch of a fourth satellite, but the system does not provide global coverage.

The ability to detect satellite interference was a concern in 2006. US STRATCOM put new procedures in place to determine the source and attribution of satellite disturbances: to improve response times, all cases are assumed to be deliberate. China was upgrading its Xi'an Satellite Monitoring Center to enable monitoring and diagnosis of satellite malfunctions, eliminate harmful interference, and prevent purposeful damage to satellite communications links. In 2006 both Japan and Europe turned to a commercial service to provide satellite interference data support.

Protection of satellite ground stations is a concern, while 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.

In 2006 Europe, Japan, and the United States each made some progress in the development of satellite laser communications, but the capability remains remote. The US Transformational Satellite Communication program demonstrated the ongoing challenges related to laser communications. The program continues to face technical difficulties, cost overruns, and schedule delays – the first reduced capacity satellite is not expected to launch until 2014.

Protection of satellites against some direct threats is improving, largely through radiation hardening, system redundancy, and greater use of higher orbits

The primary source of protection for satellites comes from the difficulties associated with launching an attack into space. Increasingly, states are placing military satellites into higher orbits where vulnerability to attacks is lower. 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. Reflecting concerns about the protection of commercial satellites, in 2002 the US General Accounting Office recommended that "commercial satellites be identified as critical infrastructure."

After facing potential cancellation due to cost overruns, the Orbital Express program was brought back on track in 2006 and is scheduled for launch in 2007. The program is designed to demonstrate automated approach and docking, fuel transfer, and components exchange, which could extend the life of satellites, enable greater manoeuvrability and help protect against some direct threats in space. The University of Florida and Honeywell are experimenting with a new type of spacecraft protection through software rather than hardware design.

The US and Russia lead in capabilities to rapidly rebuild space systems following a direct attack on satellites

The ability to rapidly rebuild space systems after an attack is critical. 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.

There is a growing interest in rapid air-launch capabilities. The QuickReach rocket, part of the US Small Launch Vehicle project, passed several tests in 2006 and NASA Ames signed an agreement with its manufacturer, AirLaunch LCC, to collaborate on air-launched space boosters. Kazakhstan's KazCosmos also announced plans to develop the Ishim air-launched rocket system, based on the Soviet era ASAT system. China indicated that it will design a three-stage air-launched rocket released from a modified H-6 bomber. Despite these initiatives, no state has developed a launch-on-demand capability.

Space Systems Negation

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.

Commercial satellite systems were targets of negation in 2006. Libyan nationals were identified as the source of months-long jamming of the mobile phone services of Thuraya Satellite Telecommunications. Moreover, the potential for commercial satellites to be third-party targets during conflict was demonstrated in the 2006 Israel-Lebanon war, during which Israel tried, but failed, to jam the Al-Manar satellite channel transmitted by the Arab Satellite Communications Organization. Amateur hackers in Indonesia demonstrated the vulnerabilities of some older commercial satellite systems by collecting transmitted data.

The US leads in the development of space situational awareness capabilities that could 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.

Updates to China's Xi'an Satellite Monitoring Center in 2006 reportedly included increased orbit determination and tracking capabilities, which were demonstrated when it successfully intercepted a satellite on 11 January 2007. US efforts to develop space surveillance capabilities that could support negation efforts were largely stalled in 2006, particularly in GEO. Despite progress on the Space Based Surveillance System, launch of the initial pathfinder satellite was further delayed to 2009 and the Orbital Deep Space Imager program was cut.

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 sub-orbital 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 leads in the development of more advanced ground-based kinetic-kill systems with the capability to directly attack satellites. It has deployed components for a ground-based ballistic missile defense system and has advanced laser programs, both of which have inherent satellite negation capabilities in LEO.

China became the third state to successfully conduct a kinetic hit-to-kill intercept of a satellite on 11 January 2007 when it destroyed a weather satellite at an altitude of approximately 850 kilometers. This was the first openly conducted ASAT demonstration since 1985. It followed US reports that a Chinese ground-based laser illuminated an American reconnaissance satellite as it passed over Chinese territory. Given the few details released about the incident, it is difficult to determine either the intensity or the intent. of the laser. Both the US and China are conducting ongoing research on high-energy lasers. Funds to testfire a US laser against a satellite in LEO from the Starfire Optical Range were initially revoked, then restored in 2006, following denial that it would be used as an ASAT test.

Proliferation of 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.

In 2006 the US experimented with potential space-based negation technologies in GEO, using two classified microsatellites to assess their potential for defense applications. The US Air Force also requested funding for an Experimental Small Satellite-11 follow-on mission, which demonstrates proximity operations and autonomous rendezvous capabilities in LEO – capabilities that could be used for passive reconnaissance missions in space or hostile negation efforts in the future.

Space-Based Strike Systems

While no space-based strike systems have been tested or deployed, the US continues to develop 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 1990s, 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.

No space-based strike systems were tested or deployed in 2006. Despite US efforts to move forward on technology, including a ground-based Multiple Kill Vehicle demonstration and budget requests by the Missile Defense Agency for a Space Based Interceptor Test Bed, space-based technology experiments, and a second NFIRE test, the Congressional Subcommittee on Strategic Forces banned the use of funds for the development of anti-satellite capabilities and space-based interceptors for the time being.

A growing number of actors are developing 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 re-entry capabilities that provide a basis for the more advanced technologies required for the delivery of mass-to-target weapons from space to the Earth.

The development of dual-use technologies that also provide enabling capabilities for space-based strike systems – including hypersonic flight and Earth re-entry technologies, global missile tracking and warning, precision navigation, and high energy lasers – continued in 2006. The technological challenges of space-based strike systems remain daunting, however, and there was no evidence that states were developing capabilities for strike purposes.