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# Acronyms

| | |
|---|---|
| **ABM** | Anti-Ballistic Missile |
| **ASAT** | Anti-Satellite Weapon |
| **ASLV** | Augmented Satellite Launch Vehicle |
| **AWS** | Advanced Wideband System |
| **BMD** | Ballistic Missile Defense |
| **CBM** | Confidence Building Measures |
| **CD** | Conference on Disarmament |
| **CNES** | Centre National d'Études Spatiales |
| **CONUS** | Continental United States |
| **COPUOS** | United Nations Committee on the Peaceful Uses of Outer Space |
| **COSPAR-SARSAT** | Committee On Space Research – Search and Rescue Satellite-Aided Tracking |
| **CSA** | Canadian Space Agency |
| **CSRS** | Counter Surveillance Reconnaissance System |
| **DARPA** | Defense Advanced Research Projects Agency |
| **DBS** | Direct Broadcasting by Satellite |
| **DOD** | United States Department of Defense |
| **DSCS** | Defense Satellite Communications System |
| **DSP** | Defense Support Program |
| **EELV** | Evolved Expendable Launch Vehicle |
| **EHF** | Extremely High Frequency |
| **EKV** | Exoatmospheric Kill Vehicle |
| **ESA** | European Space Agency |
| **EU** | European Union |
| **FALCON** | Force Application and Launch from the Continental United States |
| **FCC** | United States Federal Communications Commission |
| **FMCT** | Fissile Material Cut-off Treaty |
| **FOBS** | Fractional Orbital Bombardment System |
| **GEO** | Geostationary Orbit |
| **GEOSS** | Global Earth Observation System of Systems |
| **GLONASS** | Global Navigation Satellite System |
| **GMES** | Global Monitoring for Environment and Security |
| **GPS** | Global Positioning System |
| **HAND** | High Altitude Nuclear Detonation |
| **HEO** | Highly Elliptical Orbit |
| **IADC** | Inter-Agency Debris Coordinating Committee |
| **ICBM** | Intercontinental Ballistic Missiles |
| **ILS** | International Launch Services |
| **INMARSAT** | International Maritime Satellite Organization |
| **INTELSAT** | International Telecommunications Satellite Consortium |
| **ISO** | International Organization for Standardization |

| | |
|---|---|
| **ISRO** | Indian Space Research Organization |
| **ISS** | International Space Station |
| **ITAR** | International Traffic in Arms Regulation |
| **ITU** | International Telecommunication Union |
| **LEO** | Low Earth Orbit |
| **MDA** | Missile Defense Agency |
| **MEO** | Medium Earth Orbit |
| **MIRACL** | Mid Infrared Advanced Chemical Laser |
| **MKV** | Miniature Kill Vehicle |
| **MOST** | Microvariability and Oscillations of Stars |
| **MPX** | Micro-satellite Propulsion Experiment |
| **MTCR** | Missile Technology Control Regime |
| **NASA** | National Aeronautics and Space Administration |
| **NFIRE** | Near-Field Infrared Experiment |
| **NMD** | National Missile Defense |
| **NOAA** | National Oceanic and Atmospheric Administration |
| **NORAD** | North American Aerospace Defense command |
| **NSTAC** | National Security Telecommunications Advisory Committee |
| **ORS** | Operationally Responsive Spacelift |
| **OST** | Outer Space Treaty |
| **PAROS** | Prevention of an Arms Race in Outer Space |
| **PEIS** | Programmatic Environmental Impact Statement |
| **PSN** | Indonesia Pasifik Satellite Nusantara |
| **QZSS** | Quazi-Zenith Satellite System |
| **RAIDRS** | Rapid Attack Identification Detections Reporting System |
| **RAMOS** | Russian-American Observation Satellite Program |
| **RFTWARS** | Radio Frequency, Threat Warning, and Attack Reporting |
| **SAINT** | Satellite Interceptor |
| **SALT** | Strategic Arms Limitations Talks |
| **SAR** | Search And Rescue |
| **SBI** | Space-Based Interceptors |
| **SBIRS** | Space-Based Infrared System |
| **SBL** | Space-Based Laser |
| **SBSS** | Space-Based Surveillance System |
| **SBSW** | Space-Based Strike Weapon |
| **SDI** | Strategic Defense Initiative |
| **SHF** | Super High Frequency |
| **SMV** | Space Maneuver Vehicle |
| **SSN** | Space Surveillance Network |
| **SSS** | Space Surveillance System |
| **STSS** | Space Tracking and Surveillance System |
| **SUPARCO** | Space and Upper Atmospheric Research Commission |
| **TSat** | Transformational Satellite Communications system |

| | |
|---|---|
| **UHF** | Ultra High Frequency |
| **UN** | United Nations |
| **UNGA** | United Nations General Assembly |
| **US** | Unites States of America |
| **USAF** | United States Air Force |
| **USML** | United States Munitions List |
| **USSR** | Union of Soviet Socialist Republics |
| **XSS** | Experimental Spacecraft System |

# Introduction

History may well judge 2004 to have been a watershed year for space security. It marked the first privately funded launch of a person into space to win the "X Prize." Commercial space revenues exceeded $100 billion for the first time in 2004. The US articulated a bold new vision for human space flight back to the Moon and on to Mars. China completed more space launches than any previous year. The resolution of the EU/US dispute over Galileo/Global Positioning System frequency allocation in 2004 opened the way for further development of an unprecedented global utility that has become essential to millions of civil, commercial, and military space actors and applications. In a few years, the US will have as much invested in space as it does in Europe.

Under the Outer Space Treaty, space is open to everyone and belonging to no one. Space is also a global commons that borders every community on Earth and secure access to and use of space has been critical to its development as a new center of strategic social, economic, and military power. Space has also become a critical part of our national and international infrastructure; it supports our medical systems, our public services, our communications systems, our financial institutions, and our militaries. Indeed, today it is difficult to imagine our societies and economies functioning without the support of space-based assets. However, the dynamics of space security remain poorly understood. Space is uniquely fragile as an environment and the resources of Earth's orbital space are limited. It is not clear how we can best balance today's competing civil, commercial, and military interests against the need for sustainable uses of space that will ensure its utility for future generations.

Building upon research first developed for a 2003 pilot project, *Space Security 2004* provides the first comprehensive set of assessments of the longer term trends and annual developments that shape the dynamics of space security, defined as ***secure and sustainable access to and use of space, and freedom from space-based threats***. We hope that this annual Space Security series will become the basic public source for legislators, researchers, officials, and commentators when they discuss space security.

*Space Security 2004* is based wholly on open source material which does impose some unavoidable limitations. For example, our analysis is inevitably more focused on those states and other actors that publish more about their space activities. We have tried to be as objective as possible, both in presenting the facts contained in this volume and in providing assessments of trends and developments. In the interest of transparency, details on the methodology used for this study can be found in Annex A.

However, assessments of the impact of these trends and developments upon space security are, of course, inherently subjective. How someone views the status of space security very often depends on where one stands. US experts have a tendency to view space security developments differently from EU, Chinese, or Russian expert participants, and this is equally true of experts from the civil, commercial, and military space sectors. Thus, we believe that one of the unique features of *Space Security 2004* is the provision, through the Space Security Survey and Space Security Working Group, of space security assessments from various space sectors and a range of space faring states. A list of participants in the Space Security Working Group is included in Annex B.

We would like to express our gratitude to the many advisors and participants who supported this project. For research and writing in *Space Security 2003*, from which much was drawn for this year's edition we would like to thank: Mr. Phil Baines, Mr. Michel Bourbonnière, Dr. Nicole Evans, Ms. Theresa Hitchens, Mr. Maciek Hawrylak, Dr. Andrew Latham, Mr. Robert McDougall, Dr. David Mutimer, Mr. Robert Schingler, Mr. Gabriel Stern, Dr. Lucy Stojak, and Mr. George Whitesides.

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For organizing the Space Security Working Group meeting in Montreal on 24-25 February 2004, we would like to express our gratitude to the McGill University Institute of Air and Space Law, and in particular to Dr. Paul Dempsey, Dr. Ram Jakhu, Dr. Lucy Stojak, and Ms. Maria D'Amico. For financial and in-kind support, we would like to thank the International Security Research and Outreach Programme at Foreign Affairs Canada, the Simons Foundation, the Secure World Foundation, the McGill University Institute of Air and Space Law, and the Pugwash Conferences on Science and World Affairs.

While we have benefited greatly from the input of many experts in the development of *Space Security 2004*, responsibility for any errors or omissions in this volume remains our own.

The views expressed in this volume represent those of the experts engaged throughout this process and do not necessarily reflect the views of the Government of Canada, Foreign Affairs Canada, Project Ploughshares, or the Space Generation Foundation.

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# The Space Environment

## Key Trends and 2004 Developments

**Growing debris threats to spacecraft, but annual rate of new debris production is decreasing** – The number of objects in Earth orbit has increased steadily since the dawn of the space age. Approximately 13,000 objects large enough to seriously damage or destroy a spacecraft are in orbit today – over 90 percent of which are space debris. While this represents a growing threat to spacecraft, the annual rate of new debris production has been decreasing since the early 1990s, due in large part to national space agency debris mitigation efforts.

The space debris population continued to grow in 2004. Work continued on US technologies to mitigate debris production, by de-orbiting non-operational satellites (e.g. the Terminator Tether) and extending the operational life of satellites (e.g. the ConeXpress). The US Missile Defense Agency (MDA) released an environmental impact statement that examined the anticipated space debris impacts of its planned missile defense space-based interceptors.

**Increasing awareness of space debris threats and continued efforts to develop international guidelines for debris mitigation** – There is widespread recognition that space debris is a growing threat. There have already been a number of on-orbit collisions with space debris. Since the mid-1990s, many space-faring states, including China, the EU, Japan, Russia, and the US, have developed national debris mitigation standards. In 2001, the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) mandated the Inter-Agency Debris Coordination Committee (IADC) to develop a set of voluntary international debris mitigation guidelines.

While the IADC submitted proposed debris mitigation guidelines to COPUOS in 2004, they were sent back to the IADC for more work after several states suggested significant modifications. At the national level, the US Federal Communications Commission (FCC) adopted new regulations in 2004, requiring geostationary satellite operators to move satellites into 'graveyard orbits' 200 to 300 kilometers above GEO at the end of their operating life.

**Growing demand for radio frequency spectrum** – Expanding satellite applications are driving growing demand for radio frequency spectrum. The number of satellites operating in the 7-8 gigahertz band commonly used by GEO satellites has been increasing. Satellite operators now spend about five percent of their time addressing frequency interference issues. The growth in military bandwidth consumption has been dramatic. The US military used some 700 megabytes per second of bandwidth during Operation Enduring Freedom in 2003, compared to just 99 megabytes per second during Operation Desert Storm in 1991.

In 2004, the US and EU reached an agreement on their long-standing dispute over frequency allocation between the US Global Positioning System (GPS) and the proposed EU Galileo navigational system. The US FCC agreed to allow spectrum sharing between certain Low Earth Orbit (LEO) operators. Plans by Vietnam to launch its first telecommunications satellite in 2005 were delayed when negotiations on frequency use with the operators of neighboring satellites failed.

**Growing demand for orbital slot allocations** – There are more than 620 operational satellites in orbit today: about 270 in LEO, 50 in Medium Earth Orbit, and slightly more than 300 in GEO. Demand is greatest for GEO orbital slots, where most communications satellites operate. Competition for orbital slot assignments has increased, and disputes between satellite operators seeking slots are more frequent.

In reaction to this scarcity of orbital slots, some actors agreed to exchange or share rights to certain slots in 2004. Telesat Canada agreed to allow a DirecTV satellite to move into one of its slots in exchange for Telesat Canada's use of a DirecTV satellite in another orbital slot. New Skies sold the rights to an orbital slot to Intelsat, which had acquired a satellite that would be too close to avoid interference if New Skies were ever to launch to that slot. Pakistan announced plans to launch an indigenous satellite in a slot that it had maintained with a place-keeping satellite. The International Telecommunications Union (ITU) delayed internal reforms designed to address slot allocation backlogs and related financial challenges.

**Space surveillance capabilities to support collision avoidance slowly improving** – The US Space Surveillance Network uses 25 sites world-wide to monitor over 9,000 space objects in all orbits, providing the primary capability used by space actors for collision avoidance purposes. Russia maintains its Space Surveillance System with 14 sites, and monitors some 5,000 objects (mostly in LEO), but does not widely disseminate this information. The EU, Canada, France, Germany, and Japan are all developing new space surveillance capabilities.

In 2004, the US began restricting access to its space surveillance information, citing concerns about the potential for the information to be used for adversarial purposes. Japan's new space debris radar became operational and can detect objects one meter in diameter at a distance of 600 kilometers.

## Space Security 2004 Survey Results

**Half of all Space Security Survey respondents and a majority of Space Security Working Group participants assessed that there was little or no effect on space security in 2004 with respect to this indicator.** A strong minority of experts assessed that space security was somewhat enhanced, citing progress on debris mitigation efforts and the conclusion of an agreement on GPS-Galileo frequency interoperability. Many considered that cooperative measures to coordinate the use of radio frequency spectrum, such as the new US FCC regulations on frequency sharing, would improve the availability of these resources. Some experts also noted that while competition over scarce resources could lead to significant conflicts in the future, such conflicts were currently still rare. Many experts who assessed that space security had been somewhat reduced cited as cause for concern the continued growth in the amount of space debris, and new US limitations on the Space Surveillance Network's provision of information to others on the orbital characteristics of satellites and debris. The potential for debris creation by kinetic energy space weapons, including the proposed testing of US space-based missile defense interceptors, was also mentioned as a cause for a negative assessment by several experts.

# Laws, Policies, and Doctrines

## Key Trends and 2004 Developments

**Progressive development of legal framework for outer space activities** – Since the signing of the Outer Space Treaty in 1967, the international legal framework related to space 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 customary international law. This legal framework establishes the principle, primarily through the Outer Space Treaty, that space should be used solely for 'peaceful purposes' and that space is not subject to claims of national sovereignty.

This legal framework prohibits the deployment anywhere in space of nuclear weapons or any other weapons of mass destruction. The abrogation of the Anti-Ballistic Missile Treaty in 2002 eliminated a long-standing US/USSR-Russia prohibition on space-based conventional weapons, stimulating renewed concerns about the potential negative implications of space weaponization for space security.

Since 1981, the UN General Assembly (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 within the UN Conference on Disarmament (CD) on a multilateral agreement related to the Prevention of an Arms Race in Outer Space (PAROS). In 2004, the UNGA once again passed a PAROS resolution, with 178 in favor, none against, and abstentions from Haiti, Israel, Palau, and the US. This vote was consistent with several years of voting patterns on earlier UN PAROS resolutions, suggesting a consistent and widespread desire on the part of states to expand international law to include prohibitions against weapons in space.

**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, the ITU, and the CD, have been mandated to address space security issues. However, most critically for space security, the CD has been deadlocked since 1998 and unable to address the PAROS issue.

The CD remained deadlocked in 2004 and unable to undertake formal work on the PAROS issue. However, useful discussions were conducted on the margins of the CD. During an informal closed session on PAROS, several states called for the establishment of a CD expert group to discuss the broader technical questions surrounding space weapons. An additional informal meeting on 26 August 2004 provided states with an opportunity to make more detailed comments on issues related to space security and PAROS. COPUOS reached agreement in 2004 on the definition of a launching state, which could have a positive effect on issues associated with the application of the Liability Convention.

**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, including the use of space to promote national commercial, scientific, and technological advances. China, Brazil, and India tend to place a focus within their national space policies on the utility of space cooperation for social and economic development.

The trend toward greater international space cooperation continued in 2004. There was a deepening of space cooperation in Europe, with an expansion of European Space Agency (ESA) membership to include Luxembourg and Greece, and a partnership with Turkey. The draft EU constitution also explicitly called for a European space policy and space program. The US announced plans in 2004 for peaceful space exploration on the Moon and Mars. The US vision proposed fulfilling commitments to the International Space Station; restoring the Space Shuttle to flight, but retiring it by 2010; undertaking robotic and human exploration of the Moon, Mars, and the Solar System; developing a Crew Exploration Vehicle for missions beyond Earth orbit; and pursuing commercial and international cooperation.

**Growing focus within national military doctrine on the security uses of outer space** – Fueled by the revolution in military affairs, the military doctrine of a growing number of states, led by China, Russia, the US, and key EU members, is increasingly emphasizing the use of military space systems to support terrestrial military operations. Dependence on space systems has led several of these states to view space assets as national security critical infrastructure. US military space doctrine has also begun to focus on the need to ensure US freedom of action in space, while preventing adversaries from accessing and using space when necessary.

Several states continued to place a greater emphasis on military space applications in 2004. The EU, France, Japan, and Russia articulated new policies designed to increase the uses of space for national security purposes. The US Air Force (USAF) released a doctrine document that outlined in greater detail the practice of 'counterspace operations.' To the extent that the USAF vision of counterspace doctrine is accepted by the US Government, this represents a significant departure from the broadly accepted international legal norm that space should be preserved as an environment that is open to all and belonging to none.

## Space Security 2004 Survey Results

**A majority of Space Security Survey respondents and Space Security Working Group participants assessed that space security had been somewhat reduced or reduced in 2004 with respect to this indicator.** The most commonly cited argument for this assessment was a strong sense that the apparent drive within US military space doctrine toward space control and counterspace capabilities could lead to the weaponization of space, and encourage other space actors to take countermeasures, such as the development of space systems negation capabilities. Some experts cited progress at COPUOS as a positive development with respect to space security. The deadlock at the CD, coupled with the perception that space-related international legal regimes are poorly enforced, was underscored by other experts as detrimental to space security. Finally, some experts pointed out that international space law has not been able to keep pace with the development of new national civil, commercial, and military space policies and capabilities.

# Civil Space Programs and Global Utilities

## Key Trends and 2004 Developments

**Growth in the number of actors gaining access to space** – By 2003, there were 10 actors with an independent orbital launch capacity, with an average of one new actor developing such a capability every eight years. A total of 44 states have accessed space through an independent launch capability or the launch capabilities of others. In the 1990s, the rate of increase in this capability doubled from just less than one to just less than two per year, mostly for civil space programs. Surrey Satellite Technology Ltd. of the UK has enabled seven countries to build their first civil satellite over the last 12 years.

2004 saw this trend toward greater civil space access continuing, with Iran announcing plans to launch a satellite in 2005, and South Korea and Russia signing an agreement on the joint development of a launch vehicle planned for use in 2007. The US Boeing Delta IV-Heavy launcher completed its first launch. While the Delta-IV Heavy launcher was developed primarily for the USAF, it will also provide new civil launch capabilities. Overall, a total of 28 civil assets, including satellites and human spaceflights, were launched in 2004, in addition to five launches involving the deployment of seven global utility satellites.

**Changing priorities and funding levels within civil space programs** – The general trend in recent years has seen civil space expenditures increase in India and China and decrease in the US, Russia, and the EU. The budget of the Indian Space Research Organisation grew over 60 percent in real terms between 1990 and 2000, while the US National Aeronautics and Space Administration (NASA) and ESA budgets dropped by 25 percent and nine percent respectively between 1992 and 2001. The annual number of civil space missions has generally held steady for the past decade, with a decreasing number of manned missions, and an increasing number of missions involving small satellites and micro-satellites. Civil space programs are increasingly including security and development applications. India has designed 19 telecommunications and remote sensing satellites for development applications, and Malaysia, Thailand, Chile, Algeria, Egypt, Nigeria, and South Africa are all placing a priority on satellites to support social and economic development.

In 2004, China announced its intention to establish a manned space station in Earth orbit within 15 years. The US announced a new NASA plan that included returning humans to the moon by 2020 and on to Mars. The US Congress granted NASA its full budget request of $16.2 billion for FY2005 — an increase of five percent over FY2004. China, France, Italy, Spain, and Saudi Arabia launched micro-satellites for civil applications in 2004, and India launched Edusat, its first dedicated educational satellite.

**Steady growth in international cooperation in civil space programs** – There have been a range of international civil space cooperation efforts over the past decades. These include the US-USSR Apollo-Soyuz docking of manned modules, USSR flights to the MIR space station with foreign representatives, joint NASA-ESA projects such as Skylab, and the Hubble Space Telescope. The most prominent example of international cooperation is the International Space

Station, involving 16 partner states, 44 launches, and an estimated cost of over $100 billion. International civil space cooperation has played a key role in the proliferation of technical capabilities for states to access space.

This trend toward greater international cooperation in civil space programs continued in 2004. A 10-Year Implementation Plan was agreed by the 47 countries within the Global Earth Observation System of Systems initiative. In May, Israel selected India to launch its first astronomy satellite. In October, France and Russia reached an agreement to allow the Soyuz rocket to be launched from the ESA spaceport in French Guyana.

**Dramatic growth in global utilities as states acknowledge strategic importance of satellite-based navigation systems** – The use of space-based global utilities, including navigation, weather, and search and rescue systems, has grown significantly over the last decade. For example, GPS unit consumption grew by approximately 25 percent per year between 1996 and 1999, generating sales revenue of $6.2 billion in 1999. Today, these systems have grown into space applications that have become almost indispensable to the civil, commercial, and military sectors, as well as most modern economies. Since 2001, satellite-based search and rescue systems have saved the lives of approximately 1,500 people per year, double the 1996 rate. The number of states developing satellite-based navigation capabilities has grown, from Russia and the US in 1990, to include three new systems led by China, the EU, and Japan in 2003. The strategic value of satellite navigation was underscored by the conflict over frequencies for Galileo and GPS.

A total of seven new global utilities satellites were launched in 2004, including one communications satellite and six navigation satellites. The longstanding EU/US conflict over Galileo/GPS frequencies was resolved in 2004. Progress was made on construction of the first two Galileo satellites, and agreements were reached between the EU and Israel and Ukraine on their formal participation in the program.

## Space Security 2004 Survey Results

**A significant minority of Space Security Survey respondents and Space Security Working Group participants assessed that there was little or no effect on space security in 2004 with respect to this indicator.** Respondents who assessed that space security had been somewhat enhanced in 2004 tended to cite the resolution of the GPS/Galileo dispute, as well as new agreements with Ukraine and Israel that will enlarge the Galileo partnership. General growth in the use of global utilities, and corresponding growth in the number of space security stakeholders, was also emphasized as being positive for space security. The role of international civil cooperation in enhancing space security was also frequently noted.

Respondents who assessed that space security had been somewhat reduced in 2004 tended to cite as an issue of concern increased civil-military cooperation — particularly in the US but also in the EU — suggesting that this could encourage some actors to view civil space assets as potential targets for space system negation efforts. Some experts expressed concern about developments associated with the use of nuclear power on civil space missions.

# Commercial Space

## Key Trends and 2004 Developments

**Continued overall growth in the global commercial space industry** – The commercial space sector, including manufacturing, launch services, space products, and operating insurance, accounted for an estimated $2.1 billion in revenues in 1980 and $91 billion in 2003. Given recent declining revenues within the manufacturing and launch sectors, this growth is currently being driven by the satellite services industry, including telecommunications, which accounted for 60 percent of 2003 commercial space revenues. Major commercial satellite telecommunications companies today include PanAmSat, Loral, SES Americom, Intelsat, and News Corporation.

The commercial space sector continued to grow in 2004, with sector-wide revenues topping $100 billion. By June 2004, the number of Direct-to-Home television subscribers reached 23.4 million. The US FCC reported in January 2004 that satellites had overtaken cable broadcasters in the competition to provide television service. Military contracts continued to be a source of predicted growth for commercial space actors, second only to sustained telecommunications growth. The privatization of Intelsat in 2004 added a major new player to the commercial space sector. Consolidation appeared to be the priority for the Russian space industry. The Isle of Man announced a zero-tax policy for the space industry in an effort to attract commercial space activities.

**Declining commercial launch costs support increased commercial access to space** – Commercial space launches now account for about one-third of the total 60-70 yearly space launches. 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 still falling. In 2000, payloads could be placed into LEO for as little as $5,000/kilogram. The European and Russian space agencies are the most active space launch providers. Today's top commercial launch providers include Lockheed Martin and Boeing Launch Services in the US, Arianespace in Europe, Energia in Russia, and two international consortia — Sea Launch and International Launch Service. Cheaper space access has become a key factor in the growth of high-resolution commercial satellite imagery.

There were 20 commercial space assets launched in 2004. Mojave Aerospace Ventures' SpaceShipOne became the first private sub-orbital spacecraft in 2004, winning a $10-million competition designed to spur innovation in commercial space access. Virgin Galactic announced a $100-million investment in SpaceShipOne flights, to begin in 2007.

Bigelow Aerospace announced the $50-million America's Space Prize for the first private orbital flight in 2004. Space Exploration Technologies sold the first contract for its Falcon V rocket, reportedly 60-70 percent less expensive than Boeing's Delta II and Delta IV launchers. US Congress passed into law the Commercial Space Launch Amendments Act of 2004, intended to promote the development of the emerging commercial human space industry.

**Government subsidies and national security concerns continue to play an important role in the commercial space sector** – 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 space industry reportedly receives 80 percent of the total value of its space contracts from government funds, and in Europe this figure stands at 50 percent. The 1987 Missile Technology Control Regime (MTCR), designed to restrict the proliferation of missile technology, has tended to encourage actors outside the regime to develop capabilities that are restricted by the regime itself.

In 1999, the US transferred control of satellite export licensing from the Commerce Department to the State Department's US Munitions List, bringing satellite product export licensing under the International Traffic in Arms Regulations regime and significantly complicating the way US companies participate in international collaborative satellite launch and manufacturing ventures.

In 2004, the European Aeronautic Defence and Space Company signed an estimated $1.3-billion deal with ESA as part of the European Guaranteed Access to Space program, and signed a second contract with Arianespace for the production of 30 Ariane 5 launchers. Officials openly discussed the possibility of ending the Ariane rocket program after government subsidies run out in 2009. The US National Geospatial-Intelligence Agency also awarded a contract to ORBIMAGE Inc. large enough to secure its role in the industry in the coming years. In February 2004, the MTCR held an initial round of consultations with China regarding its intention to join the regime.

## Space Security 2004 Survey Results

**A significant minority of Space Security Survey respondents and a majority of Space Security Working Group participants assessed that there was little or no effect on space security in 2004 with respect to this indicator.** A significant minority of experts assessed that the continued growth of the commercial space sector had a positive impact upon space security, often noting that this growth, combined with increasing military-commercial interdependence, would underscore the importance of secure and sustainable access to, and uses of, space. The continued vulnerabilities of commercial space assets and the minimal incentives for commercial actors to protect their satellites were highlighted by a number of experts who assessed that space security had been somewhat reduced with respect to this indicator.

Some respondents noted that growth in the commercial space sector was encouraging the development of new regulatory frameworks which could help to encourage the sustainability of space security. Further, some respondents noted that SpaceShipOne's successful sub-orbital space flight was a positive development related to growing access to space. Some respondents pointed out that, although they felt export controls may have a negative impact on the US commercial space sector, such controls were likely to motivate other space actors to develop their own capabilities, thus increasing secure access for the international community writ large.

# Space Support for Terrestrial Military Operations

## Key Trends and 2004 Developments

**The US and USSR/Russia 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 the end of 2003, the US and USSR/Russia had together launched more than 2,000 military satellites, while the rest of the world had launched only 30 to 40.

The US has dominated the military space arena since the end of the Cold War. The US currently accounts for 95 percent of total global military space expenditures and maintains approximately 135 operational military-related satellites — over half of all military satellites in orbit. Russia is believed to have some 61 operational military 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 the 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. The US has also begun to pursue responsive space lift capability, aiming to reduce the time to deploy new space systems.

While the US continued to lead in the development of military space programs in 2004, several key programs encountered cost overruns and delays. The US Space-Based Infrared System-High, the Space-Based Radar, the Transformational Satellite Communications System, and the Evolved Expendable Launch Vehicle were all over budget. In reaction, the US Congress cut funding for the Space-Based Radar and the Transformational Satellite Communications System. The US small satellite programs TacSat1 and XSS-11, both initially scheduled to launch in 2004, were delayed until 2005. The Responsive Access, Small Cargo, Affordable Launch Vehicle (RASCAL) program also encountered difficulties.

2004 also saw successes for some US military space programs. The 11$^{th}$ Ultra High Frequency Follow-On satellite was handed over to the USAF after successful on-orbit testing by Boeing in March 2004. The Wideband Gapfiller satellite reported being on track to launch at the end of 2005. The Space Tracking and Surveillance System was noted to be ahead of schedule, and the Next-Generation GPS system reported being on track.

In June 2004, the Russian Space Forces launched the second of a projected four Tselina-2 signals intelligence satellites. In July 2004, the commander of the Russian Space Forces noted that Russia will focus on "maintaining and protecting" its fleet of satellites, including launching the remaining seven satellites needed to complete the GLONASS navigation system by 2008. In October 2004, Russian Federation Armed Forces announced that their troops had begun to receive GLONASS navigation units. Russia's space chief claimed in July 2004 that the government had been too slow to fund the Angara rocket as a replacement for the Proton, delaying the final development of the new rocket until 2008 at the earliest.

**More states developing military space capabilities** – 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 Feng Huo series satellite, and has deployed a pair of Beidou navigational satellites to ensure it can maintain navigational capability in the face of US efforts to deny GPS services in times of conflict. China also maintains two Zi Yuan series satellites in LEO for tactical reconnaissance and surveillance functions, and is believed to be purchasing additional commercial satellite imagery from Russia to suit its intelligence needs.

EU states have developed a modest range of military space systems. France, Germany, Italy, and Spain jointly fund the Helios 1 military observation satellite system in LEO, which provides images with a one-meter resolution. France, Germany, and Italy are planning to launch six low-orbit imagery intelligence systems to replace the Helios series by 2008. The UK maintains a constellation of three dual-use Skynet 4 communications satellites in GEO. The EU Galileo satellite navigation program, initiated in 1999, is intended to operate principally for civil and commercial purposes, but will have a dual military function.

Israel operates a dual-use Eros-A imagery system as well as the military reconnaissance and surveillance OFEQ-5 system. India maintains its Technology Experimental Satellite as well as a naval satellite, both of which provide military reconnaissance capabilities. Japan operates the commercial Superbird satellite, which also provides military communications and has two reconnaissance satellites, one optical and one radar, which it launched in 2003.

A total of 26 military space assets were launched in 2004, including 21 by the US and Russia, and 12 by other states. China reportedly launched three military reconnaissance satellites in 2004. In December 2004, France launched four 120-kilogram Essaim signals intelligence satellites. The Israeli Air Force changed its name to the Israeli Air and Space Force in 2004, while the launch of its OFEQ-6 reconnaissance satellite failed in its third stage in September. South Korea announced the creation of an Air Force Space Command, and Thailand signed a deal with a French company for production of its first intelligence and defense satellite.

## Space Security 2004 Survey Results

**A majority of Space Security Survey respondents and Space Security Working Group participants assessed that space security had been somewhat reduced, or reduced, in 2004 with respect to this indicator.** The most common supporting argument for this assessment was that the growing importance of military space systems, combined with perceptions of their vulnerabilities, was driving a new space systems protection-negation dynamic which was undermining the sustainability of space security. While it was clear that a majority of expert respondents assessed that space systems had improved terrestrial military operations, a lack of transparency and trust between key military space actors remained a significant problem.

# Space Systems Protection

## Key Trends and 2004 Developments

**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 –** One key element of space system protection is the timely detection and warning of attacks to enable defensive responses. US Defense Support Program satellites provide some warning of conventional or nuclear ballistic missile-based anti-satellite (ASAT) attacks. Russia began rebuilding its aging missile launch warning system in 2001 by replacing its Oko series satellites with three early-warning satellites (two in HEO and one in GEO). France is due to launch two missile-launch early-warning satellites, Spirale-1 and 2, in 2008. 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. Directed energy attacks such as laser dazzling or blinding, or microwave attacks, move at the speed of light, making it very difficult to obtain advance warning. The US is also developing capabilities to detect in-orbit attacks on satellites through its Rapid Attack Identification, Detection and Reporting System (RAIDRS) program.

In 2004, the US allocated $189 million for a contract to produce a Pathfinder satellite for its new Space-Based Space Surveillance System. The US RAIDRS program received $6.6 million in FY2004, and $16.4 million was requested for its development in FY2005. The 2004 US Defense Authorization Act included restrictions on the provision of satellite orbital information to other actors, a move which could restrict the abilities of other actors to maintain space situational awareness for protection purposes.

**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 their ground stations and communications links. For example, a second primary ground station for the critical US GPS system was only put in place some six years after the system itself was operational. 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. The US has been developing a variety of jamming protection capabilities, including its Global Positioning Experiments project, which would use airborne pseudo-satellites to provide GPS signals with the capability to overpower jammers.

2004 saw evidence of greater efforts to address the protection of satellite ground stations and communications links. China announced that it would launch a 'jam-proof' communications satellite in 2005. The US completed testing of a jam resistant phased array antenna for its Advanced Extremely High Frequency defense communications satellites. In March 2004, a US National Security Telecommunications Advisory Committee study emphasized that the most likely threats to commercial satellites are attacks on ground facilities, from computer hacking or, possibly but less likely, jamming of communications.

**Protection of satellites against some direct threats is improving, largely through radiation hardening, system redundancy, and greater use of higher orbits** – Both the range of actors employing satellite protection capabilities and the depth of these capabilities are increasing. China, the EU, and Japan are developing navigation satellites that will increase the global redundancy of such critical systems. States are increasingly placing military satellites into higher orbits where vulnerability from various attacks is lower than in LEO, due to greater warning times and difficulty of access. Most key US/NATO and Russian military satellites are already 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."

This growing emphasis on protection capabilities continued in 2004. The EU and US agreement on Galileo-GPS helped to secure greater redundancy of satellite navigation systems through interoperability. The US is reportedly developing a stealth satellite, known as Misty-3, with enhanced protection through its ability to evade detection by the space surveillance systems of other actors.

**Russia and the US lead in capabilities to rapidly rebuild space systems following a direct attack on satellites** – Russia and the US maintain critical space systems protection capabilities through the ability to responsively re-constitute satellite systems. The US is supporting two responsive initiatives. The FALCON - Force Application and Launch from CONUS (CONtinental US) program seeks to develop a rocket capable of placing 100-1,000 kilograms into LEO within 24 hours, and the RASCAL program seeks to deliver 50-130 kilograms into LEO on short notice. The US is also supporting the High Frequency Active Auroral Research Program, focused on measures to mitigate the environmental impact of a nuclear attack in space.

In 2004, Russia conducted a military exercise which included launches to simulate "the replacement of satellites lost in action." In the US, contracts worth $41 million were signed for Phase II of the FALCON program.

## Space Security 2004 Survey Results

**A majority of Space Security Survey respondents assessed that there was little or no effect on space security in 2004 with respect to this indicator, while the largest number of Space Security Working Group participants assessed that space security had been 'somewhat enhanced.'** Several expert respondents made the point that this positive assessment was justified by a growing awareness of the need for protection capabilities, coupled with enhanced capabilities to resist jamming of communications links. A number of expert respondents argued that threats to satellites are being inflated. Most agreed that there was insufficient effort being focused on efforts to protect satellite ground stations from attacks, where vulnerabilities are greatest. Experts frequently noted concerns associated with a nuclear attack in space related to the announcement by North Korea that it now possesses nuclear weapons.

# Space Systems Negation

## Key Trends and 2004 Developments

**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 electronic jamming incidents targeting communications satellites have been reported in recent years, with interruptions in US broadcasting service blamed on Iran working within Cuba, Turkey blocking Kurdish news broadcasts, and the Falun Gong group in China. 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 appears to be the leader in developing advanced technologies to temporarily negate space systems by disrupting or denying access to satellite communications.

US leadership in developing capabilities to negate satellite communications continued in 2004 with the deployment of the US Counter Satellite Communications System, a mobile system designed to target satellite communications signals. A December 2004 US *Presidential Directive on Space-Based Positioning, Navigation and Timing Systems* called for the development of US capabilities to deny local access to GPS signals, without disrupting other services.

**The US leads in the development of space situational awareness capabilities to support space negation** – Several space actors are increasingly investing in space surveillance capabilities for debris monitoring, satellite tracking and telemetry, and asteroid detection. The US and Russia maintain the most extensive space surveillance capabilities. China and India also have satellite tracking, telemetry, and control assets essential to their civil space programs. Canada, France, Germany, and Japan are all actively expanding their ground-based space surveillance capabilities. Although this technology enhances transparency and enables space collision avoidance, it also provides capabilities for targeting and space negation. For example, the US has explicitly linked its development of enhanced space surveillance systems to its efforts to enable offensive counterspace operations.

The US continued development of a range of space surveillance capabilities linked to space control applications in 2004, including the Orbital Deep Space Imager, designed to operate in GEO to provide a near real-time operating picture in support of space control operations; the Rapid On-Orbit Anomaly Surveillance and Tracking system, which will use lightweight components to provide low-cost space situational awareness; the Deep View program, designed to provide images of smaller objects in orbit; and, the Space Surveillance Telescope, designed to identify harder-to-detect orbital objects.

**Ongoing proliferation of ground-based capabilities to attack satellites** – A variety of US and USSR/Russian programs throughout the Cold War and into the 1990s sought to develop ground-based ASAT weapons employing conventional, nuclear, and directed energy capabilities. 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 capabilities, and of those, 10 have an orbital launch capability. As many as 30 states may already have the capability to use 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 intensified its efforts to deploy a ground-based ballistic missile defense system, widely assessed to provide an inherent LEO satellite negation capability.

In 2004, the first kill vehicles for the US ground-based missile defense system were deployed to Fort Greely, Alaska. The US Airborne Laser, designed for boost-phase missile defense, successfully generated a laser beam and is moving to flight testing — a key milestone for another system with an inherent satellite negation capability. The USAF "Counterspace Operations" doctrine released in 2004 recommended the development of satellite negation options, including kinetic-kill ASATs and directed energy weapons. The US Congress cut funding for the Counter Surveillance/Reconnaissance System, believed to be a mobile system designed to use lasers to disrupt the sensors of surveillance satellites.

**Increasing access to space-based negation enabling capabilities** – Space-based negation efforts require sophisticated capabilities, such as precision in-orbit maneuverability and space tracking. Many of these capabilities have dual-use potential. For example, micro-satellites provide an inexpensive option for many space applications, but could be used as kinetic-kill vehicles. The US leads in the development of most of these enabling capabilities, though none appear to be integrated into space-based negation systems.

US programs in this area experienced some setbacks in 2004. Tests for the NASA Demonstration for Autonomous Rendezvous Technology satellite and the Air Force Experimental Spacecraft System-11 were delayed. Other actors, both commercial and governmental, have made recent advances in acquiring access to space — the basic enabling technology for both ground-based direct ascent and space-based ASATs. SpaceShipOne of the American company Mojave Aerospace Ventures, became the first private manned spacecraft by successfully completing a test flight into space on a sub-orbital trajectory. The Iranian Defense Minister was reported in 2004 announcing Iran's intentions to launch a satellite into orbit using indigenous launch capacity based on its extensive missile program.

## Space Security 2004 Survey Results

**A majority of Space Security Survey respondents and Space Security Working Group participants assessed that space security was somewhat reduced or reduced with respect to this indicator in 2004.** Deployment of the US Counter Satellite Communications System was frequently cited as a significant development, as was continued pursuit of enabling technologies for permanent negation of space systems, including those developed through US ballistic missile defense programs. Several participants acknowledged the current US emphasis on temporary and reversible negation techniques, but noted that retaining the option of using space negation systems, particularly kinetic-kill weapons, negatively impacts space security. Some respondents noted that budget limitations on many US programs for negation enabling technologies limited the potential negative impact of these systems.

# Space-Based Strike Weapons

## Key Trends and 2004 Developments

**While no space-based strike weapons (SBSW) have yet been tested or deployed in space, 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 SBSW systems. Under the Strategic Defense Initiative in the 1980s, the US invested several billion dollars in the development of a space-based interceptor (SBI) concept called Brilliant Pebbles, and tested targeting and propulsion components required for such a system. The US and USSR were both developing directed energy SBSW systems in the 1980s, although today these programs have largely been halted.

US research and development efforts associated with the SBI program declined in the 1990s, but were revived by the US MDA in 2000. The Near-Field Infrared Experiment (NFIRE), due for launch in 2006, was planned to be the first fully integrated SBSW spacecraft with a sensor platform and a kinetic-kill vehicle. Further MDA plans include the deployment of a test-bed of three to six integrated SBI by 2011-2012. The annual SBI budget is estimated to be only about $100 million within a broader MDA budget of $10 billion. However, even at these funding levels, the timeline for developing the technical capabilities for SBI appears to be decreasing. While such a system would have limited strategic utility, it would represent the first deployment of weapons in space.

In February 2004, the MDA requested $68 million for FY2005-2006 for the development and deployment of the NFIRE satellite. It would include a sensor package which would test lightweight infrared sensors for missile tracking, as well as a kill vehicle planned to simulate missile intercept maneuvers, demonstrating necessary attitude control, high-G thrust maneuvering, and autonomous missile tracking.

In May 2004, the US Senate Armed Services Committee authorized funding for NFIRE, but added the condition that the test be conducted in such a way as to avoid intercepting the target. In June 2004 the US House of Representatives cut funding for NFIRE. By August 2004, the House of Representatives and the Senate settled to maintain funding for NFIRE at the requested amount.

In August 2004, citing technical difficulties, the MDA announced that the NFIRE kill vehicle main thruster had been removed and that the launch date had been pushed back from the first quarter of 2006 to the last quarter, with test missile flybys moved to 2007. Presently, NFIRE is planned to perform a test with a 20-kilometer flyby of one or two missiles to simulate a kill operation. These developments suggest that the MDA considers itself just a few years away from being able to deploy a fully integrated SBSW system.

**A growing number of actors are developing SBSW precursor technologies outside of SBSW programs** – A majority of SBSW prerequisite technologies are dual-use. They are not related to dedicated SBSW programs, but 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 SBSW systems, their development does bring these actors technologically closer to such a capability.

Both the number of such technologies being pursued in non-SBSW programs and the number of actors doing so are increasing. For example, India and Israel are developing precision attitude control and large deployable optics for civil space telescope missions. In the last 12 years, a total of nine states have deployed a first small or micro-satellite — a key SBI precursor technology. China and the EU are developing re-entry technologies which are also required for the delivery of mass-to-target weapons from space to the Earth.

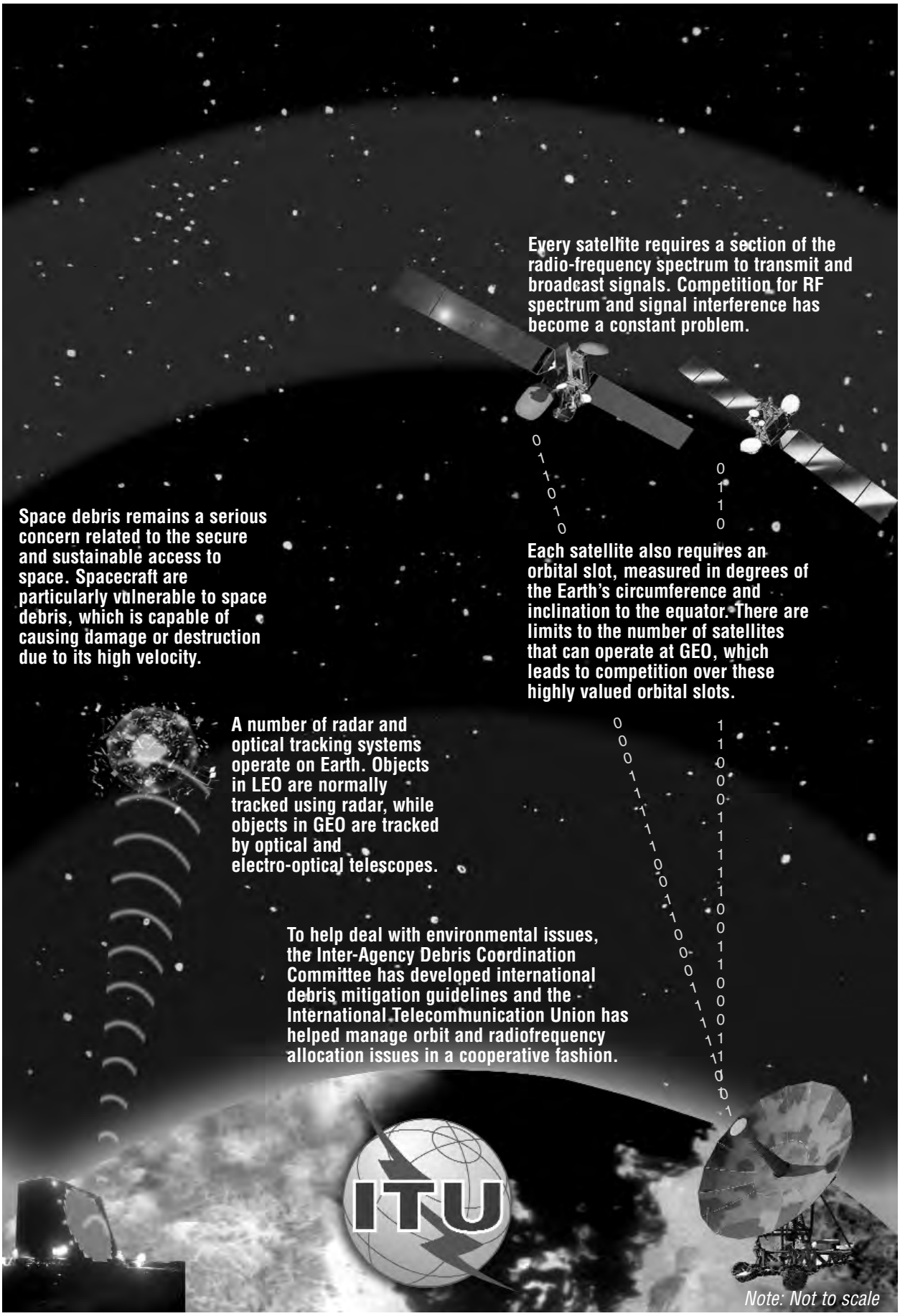
The trend toward the progressive development of dual-use capabilities that are also prerequisite SBSW capabilities continued in 2004. On 22 March and 18 October respectively, Israel and the Ukraine joined the EU Galileo project, providing the basis for their future access to a key, high-precision satellite navigation capability. French micro-satellites were launched in the joint civil-military Myriade micro-satellite program in June and December. On 24 October, China announced a civilian space telescope mission that will demonstrate precision attitude control capabilities.

## Space Security 2004 Survey Results

**A majority of Space Security Survey respondents and Space Security Working Group participants assessed that there was little or no effect on space security in 2004 with respect to this indicator.** One of the most common comments supportive of a more negative assessment was related to the potential of SBSW to stimulate an arms escalation dynamic, in particular by encouraging the development of space systems negation capabilities by other states. Another frequently mentioned concern expressed by experts was related to the apparent determination of the US MDA to pursue the development and deployment of interceptors for a space-based anti-ballistic missile system. Others noted that the scale of US spending on SBSW was relatively modest. Many respondents welcomed the decision by the MDA to remove the kill vehicle on NFIRE, noting that this was a positive development with respect to space security.

## Overall Space Security 2004 Assessment

Overall, a strong majority of 71 percent of Space Security Working Group experts assessed that space security had been somewhat reduced in 2004. The most common reason for this assessment was the view that developments in military space doctrine, particularly in the US, could limit the secure access to space and lead to negative strategic reactions internationally. Many experts also pointed to the development of ASAT technology through funded military and dual-use civil programs. Some 8 percent of SSWG respondents assessed that space security had been somewhat enhanced in 2004 referring to increased international cooperation, budget cuts in certain ASAT-capable military space programs, and commercial sector growth. Finally a solid minority of 21 percent assessed that, on a balance, developments in 2004 had had little or no effect on space security.


Every satellite requires a section of the radio-frequency spectrum to transmit and broadcast signals. Competition for RF spectrum and signal interference has become a constant problem.
Space debris remains a serious concern related to the secure and sustainable access to space. Spacecraft are particularly vulnerable to space debris, which is capable of causing damage or destruction due to its high velocity.
Each satellite also requires an orbital slot, measured in degrees of the Earth's circumference and inclination to the equator. There are limits to the number of satellites that can operate at GEO, which leads to competition over these highly valued orbital slots.
A number of radar and optical tracking systems operate on Earth. Objects in LEO are normally tracked using radar, while objects in GEO are tracked by optical and electro-optical telescopes.
To help deal with environmental issues, the Inter-Agency Debris Coordination Committee has developed international debris mitigation guidelines and the International Telecommunication Union has helped manage orbit and radiofrequency allocation issues in a cooperative fashion.
ITU
Note: Not to scale

# 1 The Space Environment

This chapter assesses trends and developments related to the space environment with an emphasis upon space debris and space resource issues such as orbital slot and radio frequency spectrum allocations.

Space debris, both naturally generated and man-made, 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 at various orbits; space surveillance capabilities which track space debris to enable collision avoidance; and efforts to reduce existing space debris populations.

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 hundreds of pieces of space debris, some 500 of which were reportedly still in orbit in 1994 from USSR ASAT tests in the 1960s, 1970s, and 1980s.[1]

A growing awareness of the impact of space debris upon 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 by this chapter. This chapter does not address natural phenomena such as solar flares and near-Earth asteroids, except in cases where the development of technologies and techniques are developed to mitigate their impact.

Actors who wish to place a satellite in orbit must obtain an 'orbital slot' in which to do so and secure a portion of the radio frequency spectrum to carry their satellite communications. Both radio spectrum and orbital slot assignments are coordinated through the International Telecommunication Union (ITU) and recognized by the ITU Convention as "limited natural resources" given their finite number.

Because space is considered, under the Outer Space Treaty, as open to everyone and belonging to no one, the allocation and use of these two scarce resources has to be negotiated among space-faring powers. This chapter assesses the trends and developments related to the demand for orbital slots and radio frequency spectrum, as well as the conflict and cooperation associated with the allocation and use of these key space environment resources. This includes compliance with existing norms and procedures to manage the allocation of orbital slots and radio frequency, developed by the ITU.

## Space Security Impacts

Space is a harsh environment, and space debris represents a growing threat to the security of access to, and use of, space. Due to very high orbital velocities, debris as small as 10 centimeters in diameter moving at 36,000 kilometers per hour in Low Earth Orbit (LEO) carries the destructive force of a 35,000-kilogram truck moving at 190 kilometers per hour. While objects have lower relative velocities in Geostationary Orbit (GEO), debris at the speed of about 1,800 kilometers per hour is still moving as fast as a bullet. No satellite can be reliably protected against this kind of destructive force.

The total amount of space debris in orbit is growing each year, although the annual amount of new debris created each year is declining. LEO is the most highly contaminated orbit. Some debris in LEO will fall back to Earth, but debris above 600 kilometers will remain a threat for decades and even centuries. There have already been a number of highly destructive and costly incidents involving space debris collisions with civil, commercial, and military spacecraft.

The development of space surveillance capabilities to track space debris to enable collision avoidance clearly provides significant space security advantages. Efforts to mitigate the production of new debris through compliance with national and international regulations can also have a positive impact on space security. Other space environment threats include radiation surges caused by solar flares which damage on-board satellite microchips, interrupt short-wave radio transmissions, and cause errors in navigation systems. Hence, measures to mitigate solar radiation effects are also important for space security.

Resource allocation, including the assignment of orbital slots and radio frequency spectrum 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 such allocations.

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 pressures and increase the availability of these scarce resources. There are strong incentives for space actors to cooperate in the allocation and use of spectrum 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.

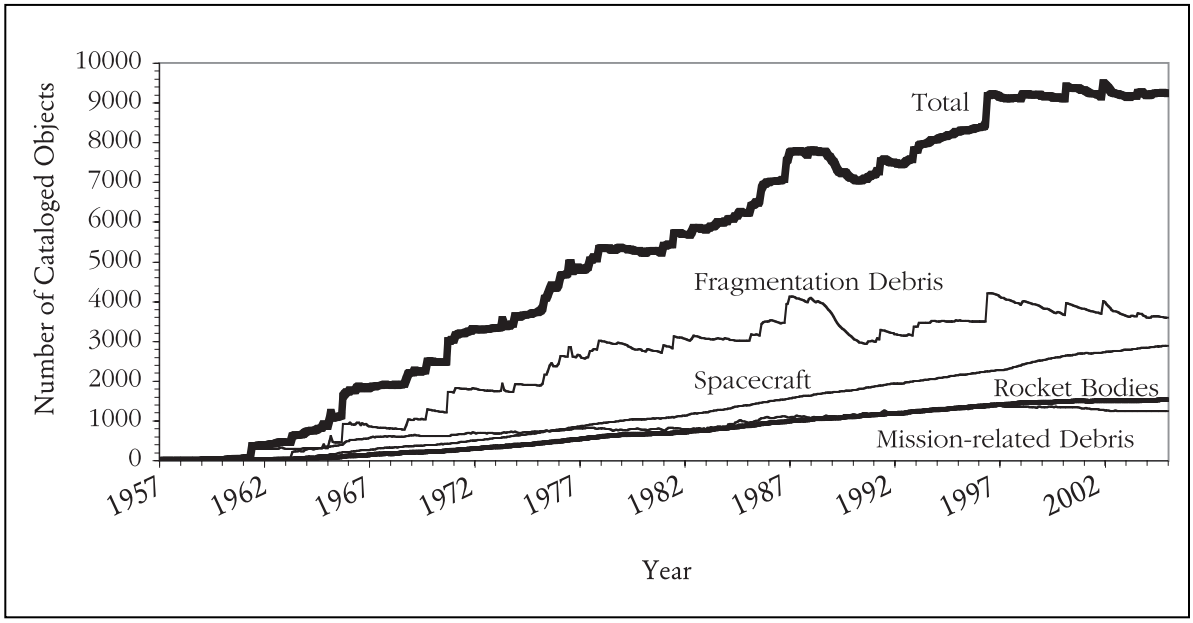
## Key Trends and 2004 Developments

### TREND 1.1: Growing debris threats to spacecraft, but rate of new debris production decreasing

The US Space Surveillance Network (SSN) is the only system that comprehensively tracks and catalogues space debris. Since 1957, the US has registered more than 27,000 large and medium-sized objects orbiting Earth, of which approximately 13,000 known objects are in orbit today, and six to seven percent of which are operational satellites.[2] At the end of June 2004, the number of these known objects that were actually catalogued stood at 9,148. The total number of catalogued objects increased in 2003, when the US Cobra Dane collateral sensor radar that had been taken offline in 1994 was reinstated in the SSN.[3] Figure 1.1 provides an overview of the number of catalogued objects in orbit.

Two key factors affecting debris production are the number of objects in orbit and the number of new satellites being launched each year. Growth in the debris population also increases the probability of inter-debris collisions with the potential to create even more debris. Between 1961 and 1996, an average rate of approximately 240 new pieces of debris a year were catalogued, due in large part to fragmentation debris and the presence of new satellites. Between 8 October 1997 and 30 June 2004, only 603 new pieces of debris were catalogued, a noteworthy decrease from the previous rate of debris generation.

**FIGURE 1.1: Number of catalogued objects in Earth orbit by object type[4]**



While the total debris population continues to increase, a decrease in the annual amount of new debris production appears to be related in large part to international debris mitigation efforts, which increased significantly in the early 1990s. A global decline in the absolute number of launches per year has also contributed to the decreased rate of debris production. However, it is debris mitigation techniques associated with specific launches, rather than the short term decrease in the number of launches, that need to be examined as an indicator of sustainable debris mitigation.

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 and is too small to be verifiably tracked and catalogued. Space scientists estimate that there are tens of millions of objects between one and 10 centimeters in size (i.e., larger than a marble), and an even greater number under one centimeter. Space debris can remain in orbit for very long periods of time, depending on the altitude and mass of the object. While debris in parts of LEO will fall back to Earth over periods of days to months due to atmospheric drag, at altitudes greater than 600 kilometers debris can remain in orbit for "tens, hundreds, or even thousands of years."[5]

Hypervelocity space debris particles one to two millimeters or larger constitute a serious hazard to the security of spacecraft, threatening unprotected fuel lines and other sensitive components.[6] 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 to 10 centimeters "will penetrate and damage most spacecraft," according to the Center for Orbital Re-entry and Debris Studies. Moreover, "if the spacecraft bus is impacted, satellite function will be terminated and, at the same time, a significant amount of small debris will be created."[7]

Today, collisions between space assets like the International Space Station and very small pieces of debris are a daily but manageable problem, and occur in LEO which has the highest concentration of space debris.[8] A 1995 US National Research Council study found that within the orbital altitude that is most full of 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.[9]

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."[10] According to US National Aeronautics and Space Administration (NASA) models, without further implementation of orbital

debris mitigation measures, the number of objects 10 centimeters and greater in orbit — which can be fatal to an average-size satellite — could grow rapidly in the second half of this century.[11] 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.[12] However, it is clear that the consequences of collisions between space debris and spacecraft can be disastrous. While major collisions have so far been rare, as noted in Figure 1.2 below, there have been several incidents of varying severity.

### FIGURE 1.2: Space debris incidents[13]

| |
|---|
| 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 Shuttles' undersides. |
| The 10-year old Hubble Space Telescope, which orbits in LEO, has a three-quarter inch hole in its antenna that is believed to have been 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. |
| The Long Duration Exposure Facility, a school-bus-sized satellite, recorded more than 30,000 impacts by debris or meteoroids during six years in orbit. |

It is also noteworthy that at least three spacecraft were damaged by solar flare events in the last three years.[14] Satellites can be protected from this hazard by temporary shutdown of electronics during a storm. Monitoring satellites, such as the European Space Agency (ESA)/NASA's Solar Heliospheric Observatory[15] and terrestrial solar telescopes, can provide one to three days warning of solar flares.

### 2004: US Missile Defense Agency (MDA) releases environmental impact statement on space debris caused by missile defense tests

In September 2004, the MDA released its required Programmatic Environmental Impact Statement (PEIS),[16] which examines threats to spacecraft in LEO as a result of proposed space-based missile interceptor tests in 2012 (see Space Systems Negation). The PEIS argued that the threat to the International Space Station and other spacecraft was minimal due to the short lifetime of debris in LEO. The PEIS did acknowledge that even small particles of debris can damage satellites and that such particles are too small for the SSN to observe.[17]

An October 2004 US Center for Defense Information report noted that the MDA's PEIS claim that the threat to satellites is low is based on testing which was configured to minimize debris creation, rather than realistic test scenarios. The report also noted that the MDA failed to discuss the impact that a complete operational constellation of such interceptors might have upon the space environment.[18]

### 2004: Progress in debris mitigation technologies

2004 also saw continued research and development into new technologies that may be able to help mitigate the production of new debris. The US Terminator Tether, under development by Tethers Unlimited, Inc., would attach to a satellite during construction and be command-activated to unwind and interact with ionospheric plasma and the Earth's magnetic field, producing a current along the tether which would cause a net drag on the spacecraft, lowering its orbit until it burned up in the Earth's atmosphere.[19]

The US Orbital Recovery Corporation is developing a ConeXpress Life Extension vehicle, a small ion-propelled spacecraft that fits into the unused space on an Ariane 5 rocket. The vehicle would attach itself to a satellite that has run out of propellant, potentially extending the operational lifetime of the satellite up to a decade. The technology might also be used to service satellites whose propellant source was somehow compromised during deployment, rendering it otherwise useless.[20]

### Net assessment

Continued annual growth in orbital debris populations represents a clear threat to the sustainability of space security over the longer term. Overall, all space actors appear to recognize the potential for space debris to evolve from a nuisance to a serious challenge to the continued secure uses of space. In this regard, space experts have consistently raised concerns about the potential for debris creation by US space-based missile defense systems. Efforts to mitigate the production of new debris, remove debris, or protect space systems from space debris can have a positive impact on space security. Progress with initiatives such as the ConeXpress and the Terminator Tether projects should help to address the challenges of de-orbiting space debris or placing used assets into graveyard orbits.

## TREND 1.2: Increasing awareness of space debris threats and continued efforts to develop international 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. The IADC brings together representatives of the space agencies of China, 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. The 1996 US National Space Policy makes it the policy of the US to "seek to minimize the creation of space debris."[21] In December 2000, the US Government issued formal orbital debris mitigation standards for space operators developed by the Department of Defense and NASA. The ESA first introduced a space debris mitigation effort in 1998. In 1999, it published the *ESA Space Debris Mitigation Handbook*, with revisions released in 2002.[22] Also in 2002, the ESA issued the European Space Debris Safety and Mitigation Standard[23] and in 2003, it announced new debris mitigation guidelines.

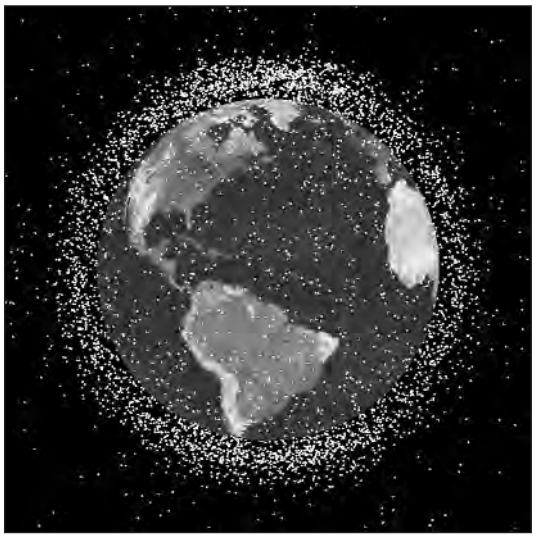
Japan and Russia, as well as several other space-faring states, also appear to strongly support the mitigation of space debris production. While there are some differences among national debris mitigation guidelines, they are broadly consistent. For example, all national guidelines address issues related 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.[24] 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.[25]

China, although a member of the IADC, has not formally adopted debris mitigation guidelines, although it is reportedly working to adopt national guidelines in line with those recommended by the IADC. 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 appearing in the space debris mitigation guidelines developed by the Coordination Committee."[26]

### 2004: IADC submits revised guidelines for debris mitigation and protection

In February 2004, the IADC submitted its proposed voluntary debris mitigation guidelines to the Science and Technical Subcommittee of COPUOS for approval. Delegates of the subcommittee expressed optimism about the guidelines, but requests by Russia, India, the Czech Republic, Italy, and the Republic of Korea for modifications caused the guidelines to be sent back to the IADC, with the hopes of subcommittee approval in 2005.[27] The matter has also been referred to the legal subcommittee of COPUOS for discussion in 2005.

**FIGURE 1.3: Space debris in LEO**[28]



In April 2004, the IADC released a revised debris "Protection Manual" describing design measures for spacecraft survivability against debris.[29] In addition, a subcommittee of the International Organization for Standardization (ISO) started working on a set of standards incorporating elements of the IADC guidelines.[30] On 22 April 2004, space situational awareness topped the list of EU security research, recognizing the importance of environmental awareness in collision avoidance.[31]

### 2004: US Federal Communications Commission (FCC) adopts satellite disposal regulations

The FCC adopted new regulations in the summer of 2004, informed by the IADC's draft debris mitigation guidelines, requiring satellite operators to move satellites at the end of their operating life into "graveyard orbits" some 200 to 300 kilometers above GEO. Compliance with the new regulations will be required for all satellite operators wishing to obtain a license to provide services in the US. Satellite operators indicated that the fuel required to achieve the graveyard orbits would be equal to that required for several months of operating time and expressed concern about the corresponding loss of revenue.[32]

### Net assessment

The failure of the COPUOS Science and Technical Subcommittee to approve the IADC recommended debris mitigation guidelines was cause for concern in 2004. However, the overall trend towards the development of progressively more detailed national and international space debris mitigation guidelines and regulations is clearly a positive space security development. Indeed, the partial implementation of these measures already appears to be having a positive

impact upon the annual rate of new debris production. However, some of these mitigation measures are expensive, which could present challenges for commercial and emerging space actors, suggesting potential restrictions upon their abilities to access and use space.

### TREND 1.3: Growing demand for radio frequency spectrum

Radio frequency spectrum — the part of the electromagnetic spectrum that allows the transmission of radio signals — is divided into portions known as frequency bands, measured in hertz. Higher frequencies are capable of transmitting more information. Communications satellites tend to use the L-band (one to two gigahertz) and S-band (two to four gigahertz) for mobile phones, ship communications, and messaging. The C-band (four to eight 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, eight to 12 gigahertz, and 18-27 gigahertz, respectively) for the US military.[33]

For technical reasons, most satellite communication falls below 60 gigahertz, meaning actors are competing for a relatively small portion of the radio spectrum. Competition is becoming particularly intense for spectrum below three gigahertz.[34] Additionally, the number of satellites operating in the seven to eight gigahertz band, commonly used by GEO satellites, has also grown rapidly over the past two decades.[35] These GEO satellites have the potential for radio frequency interference, since the advantages of GEO for many satellite applications result in a large number of satellites vying for this particular orbit.

Growth in the number of operational satellites in space at any given time has led to a corresponding increase in the demand for bandwidth with which to communicate with these assets. For example, in Operation Enduring Freedom in 2001, the US military used some 700 megabytes per second of bandwidth, compared to about 99 megabytes per second during Operation Desert Storm in 1991.[36] During Operation Desert Storm, it is reported that certain air tasking orders and time-sensitive intelligence information were delivered by hand, due to a lack of available bandwidth.[37] As an example of the kind of growth being planned for by the US military, the Wideband Gapfiller Satellite system is being 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.[38]

While crowded orbits can result in signal interference between satellites, new technologies are being developed which address the need for greater frequency usage, allowing more satellites to operate closer to one another's frequencies without interference. Technologies, such as frequency hopping, lower power

output, laser technology, digital signal processing, frequency-agile transceivers, and software-managed spectrum, have the potential to significantly improve bandwidth use, and hopefully alleviate certain existing and potential future conflicts over bandwidth allocation. In general, present-day receivers are also being produced with higher levels of tolerance for interference than they were decades ago, reflecting the need for increased frequency usage and sharing.[39]

There is also significant research being conducted on using lasers for communications, particularly by the US military. The use of lasers, which transmit information on precise frequencies as opposed to less focused radio waves, would allow higher bit rates and tighter placement of satellites, alleviating some of the current congestion and concern about interference. The main proposed system to make use of such technology is the US military Transformational Satellite Communications System. However, this system is not expected to be fielded before 2012. The planned US NeXt Generation Communications Program would allow several users to share one band of frequencies, with their respective devices intelligently searching through the allocated band for unused portions for transmission.[40]

Today, issues of interference arise primarily when spacecraft either want to use the same frequencies or when their fields of view overlap. While interference is not currently at epidemic proportions, it is a daily fact of life for satellite operators. For example, AsiaSat's general manager of engineering 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."[41]

Still, an official at another satellite operator, New Skies, noted 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."[42] The simplest way to reduce such interference is to ensure that all actors have access to reasonable and sufficient bandwidth. To this end, in July 2002, the US agreed to release military-reserved spectrum from 1,710-1,755 megahertz to the commercial sector by 2008, to free up space for commercial third-generation (3G) wireless communications.[43]

Adopted in 1992, the current ITU Convention[44] governs the international use of the finite radio spectrum and orbital slots used to communicate with and house satellites in orbit. Article 35 of the Convention 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."[45] Military communications are exempt from the Convention, though they must nonetheless observe measures to prevent harmful interference as much as possible.

International negotiations over radio frequency allocations have tended to become politicized, involving bargaining over systems and capabilities which

can take years.[46] Moreover, 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."[47]

### 2004: US and EU reach agreement over Global Positioning System (GPS)-Galileo interoperability

On 25 February 2004, the US and EU announced they had reached an agreement in their long-time dispute over frequency allocation and interoperability between the US GPS and the EU's proposed Galileo navigational system. The agreement addressed interoperability while preserving certain portions of the spectrum for secure military use by the GPS.[48] This development was a milestone in that it set the stage for cooperation between two major space powers operating what will be the world's only two global navigation systems.

### 2004: FCC announces spectrum-sharing decisions

Seeking to alleviate competition for the most commonly used radio frequency spectrum, the FCC announced in July 2004 a decision to allow spectrum sharing in the frequency bands of 1,610 megahertz-1,625.5 megahertz and 2,483.5 megahertz-2,500 megahertz. The decision allows Code Division Multiple Access mobile satellite service operators and Time Division Multiple Access operators to share the L-band, with fixed and mobile terrestrial operators in the S-band. The same order from the FCC announced a notice of proposed rulemaking to explore whether the two types of operators might share additional spectrum in the L-band.[49] These decisions would imply that progress is being made on the ability to safely share frequency, and thus that the availability of this scarce resource is somewhat increasing.

### 2004: World Broadcasting Union submits procedures to reduce interference

In March 2004, the World Broadcasting Union's International Satellite Operations Group submitted a unanimously approved set of Universal Access Procedures to the ITU, "aimed at significantly reducing satellite interference."[50] Of primary concern was the potential for interference by 'rogue' carriers that transmit using satellite capacity assigned to other users, interrupting legitimate and often costly services.

## 2004: Vietnam's efforts to coordinate frequency usage fail

Vietnam's plans to launch its first telecommunications satellite in 2005 were pushed back in 2004, after negotiations with Japan and Tonga failed to identify an operating frequency for Vietnam's satellite which would not interfere with the other countries' neighboring satellites. These negotiations failed despite the fact that Vietnam had previously reserved a frequency position with the ITU. The orbital slot will be lost if not used by February 2006.[51] This development illustrates the continued challenges facing the ITU in regulating the allocation of certain contested orbital slots, and the ongoing difficulty of certain space actors in obtaining a secure use of space.

## Net assessment

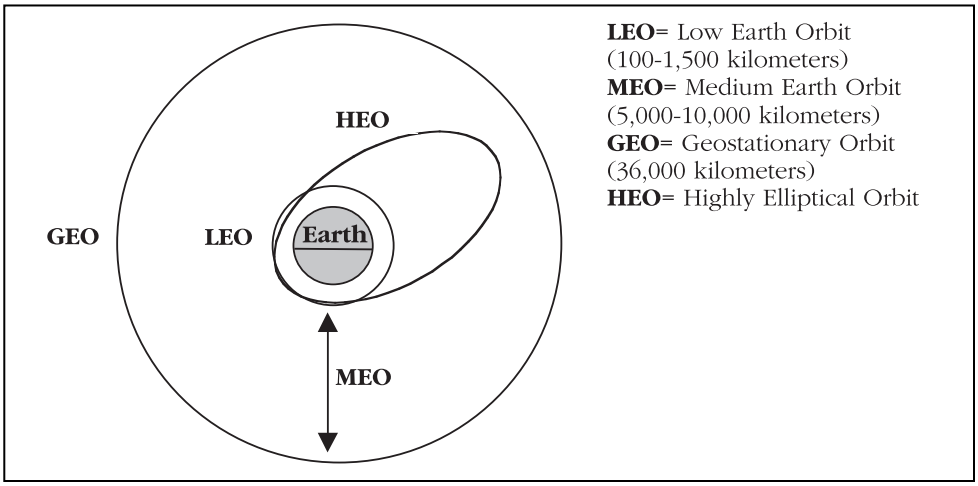
Against a general trend of growing demand for radio frequency spectrum, some developments in 2004, such as the US FCC spectrum sharing decision and the World Broadcasting Union proposals to reduce satellite signal interference, suggest some progress in addressing this challenge. While increased demand for radio frequency spectrum demonstrates an increase in the uses of space, if not adequately addressed, such increased demand has the potential to negatively affect space security in the long term. What appears to be a resolution of the GPS-Galileo dispute was clearly a positive development. However, the failure of Vietnam to resolve its radio frequency interference issues suggests that competition for this scarce resource will continue to generate space resource management issues for some time.

## TREND 1.4: Growing demand for orbital slot allocations

Today's satellites operate in three basic orbital bands: Low Earth Orbit (LEO), Medium Earth Orbit (MEO), and Geostationary Orbit (GEO) (see Figure 1.4 ). There are approximately 620 operational satellites in these orbits, with about 270 in LEO, up to 50 in MEO, and slightly more than 300 in GEO.[52] Highly Elliptical Orbits (HEO) are also increasingly being used for specific applications, such as early warning satellites.

A satellite's orbit determines the types of services it can best provide. LEO is often used for remote sensing, and MEO is home to critical navigation systems such as the GPS and the forthcoming EU Galileo system. Most communications and weather satellites are in GEO. The GEO orbit is unique in that the orbital movement of satellites at this altitude is synchronized with the Earth's 24-hour rotation, so that the satellite appears to remain stationary over a single area on Earth, eliminating the need for expensive tracking receivers.

**FIGURE 1.4: Types of orbits**




The best GEO slots are those located above or close to the equator, which facilitates a greater communications footprint, since satellites in an orbit with an inclination too far north of the equator may not be able to communicate with parts of the southern hemisphere. Around three-quarters of the Earth's surface is water, with little demand for satellite communication in those regions. "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 United States."[53] Similar limitations are true for all geographic regions, and in the case of the US, its range of desirable slots is also optimal for Canada, Mexico, and parts of Latin America, resulting in competition amongst these actors.

The ITU Convention states that radio frequencies and GEO "must be used efficiently and economically so that countries or groups of countries may have equitable access to both."[54] In the case of the GEO orbit slots allocated by the ITU, the principle has been interpreted as meaning that such positions should be made available on a first-come first-served basis. In order to avoid radio frequency interference, GEO satellites are required to maintain at least two degrees of orbital separation, depending on what band they are using to transmit and receive signals, and the field of view of their ground antennas.[55] This means that a maximum of 180 satellites could occupy the prime equator (0 degree inclination) orbital path. In the most desired equatorial arc around the continental US, there is room for only 38 satellites.

GEO satellites must generate high-power transmissions to deliver a strong signal to Earth, due to distance concerns and the use of high bandwidth signals for television or broadband applications.[56] According to an AsiaSat official, true spacing to avoid interference should be five degrees, as the two degree stipulation is based on restrictions on the size of the satellite's antenna and the power of the transmission. Current US FCC policies require US direct broadcast satellites to be spaced nine degrees apart.[57]

There are measures which can help reduce the problem of competition for orbital slots and mitigate signal interference. First, the US FCC's two-degree spacing requirement only applies to satellites that wish to use the same frequency. Satellites with different frequencies can be spaced as little as one-tenth of a degree away from one another.[58] Second, some satellite operators — primarily direct-to-home video suppliers — have begun stacking satellites in the same orbital slot (often known as "hot bird" slots) to be able to provide more service.[59] For example, the 91-92 degrees West slot in GEO houses a Brazilsat, two Galaxy satellites, and a Canadian Nimiq satellite.[60]

Over the years, this increased demand has resulted in greater competition, motivating some space actors to file requests for orbital slots prematurely and/or in greater quantity than necessary, creating a backlog of work at the ITU and long delays for those with legitimate requests. One example of the type of conflicts this can cause occurred in 1992, when the Indonesian Pasifik Satellite Nusantara (PSN) company placed a satellite into a vacant GEO slot which was registered to Tonga. Indonesia refused to abide by the ITU ruling granting Tonga the slot, or to recognize Tonga's leasing arrangements. The dispute escalated in July 1993, when a US firm leased the slot from Tonga and orbited a satellite into position. In 1996, Tonga leased the same slot to a Chinese company, which prompted PSN to jam the satellite. Ultimately the 1998 Asian financial crisis forced PSN to abandon its project. Perhaps most worrisome is that Indonesia consistently refused to acknowledge the right of the ITU to grant slots, while the ITU was incapable of stopping Indonesia's actions.

Compounding these issues to some extent have been ITU revenue shortfalls and disputes over satellite network filing fees. In 2002, the ITU predicted a $16-million shortfall for 2004-2007. Since 1999, the ITU has been implementing a cost recovery scheme for processing satellite network filings, charging members a filing fee. While these were also intended to quell "paper satellite" filings, a growing percentage of the cost recovery revenues have been moving into the ITU's general operating budget. Average cost recovery fees have risen from about $1,126 in 2000, to $13,146 in 2002, and $31,277 in 2003, and member states are increasingly skeptical whether the high fees actually represent the cost of processing the filings. The result has been patterns of non-payment, causing tensions between satellite operators and the ITU. In 2002, an Ad Hoc Group on Cost Recovery for Satellite Network Filings was formed to consider the methodology behind satellite network filing charges, and to make recommendations to the ITU Council.[61]

## 2004: Competition and cooperation in the allocation and use of orbital slots

2004 saw mixed developments in the allocation and use of orbital slots. Telesat Canada and DirecTV came to an agreement in August 2004 in which Telesat Canada allowed DirecTV to move an existing satellite into its slot at 72.5 degrees West, in exchange for Telesat Canada's use of DirecTV's satellite in the

orbital slot at 82 degrees West. DirecTV, the largest satellite TV service provider in the US, wanted the slot in question in order to be able to offer local programming to an additional 24 US-based markets. Conversely, Telesat Canada had a use for DirecTVs on-orbit spare at 82 degrees West as a replacement for a faulty satellite, using it to offer direct-to-home services in Canada. DirecTV's vice-president Bob Marsocci described the exchange as a "creative spectrum-sharing agreement that reflects the increasingly [sic] value of orbital slots."[62]

In other orbital slot developments, New Skies sold the rights to its orbital slot at 120.8 West to Intelsat, who, through the purchase of Loral Space and Communications earlier in 2004, had acquired a satellite at 121 degrees West — too close to avoid interference if New Skies were ever to launch to their slot. The agreement, signed on 5 May 2004 and involving a cash settlement of $32 million, prevented the possibility of Intelsat's satellite being evicted from its current position.[63]

In July 2004, Cablevision Systems Corporation won a $3.2-million bid — the minimum requirement for the slots in question[64] — for two orbital slots from the FCC, giving it access mainly to the west coast of the US.[65] With the minimum-required bid of $5.8 million, EchoStar Communications won a bid for a slot giving it access to the entire western half of the US.[66] A new start-up named Ciel won a competition over Canada's existing dominant commercial satellite services provider Telesat Canada for the orbital slot at 129 degrees West. Although officials from Ciel admit that breaking into Telesat Canada's monopoly will be a challenge, they assert that there is clearly a demand for greater capacity,[67] indicating increasing future demand for these resources. Nonetheless, the fact that certain auctions were won by minimum bids may suggest that there is not necessarily fierce competition for each and every orbital slot.

### 2004: Placement of Pakistani satellite motivated by desire to reserve orbital slot

In May 2004, the chief of Pakistan's Space and Upper Atmosphere Research Commission (Suparco) announced it is drafting a plan to launch an indigenous satellite within five years at an estimated cost of $200 million. He noted that the satellite it would be replacing, the Paksat-1, was launched in 2002 "essentially to occupy the orbital slot for Pakistan." He did not specify what the function of the new satellite would be.[68]

### 2004: ITU's Ad Hoc Group on Cost Recovery for Satellite Network Filings delays recommendations

The ITU's Ad Hoc Group on Cost Recovery for Satellite Network Filings recommended to the 2004 ITU Council that there be no change in cost recovery methodology until 2005, to allow more time for analysis of true costs associated

with satellite filings. Although the decision to look into filing methodology more thoroughly seems to have eased difficulties between the ITU and satellite operators, tensions still remain. As Via Satellite noted, "If the cost recovery fee issue remains unresolved, operators may be forced to look for an alternative for coordinating satellite networks. Without the participation of satellite operators, the ITU cannot sustain its role as an international spectrum manager."[69]

### Net assessment

The increasing use of space also inevitably leads to an increased demand for the limited resources required to support that use. While progress on new technologies for closer satellite spacing are positive for space security, disputes related to the ITU's system for filing for and allocating orbital slots are cause for concern. As the only international body mandated to coordinate orbital slots and frequency allocation, the ITU plays a central role in mediating the competing resource demands of space actors. Efforts to undermine the ITU's legitimacy and effectiveness could have a negative effect upon space security by encouraging more unilateral approaches to the management of scarce orbital slots.

## TREND 1.5: Space surveillance capabilities to support collision avoidance slowly improving

Space surveillance capabilities are vital to the mitigation of environmental hazards. The American SSN is the only network that systematically tracks and catalogues orbital debris. The system is comprised of radars and optical sensors at 25 sites worldwide, as well as one dedicated on-orbit satellite.[70] The SSN can track objects in LEO with a radar cross-section of five centimeters in diameter or greater. The US system uses a tasked sensor approach, which means that not all of orbital space is searched at all times, and thus objects may be observed and then lost again. The system makes up to 80,000 observations daily. Objects one to five centimeters in size, which cannot be dealt with by protective shielding on satellites, are not detectable by the system.

The broader category of space situational awareness, within which space surveillance is a primary capability, remains one of the US' "most urgent space security shortcomings," according to leading experts.[71] Therefore, the US has been bolstering such capabilities. The US Deep View program plans to develop a high-resolution radar imaging capability to characterize smaller objects in Earth orbit.[72] The US Space Surveillance Telescope program will "demonstrate an advanced ground-based optical system to enable detection and tracking of faint objects in space, while providing rapid, wide-area search capability."[73] Upgrades to the Naval Space Surveillance 'Fence' are also under construction. Of the more than 275,000 observations processed daily by the US to update orbital information, over half come from the Space Surveillance Fence.[74] The upgrade would allow the Fence to operate at higher frequencies, which would be expected to result in a significant increase in the number of objects tracked.

Russia also has a 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.[75] The main optical observation system, Okno, allows detection of objects up to 40,000 kilometers,[76] although its capacity to detect smaller objects is unclear. The Russian Academy of Sciences also participates in Russia's SSS.[77] However, the SSS cannot track satellites at very low inclinations, and operation of their surveillance sites is reportedly erratic, with systems coming and going online.[78] The network as a whole carries out some 50,000 observations daily, contributing to a catalogue of approximately 5,000 objects, mostly in LEO.[79] Furthermore, while information from the system is not classified, Russia does not have a formal system in place for widely disseminating information about observations.

Other states, France and Germany in particular, have also emphasized surveillance for debris monitoring. Since 1999, France has operated the Graves radar, which tracks satellites over French territory below 1,000 kilometers. The development of this system was reportedly motivated by a desire for independence from US and Russian space surveillance capabilities.[80] The German Defense Research Organization also operates the High Power 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 size at altitudes of 1,000 kilometers.[81]

The EU maintains information from the SSN in their own Database and Information System called DISCOS, which also takes inputs from Germany's High Powered Radar, ESA's Space Debris Telescope in Spain, and the one-meter Zeiss telescope. Both the Zeiss and Space Debris telescopes focus on observations in GEO and can detect objects down to approximately 15 centimeters in size in that orbit.[82] ESA is developing a Space Debris Avoidance Service,[83] and some experts suggest existing European astronomical facilities could be used to support a European space surveillance and monitoring system.[84]

China, since joining the IADC in 1995, also maintains its own catalogue of objects, using data from the SSN, in order to perform avoidance maneuver calculations and debris modeling.[85] China announced its intentions to field a space debris monitoring center by 2005 in order to contribute to international efforts to track space debris and to provide self-sufficiency in this area. The initial operating capability is hoped to be 30 centimeters in GEO.[86]

Canada is developing a SAPPHIRE system, which will feature a space-based sensor that will provide observations of objects in medium to high Earth orbits (6,000 to 40,000 kilometers). The data will be included in a space catalogue, maintained by the North American Aerospace Defense Command (NORAD), to provide space situational awareness.[87] Canada's planned Near Earth Orbit Surveillance Satellite asteroid discovery and tracking mission also has dual-use space surveillance capabilities.

## 2004: Progress on Space-Based Surveillance System (SBSS)

2004 saw progress on the SBSS, set for launch in 2007, and the Orbital Deep Space Imager. Both surveillance systems will have inherent capabilities for identifying and tracking orbital debris, but are being developed as part of the US space situational awareness and the broader space control missions (see Space Systems Negation).

## 2004: US changes practices on orbital data sharing

The November 2004 US Defense Authorization Act included new restrictions on the provision of information on the orbital characteristics of the spacecraft and debris being tracked by NORAD.[88] The US implemented these stricter controls due to concerns that the information could also be used for adversarial purposes, such as the targeting of satellites. NORAD had previously published data freely on its website to registered users, with some restrictions on the orbital information on US classified satellites and the volume of data that could be downloaded within a certain time period. The new restrictions will oblige users to pay for this orbital information and agree not to transfer such information to other actors without Department of Defense permission.[89] This development has fueled reactions from amateur astronomers and scientists whose work depends on NORAD data. Governments and other operators use the data for collision avoidance and orbital manoeuvring. Thus, there is growing concern in the international community about dependence upon the US for such crucial information, and calls are increasing for a collaborative effort to develop an international space monitoring capability. As noted above, while Russia does have a space surveillance database as well, it has not been widely available.

## 2004: Japan's new space debris radar becomes operational

In April 2004, Japan opened a new radar station dedicated solely to the observation of space debris. Its purpose is to help with manned space missions. The radar can detect objects down to one meter in diameter at a distance of 600 kilometers, and track up to 10 objects at once. Although, the Japan Space Forum, which built and will operate the facility, did not comment on whether or how the radar station might contribute to worldwide efforts at cataloguing debris and preventing collisions, the system will inherently provide this capacity. The station will be operated by the Tsukuba Space Center, a division of the Japan Aerospace Exploration Agency.[90]

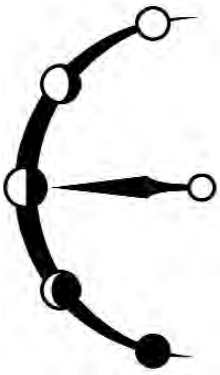
## Net assessment

In general terms, space surveillance capabilities continue to improve as more actors become involved in this area critical to collision avoidance. However, important constraints remain, such as technology limitations, cost considerations, and barriers to cooperation and transparency caused by concerns

that surveillance information might be used in an adversarial manner. This dual nature of surveillance technology also tends to hinder international cooperation, with the potential to undermine the degree to which these capabilities are used effectively to enable collision avoidance efforts and maintain the security of space uses.

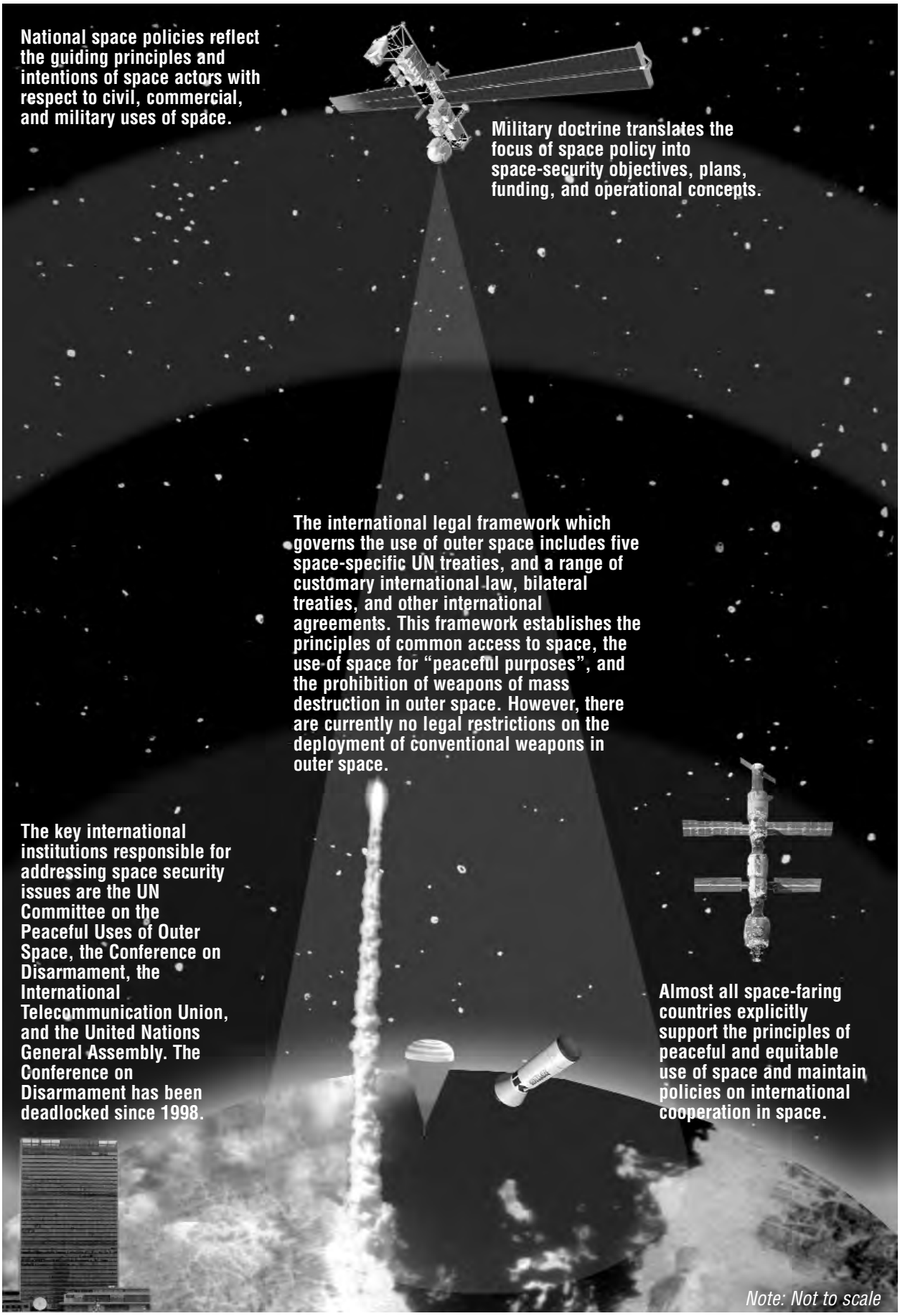
## Space Security 2004 Survey Results

| ***Overall, how have developments related to the space environment in the past year affected space security?*** | | | | | |
|---|---|---|---|---|---|
| Space Security Survey (14 January-21 February 2005) | | | Space Security Working Group Survey (24-25 February 2005) | | |
| Enhanced | 1 | 1% | Enhanced | 0 | 0% |
| Somewhat Enhanced | 40 | 32% | Somewhat Enhanced | 10 | 38% |
| Little or No Effect | 65 | 52% | Little or No Effect | 13 | 50% |
| Somewhat Reduced | 15 | 12% | Somewhat Reduced | 2 | 8% |
| Reduced | 3 | 2% | Reduced | 1 | 4% |
| Total | 124 | | Total | 26 | |



**Half of all Space Security Survey respondents and a majority of Space Security Working Group participants assessed that there was little or no effect on space security in 2004 with respect to this indicator.**

A strong minority of Space Security Survey respondents and Space Security Working Group participants assessed that space security was somewhat enhanced, citing progress on debris mitigation efforts and the conclusion of an agreement on GPS-Galileo frequency interoperability. Many considered that cooperative measures to coordinate the use of radio frequency spectrum, such as the new US FCC regulations on frequency sharing, would improve the availability of these resources. Some experts also noted that while competition over scarce resources could lead to significant conflicts* in the future, such conflicts were currently still rare. Many experts who assessed that space security had been somewhat reduced cited as cause for concern the continued growth in the amount of space debris, and new US limitations on the Space Surveillance Network's provision of information to others on the orbital characteristics of satellites and debris. The potential for debris creation by kinetic energy space weapons, including the proposed testing of US space-based missile defense interceptors, was also mentioned as a cause for a negative assessment by several experts.


National space policies reflect the guiding principles and intentions of space actors with respect to civil, commercial, and military uses of space.
Military doctrine translates the focus of space policy into space-security objectives, plans, funding, and operational concepts.
The international legal framework which governs the use of outer space includes five space-specific UN treaties, and a range of customary international law, bilateral treaties, and other international agreements. This framework establishes the principles of common access to space, the use of space for "peaceful purposes", and the prohibition of weapons of mass destruction in outer space. However, there are currently no legal restrictions on the deployment of conventional weapons in outer space.
The key international institutions responsible for addressing space security issues are the UN Committee on the Peaceful Uses of Outer Space, the Conference on Disarmament, the International Telecommunication Union, and the United Nations General Assembly. The Conference on Disarmament has been deadlocked since 1998.
Almost all space-faring countries explicitly support the principles of peaceful and equitable use of space and maintain policies on international cooperation in space.
Note: Not to scale

# 2 Space Security Laws, Policies, and Doctrines

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

Space security-relevant international law has become progressively more extensive and now includes, among other agreements discussed below, 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 remove space from national appropriation and prohibit certain military space activities, such as placing in outer space objects carrying nuclear weapons or any other kinds of weapons of mass destruction.

This chapter also assesses trends and developments related to space security-relevant international institutions mandated to address the international uses of space, such as the UN Committee on the Peaceful Uses of Outer Space (COPUOS), the UN Conference on Disarmament (CD), and the UN General Assembly (UNGA). While COPUOS tends to focus exclusively on commercial and civil space issues, the CD has attempted to address military space challenges through its work on the prevention of an arms race in outer space. 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 dealt with in the Space Environment chapter.

National space security policies include authoritative national policy statements regarding the principles and objectives of space actors with respect to the access to, and use of, space by both themselves and others. 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. National civil and commercial space developments are examined in the Civil Space Programs and Global Utilities and Commercial Space chapters.

This chapter also examines national military space policies and doctrines through which national space policies are translated into military space programs and capabilities. Reflecting the fact that space is increasingly being used to support military operations, some space actors also have specific national military space doctrines that support the development of specific military space applications such as navigation, communications, intelligence, surveillance, reconnaissance, or meteorological capabilities.

## Space Security Impacts

National and international law directly impact space security considerations since this legal framework establishes key space security parameters, such as the common access to space, prohibitions regarding the placement of certain weapons in space, and the obligation to ensure that space is used for peaceful — meaning 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 directly or indirectly result in space-based threats. International law also tends to promote 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 a framework necessary for the sustainable commercial uses of space.

International institutions play an essential role in space security, providing a venue to develop new international law, discuss issues of collective concern, and mediate potential disagreements over the allocation of scarce space resources in a peaceful manner. Ongoing discussion and negotiation within these institutions also helps build a degree of transparency, if not trust, among space-faring states.

National space policies and doctrines both reflect and inform space actors' use of space, as well as their broad civil, commercial, and military priorities. As such, the relationship of policies and doctrines to space security varies, depending 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 capabilities to access and use space, increasing the number of space actors with space assets and thus an interest in maintaining 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. Policies and doctrines that remain ambiguous on these counts may nonetheless have a negative impact on space security if they are misperceived by peer competitors as threatening, and stimulate the development of policies, doctrines, and capabilities to counterbalance these assumed threats. Furthermore, military doctrines that rely heavily on space can have mixed impacts on space security by both underscoring the need for the secure and sustainable use of space, and pushing states to develop protection and negation capabilities to protect valuable space systems.

## Key Trends and 2004 Developments

### TREND 2.1: Progressive development of legal framework for outer space activities

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

The UN Charter establishes the fundamental objective of peaceful relations between state actors, 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*** - Often referred to as the Magna Carta of outer space, the Outer Space Treaty (OST) represents the primary basis for legal order in the space environment. However, the OST has several gaps. It contains no verification or enforcement provisions, does not expressly prohibit conventional weapons in outer space, nor does it prohibit ground-based anti-satellite weapons (ASATs). 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.[2]

The lack of definitional clarity in the OST presents several challenges. Although the prevailing view holds that space begins at 100 kilometers above the Earth, the definition of outer space remains unclear in the OST. This issue has been on the agenda of both the Legal, and Scientific and Technical Subcommittees of COPUOS since 1959, and remains to be resolved.[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.[4] Although the USSR did secretly undertake a military space program, the interpretation 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 purposes' does mean 'non-aggressive' purposes. Thus, while space assets have been used extensively to support terrestrial military operations, actors have stopped short of actually deploying weapons in space. This said, it is also noteworthy that there is also no widely accepted definition of the term 'space weapon.' Various interpretations 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.[6]

**FIGURE 2.1: Key provisions of the Outer Space Treaty**[7]

| Article | Provision |
|---|---|
| Preamble | Recognizes the 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. |
| Article III | 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.<br>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 non-governmental entities. |
| Article IX | Parties to the Treaty shall be guided by the principles of cooperation and mutual assistance in the exploration and use of outer space.<br>State 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. |

***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 any damages to a state's surface, air, or space assets as a result of another state's space activities are to be compensated by the state that launched the offending object. The Convention reiterates that state parties remain responsible for the activities of their nationals and non-governmental 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 definition of the term "launching state."

***Registration Convention*** - This Convention establishes a mandatory system of registration of objects launched into space. Mandatory reporting to the Secretary-General of the UN on several data points is required, such as the date and location of the launch, changes in orbital parameters after the launch, and the recovery date of the spacecraft. This central registry's purported benefits are, in theory, effective management of space traffic, enforcement of safety standards, and attribution of liability for damage. Furthermore, the Convention acts as a space security confidence-building measure (CBM) by promoting transparency.

Lack of compliance remains a problem for the Registration Convention. While information is to be provided "as soon as practicable," in practice this can take weeks, months, or is never provided at all. For example, by 2001, the US had failed to register 141 of its over 2,000 satellite payloads.[8] To date, not one of the satellites registered has ever been described as having a military function. 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.

***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. 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, and reflecting the conviction of the international community on these issues.

**FIGURE 2.2: Key UN space principles**

| |
|---|
| **Declaration of Legal Principles Governing the Activities of States in the Exploration and Uses of Outer Space (1963)**[9]<br>Space exploration should be carried out for the benefit of all countries.<br>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.<br>States are liable for damage caused by spacecraft and bear international responsibility for national and non-governmental activities in outer space. |
| **Principles on Direct Broadcasting by Satellite (1982)**[10]<br>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)**[11]<br>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)**[12]<br>Nuclear power may be necessary for certain space missions, but safety and liability guidelines apply to its use. |
| **Declaration on Outer Space Benefits (1996)**[13]<br>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 the Prevention of an Arms Race in Outer Space (PAROS).[14] The 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.[15] However, the US — the primary space power — is one of the states that has consistently abstained from voting on the resolution since 1995, along with Israel and a few others.

***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] The Moon Agreement is not widely ratified and lacks support from major space powers.[17] Objections to its provisions regarding an international regime to govern the exploitation of the Moon's natural resources, differences 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 appear to have kept most states from ratifying this Agreement.

***Astronaut Rescue Agreement*** - This Agreement accords astronauts a form of diplomatic immunity and requires that assistance be rendered to astronauts in distress, whether on sovereign or foreign territory. The Agreement requires that astronauts and their spacecraft are to be returned promptly to the 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 | 88 | 25 |
| Liability Convention | 1972 | 82 | 25 |
| Registration Convention | 1975 | 45 | 4 |
| Moon Agreement | 1979 | 10 | 5 |

***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 use and 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 (SALT) I agreement, has been a recognition of the legitimacy of space-based reconnaissance — or National Technical Means (NTMs) — as a mechanism of treaty verification, and a related prohibition of interference with these space assets.[18] 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."[19] A summary of the key space security-relevant provisions of these agreements is provided below in Figure 2.4.

**FIGURE 2.4: Multilateral and bilateral arms control and outer space agreements**

| Agreement | Space security provisions |
|---|---|
| Limited Test Ban Treaty (1963) | Prohibition of nuclear weapons tests or any other nuclear explosion in outer space[20] |
| 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[21] |
| Hotline Modernization Agreement (1973)* | Sets up direct satellite communication between the US/USSR[22] |
| Anti-Ballistic Missile Treaty (1972)*† | Prohibition of space-based anti-ballistic missile systems[23] |
| Environmental Modification Convention (1977) | Bans, for use as a weapon, modification techniques having widespread, long-lasting, or severe effects on space[24] |
| Strategic Arms Limitation Treaty II (1979)* | Acceptance of, and prohibition of interference with, national technical means of verification Prohibits fractional orbital bombardment systems (FOBS)[25] |
| Launch Notification Agreement (1988)* | Notification and sharing of parameters in advance of any launch of a strategic ballistic missile[26] |
| Conventional Armed Forces in Europe Treaty (1990) | Acceptance of, and prohibition of interference with, national and multinational technical means of verification[27] |
| Strategic Arms Reduction Treaty I (1991)* | Acceptance of, and prohibition of interference with, national technical means of verification [28] |
| Intermediate-Range Nuclear Forces Treaty (1997) | Acceptance of, and prohibition of interference with, national technical means of verification [29] |
| Memorandum of Understanding establishing a Joint Data Exchange Center (2000)* | Exchange of information obtained from respective early warning systems[30] |
| 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
† Abrogated in 2002

### *Other laws and regimes*

Coordination among participating states in the Missile Technology Control Regime (MTCR) adds another layer to the international space law framework.[31] The MTCR is not a treaty but rather a voluntary arrangement between 34 states to apply a common export control policy on an agreed list of technologies, such as launch vehicles which could also be used for missile deployment (see Commercial Space).[32] 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.[33] To increase transparency and reduce mistrust among subscribing states, it introduces CBMs such as the obligation to announce missile launches in advance.

Finally, the treaties which 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.[34] 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.

Domestically, the blossoming of space commerce and the potential for space tourism has led at least 20 states to develop national laws to regulate space activities.[35] 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, and thus can have a negative impact on space security.[36]

### *Space security proposals*

The last 25 years have also seen a number of proposals to address gaps in the space security regime. In 1981, the USSR proposed a "Treaty on the Prohibition of the Stationing of Weapons of Any Kind in Outer Space." The proposed treaty would ban the orbiting of objects carrying weapons of any kind, and the installation of such weapons on celestial bodies or in outer space in any other manner. States would also undertake not to destroy, damage, or disturb the normal functioning of unarmed space objects of other states.

In 1983, the USSR put forth a modified version of the 1981 proposed treaty entitled "Treaty on the Prohibition of the Use of Force in Outer Space and From Space Against Earth." The proposed treaty would prohibit the threat or use of force against space objects in orbit, on celestial bodies, or stationed in outer space. It would equally ban the testing or deployment of space-based weapons, the testing and deployment of ASATs, and the use of manned spacecraft for military purposes.

On 28 June 2002, China and Russia, in conjunction with the delegations of Vietnam, Indonesia, Belarus, Zimbabwe, and Syria, submitted a joint working paper called "Possible Elements for a Future International Legal Agreement on the Prevention of Deployment of Weapons in Outer Space."[37] The paper proposed that state parties party to such an agreement undertake not to place in orbit any object carrying any kinds of weapons, 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, and the properties and parameters of objects being launched into outer space, and notify others of launching activities.

Non-governmental organizations (NGOs) have also tried to address the gaps in the international legal framework. For example, the Union of Concerned Scientists and the Henry L. Stimson Center respectively drafted a model treaty banning ASATs (1983)[38] and a code of conduct (2003) on dangerous military practices in space.[39]

### 2004: PAROS resolution passes at UNGA

The strong support for PAROS continued in 2004, strengthening the norm against the deployment of weapons in outer space. The UNGA once again passed a PAROS resolution with 178 states in favor, none against, and abstentions from Haiti, Israel, Palau, and the US.[40]

### Net assessment

On the whole, the progressive legal codification of outer space, at both the international and national levels, has had a largely positive effect on space security. It has helped establish the norm of the peaceful uses of space, encouraged transparency among space actors, regulated use of scarce space resources, and prohibited activities that directly or indirectly affect space security. However, the abrogation of the Anti-Ballistic Missile Treaty in 2002 eliminated a long-standing US/USSR prohibition on space-based conventional weapons, stimulating renewed concerns about the potential negative implications of space weaponization for space security.

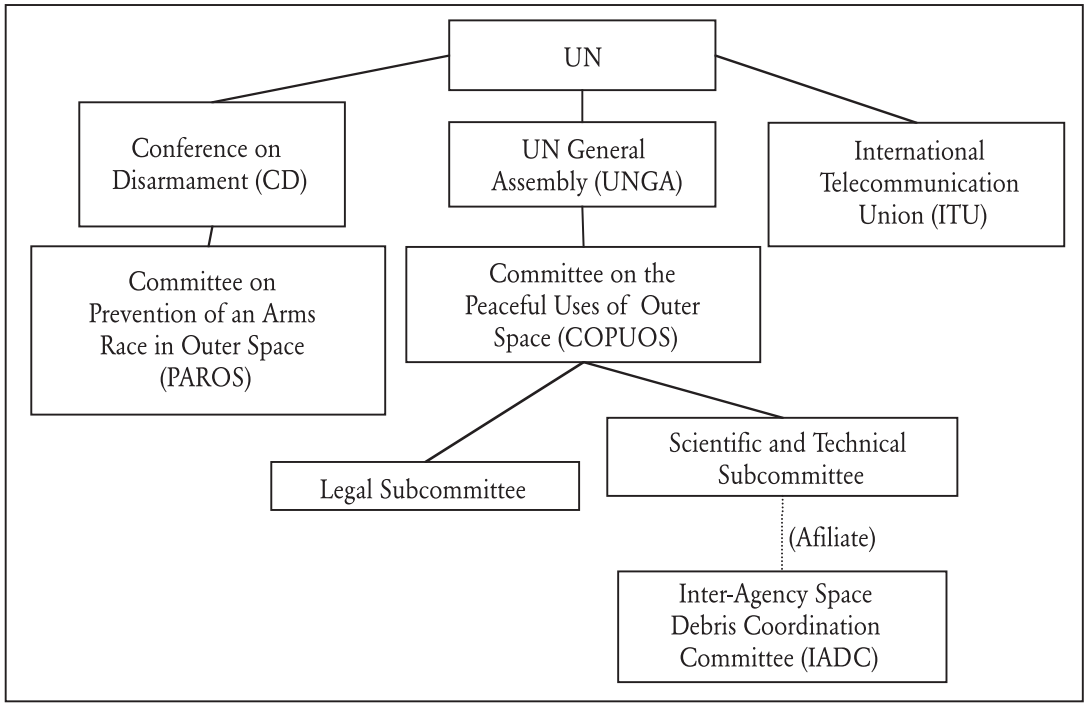
## TREND 2.2: COPUOS remains active, but the Conference on Disarmament has been deadlocked on space weapons issues since 1998

An overview of the relationships among key space security-relevant institutions is provided in Figure 2.5. The UN General Assembly is the main deliberative organ of the United Nations and is composed of representatives of 192 Member States. 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 often considered as carrying 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 the Committee on the Peaceful Uses of Outer Space 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.[41] There are currently 67 COPUOS

Member States. The Inter-Agency Space Debris Coordination Committee was established in 1993 as a stand-alone agency composed of the space agencies of major space actors, and has played a key role in developing and promoting space debris mitigation guidelines. The group submitted recommendations for limiting debris to the COPUOS Scientific and Technical Subcommittee in 2002 (see The Space Environment).[42]

**FIGURE 2.5: International space security-relevant institutions**




The CD was established in 1979 as the primary multilateral disarmament negotiating forum of the international community. The CD presently has 66 Member States, and a number of observer states. Member States meet in three sessions on an annual basis and conduct work by consensus. The CD has repeatedly attempted to address the issue of the weaponization of space. In 1982, the People's Republic of Mongolia put forward a proposal to create a committee to negotiate a treaty to that effect.[43] After three years of deliberation, the CD Committee on PAROS was created and given a mandate not to negotiate but "to examine, as a first step (…) the prevention of an arms race in outer space."[44] From 1985 to 1998, the PAROS committee made several recommendations for space-related confidence-building measures.[45]

The CD has been unable to agree upon a plan of work since 1998. The US has prioritized the negotiation of a Fissile Material Cut-off Treaty (FMCT) over action on PAROS, while China has prioritized the reverse, with the result being a stalemate on both. 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.[46] The 2002 Five Ambassadors Initiative again

attempted to resolve blockage, proposing an agenda that decoupled the establishment of an ad hoc PAROS committee from any eventual treaty on the non-weaponization of space. During the 2002 session of the CD, China stated that it could agree on the "Amorim proposal" for a CD work program if the mandate of the ad hoc PAROS committee was upgraded from discussions to negotiations to reach an international legally binding instrument, a proposal rejected by the US.[47]

### 2004: Deadlock continues at CD, but informal discussions of space security issues continue

While the CD remained deadlocked in 2004, the president of the CD called for a series of informal discussions on a number of issues including PAROS.[48] On 27 May 2004, during an informal closed session on PAROS held by the CD, several states called for the establishment of a CD expert group to discuss the broader technical questions surrounding space weapons. A 26 August 2004 meeting provided states with an opportunity to make more detailed comments. Sri Lanka noted that a no-first-use policy for space weapons would provide considerable protection to space assets until a treaty could be negotiated. Sweden called for informal debate on the dual-use nature of space technologies.

France advanced its principles of space activity: free access for all peaceful applications, maintenance of the security and integrity of orbital satellites, and consideration for the legitimate defense interests of states. Canada stated that work needed to be conducted on both the definition of the term space weapon, and on verification measures associated with a space weapons ban. China and Russia presented non-papers on verification measures for a treaty to ban weapons in outer space, and on existing international legal instruments on the topic of space weapons. They noted that political, technical, and financial verification challenges should not delay the negotiation of a treaty. Meanwhile, the US declared that it was not prepared to negotiate PAROS, stating "We just don't see that as a worthwhile enterprise."[49]

In March 2004, the UN Institute for Disarmament Research, in collaboration with Canada and several NGOs, convened an expert meeting to examine space security issues. The meeting examined a range of incremental steps to ensure space security, such as confidence-building and transparency measures, codes of conduct regarding space debris and satellite maneuvering, and unilateral declarations of no-first-deployment of space weapons or ASATs.[50]

### 2004: Russia restates pledges on no-first-deployment of space weapons

Speaking to the UNGA First Committee on 6 October 2004, Russia reiterated its 20-year-old pledge not to be the first to deploy any kinds of weapons in outer space and encouraged other space-faring states to do the same.[51] Canada reiterated its desire to see a ban on space weapons and called for universal ratification of the Outer Space Treaty in time for its 40th anniversary in 2007.[52]

The Netherlands, on behalf of the EU, made a three-point statement noting: the EU is actively cooperating in various space initiatives which should be developed in a peaceful environment; it is within the CD that any decision should be taken regarding work on PAROS; and the EU supports the establishment of a subsidiary body of the CD to deal with this matter.[53]

In June 2004, COPUOS admitted Libya and Thailand, bringing membership of the Committee up to 67. In April 2004, the Legal Subcommittee of COPUOS agreed on the text of a draft resolution on the application of the concept of the "launching state," for consideration by the UNGA. On 10 December 2004, the UNGA adopted COPUOS's draft resolution.[54] Agreement on this definition should facilitate adherence and application of the Liability and Registration Conventions.[55]

Certain state parties of the Legal Subcommittee also expressed the view that the current legal framework for outer space activities required modification and further development to keep pace with advances in space technology and space activities.[56] Furthermore, the view was expressed that states should pay greater attention to complying with Article IV of the Registration Convention and that effort should be made in clarifying the definition of a "space object" under the Convention.[57]

### Net assessment

These 2004 developments suggest continuity with the dominant trend in this important space security sector. By facilitating multilateral discussions and negotiation of debris mitigation guidelines, confidence-building measures, and treaties, international institutions continue to play a central role in the maintenance of space security. The ITU has been essential in resolving disputes over the allocation of scarce space resources such as orbital slots and radio frequency spectrum (see The Space Environment).

Discussions at the PAROS Committee of the CD, COPUOS, and UNGA have served to both promote international cooperation and transparency in space and to reinforce the norm of the use of space for peaceful purposes. However, the deadlock at the CD remains a concern, especially when the number of actors accessing space for civil, commercial, and military purposes is growing, and issues such as space weaponization would affect many key space actors.

## TREND 2.3: Space-faring states' national space policies consistently emphasize international cooperation and the peaceful uses of outer space

The national space policies of all space-faring states explicitly support the principles of peaceful and equitable use of space. Similarly, almost all make explicit reference to the goals of using space to promote national commercial,

scientific, and technological progress, with states such as China, Brazil, and India emphasizing economic development. Virtually all space actors underscore the importance of international cooperation in their space policies.

The US has the most to offer to international cooperative space efforts, but at the same time is the least dependent upon such efforts to achieve its national space policy objectives. US national space policy declares an intention to "pursue greater levels of partnership and cooperation in national and international space activities and work with other nations to ensure the continued exploration and use of outer space for peaceful purposes."[58] Such cooperation aims to promote cost-sharing and provide benefits to the US by increasing access to foreign scientific and technological data as well as foreign research and development facilities.[59] It also seeks to enhance relations with US allies and Russia, while supporting initiatives with emerging space-faring states.[60] US national space policy also notes that space cooperation must protect the commercial value of American intellectual property and ensure that technology transfers do not undermine US competitiveness and national security.[61] Overall, it is clear that US space efforts have played a central role in the dissemination of space access and use capabilities to other states.

Russia is deeply engaged in cooperative international space activities, arguing that international cooperation is more efficient in the field of space exploration than breakthroughs by separate states.[62] The International Space Station (ISS) and the Russian-American Observation Satellite Program (RAMOS) for the early warning detection of missile launches are seen as a good example of this strategy, although RAMOS was cancelled in 2004 (see Space Support for Terrestrial Military Operations).[63] Russia has also undertaken cooperative space ventures with France, Germany, Canada, China, India, Bulgaria, Hungary, Pakistan, Portugal, Israel, and the EU on various occasions.[64] Thus, like the US, Russian space cooperation activities have tended to support the proliferation of capabilities to access and use space.

China maintains a public commitment to the peaceful use of outer space in the interests of all mankind.[65] While China actively promotes international exchanges and cooperation, it has stated that such efforts must encourage independence and self-reliance in space capabilities.[66] The Chinese White Paper on space 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.[67] 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.[68] China has also pursued space cooperation with at least 12 states, and is collaborating with Brazil on a series of Earth resources satellites.[69]

International cooperation is a key focus of the national space policies of European actors. France, Germany, and the UK all have extensive cooperative ventures with the US. The European Space Agency (ESA) facilitates European space cooperation by providing a platform for discussion and policy making for the European scientific and industrial community.[70] Many see this cooperation, and the resultant European excellence in space, as one of the most visible achievements of European cooperation in science and technology. However, it is also clear that Europe currently lacks the resources to meet its stated space policy. For this reason, it continues to pursue cooperation with the larger space powers, specifically the US and Russia.

## 2004: Closer European cooperation in space

2004 saw a continued widening and deepening of European space cooperation. In January 2004, the European Parliament adopted a resolution on an action plan for broader cooperation and coordination among Member States in space. In March 2004, the ESA's executive council unanimously approved the membership applications of Greece and Luxembourg, whose accession is expected to be complete by 1 December 2005. In July 2004, the Council of the European Union established a European Global Navigation Satellite System Supervisory Authority.[71]

In July 2004, the ESA and Turkey signed a Framework Cooperation Agreement concerning the Exploration and Use of Outer Space for Peaceful Purposes.[72] In October 2004, the Member States of the EU signed a treaty establishing a Constitution for Europe. Article III-254 of the Constitution explicitly calls upon the EU to draw up a European space policy and a European space program to strengthen cooperation for the exploration of space.[73] In November 2004, the 27-member European Space Council met for the first time to lay the foundation for common European space policies and programs.[74] This new EU-ESA space policy is to be finalized in 2005.[75]

## 2004: US unveils new vision for space exploration and promotes new space transportation policy

On 14 January 2004, the US unveiled a new "Vision for Space Exploration," detailing plans to go to the Moon, Mars, and beyond. The vision proposes fulfilling commitments to the ISS; restoring the Space Shuttle to flight but retiring it altogether by 2010; undertaking robotic and human exploration of the Moon (before 2020), Mars, and the Solar System; developing a Crew Exploration vehicle for missions beyond Earth orbit; and pursuing commercial and international cooperation.[76] The vision outlined an ambitious plan with only modest proposed changes in funding for NASA's overall and programming budgets.

On 21 December 2004, President Bush authorized a new Space Transportation Policy which promotes assured access to space as a requirement to national

security; seeks to enhance the reliability, responsiveness, and cost-effectiveness of Earth-to-orbit space transportation; and encourages a viable domestic commercial space transportation industry, including commercial human spaceflight.[77]

### Net assessment

As these 2004 developments illustrate, the trend toward greater international space cooperation continues. This pursuit of international cooperation has tended to promote transparency and the diffusion of capabilities to access and use space. In this sense, international cooperation continues to exert a positive impact on space security. The deepening and institutionalization of cooperation in space among European states represents a continuation of regional cooperation in space.

The new American vision for space exploration also represents a continuation in the trend of scientific exploration in US space policy. Both developments should exert a positive effect on space security by underscoring the collective benefits of the secure and sustainable uses of space, and by reinforcing the norm of the use of space for peaceful purposes. However, it should be noted that the proliferation of dual-use technologies through international cooperation has the potential to both positively and negatively affect space security over the longer term.

## TREND 2.4: Growing focus within national military doctrine on the security uses of outer space

Fueled by the revolution in military affairs, the military doctrine of a number of states has begun to reflect a growing focus on space-based applications to support a variety of military force enhancement functions (see Space Support for Terrestrial Military Operations). Related to this trend is a tendency among states such as China, Russia, and the US to view their space assets as an integral element of their national critical infrastructure.

US military space doctrine reflects a growing interest in space control, defined as the "freedom of action in space for friendly forces while, when directed, denying it to an adversary."[78] It also remains 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.[79] Related to concerns about the vulnerability of US space assets, there is a robust debate within the US on how to best assure the security of these 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 on-board protection capabilities for space assets, coupled with offensive counterspace systems to ensure space control for US forces.[80]

Others in this debate advocate enhanced protection measures, but oppose the deployment of weapons in space.[81] However, despite concerns in some quarters regarding the picture of future space operations presented in documents like the *US Space Command Vision for 2020* (1997) and the *Long Range Plan* (1998),[82] official US military space doctrine has remained focused primarily on force enhancement, as reflected in the US DOD 1999 S*pace Policy.*[83] The authoritative US joint doctrine on such matters, *Joint Publication 3-14*, also reflects 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 systems and responsive space access.

Interest in developing an anti-ballistic missile system in the US has also fuelled discussion and plans for space-based interceptors and space-based lasers. Most notable was President Reagan's Strategic Defense Initiative proposed in 1983. While not explicitly mentioning particular land, sea, or space-based systems, the 1996 *National Space Policy* calls for the development of national missile defense. In addition, 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."[84] More recently, the US Missile Defense Agency called for the placement of a test-bed for missile interceptors in outer space by 2012 (see Space-Based Strike Weapons).[85]

In all of its 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.[86] Therefore, a basic Russian national security objective is the protection of Russian space systems, including ground stations.[87] These concerns derive from Russia's assessment that modern warfare is increasingly becoming dependent upon space-based force enhancement capabilities.[88] 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.[89] The second priority is the upgrade of the Russian nuclear missile attack warning system. Together, these recent developments are seen as having a critical role in guaranteeing Russia's secure access to space.[90] 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.[91] Thus, Russia has actively argued for a treaty prohibiting the deployment of weapons in space.

China's military space doctrine appears to be influenced by assessments of US space capabilities, including space-based missile defenses, and what China perceives to be America's increasingly aggressive pursuit of space dominance.[92] The official Chinese position is that space security will be undermined rather than enhanced by the weaponization of space, that weaponization will lead to a costly and destabilizing arms race in space, and that this would be detrimental to both Chinese and global security. As a result, China has proposed a

multilateral treaty banning all weapons in space and has pressed its case for such a multilateral treaty within the PAROS talks at the CD.[93]

Official US assessments have expressed concern at what appear to be Chinese intentions to develop "anti-satellite weapons that are useful as a deterrent against enemy space systems, in order to gain the initiative in future wars."[94] Others have assessed that while basic research on ASAT technologies has been underway in China since the 1980s, evidence of China's commitment to developing an operational anti-satellite capability remains unclear.[95] What both camps seem to agree on is that China has the ability to develop basic space negation capabilities and that the Chinese military leadership understands the important role such a capability would play in any military confrontation with the US or its allies.

EU space policies recognize that its efforts to assume a larger role in international affairs will require the development of space assets such as global communications, positioning, and observation systems.[96] While most EU space capabilities have focused on civil applications, there is an increasing awareness of the need to strengthen dual-use capabilities. According to the EU, creating an intergovernmental agency in the field of defense capacities development, research, acquisition, and armament by the end of 2004 represents a cornerstone for the development of security technologies, and thus for space activities as well.[97]

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.[98] At the national level, French military space doctrine recognizes the primordial role of space support. 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."[99]

### 2004: Several states placing greater emphasis upon national security space applications

Several states continued to seek to use space to further national security purposes in 2004. In November 2004, EU Foreign Ministers adopted an internal report on how to build a space capacity to fulfill the objectives outlined in the European Security Strategy.[100] The ESA, founded on a peaceful mandate, has recently formed a space security office.[101] During a speech announcing the launch of the Helios 2A military satellite, French Minister of Defense Michele Aliot-Marie called for a European "mastery of space," comparing space in the current decade to nuclear technology in the 1960s. Aliot-Marie emphasized that space power has become for France a necessity for sovereignty and international great power projection.[102]

The Japanese Diet held discussions in July 2004 regarding the extent to which Japan's constitution should allow the use of space in support of its Self Defense Forces.[103] India's new army doctrine, released in November 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.[104]

## 2004: US Air Force releases Counterspace Operations doctrine

In August 2004, the USAF released a *Counterspace Operations* doctrine document, the first to clarify the concepts of 'space situation awareness,' 'defensive counterspace,' and 'offensive counterspace.' As well, it was the first to make explicit mention of military operations conceived "to deceive, disrupt, deny, degrade, or destroy adversary space capabilities."[105] Although the *Counterspace Operations* document represents the views of the USAF and not necessarily that of the US Government,[106] it did provide an important indicator of where US policy may be heading. For example, in December 2004, the US issued a Presidential directive calling on the US Department of Defense to develop its ability to deny an adversary the use of satellite-based positioning, navigation, and timing systems during a conflict.[107]

## 2004: Meeting of Russian Space Agency board releases Russia's space policy priorities

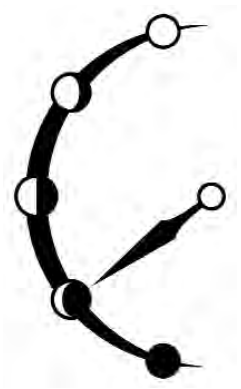
In October 2004, the Russian Space Agency announced its space priorities for 2006-2015. In particular, it emphasized the development of new space rockets and equipment, satellite communication and remote sensing, improvement of the GLONASS satellite navigation system, and further development of the Baikonur and Plesetsk cosmodromes.[108] In February, Russia conducted military exercises that included scenarios involving "air and space attacks."[109]

## Net assessment

The growing emphasis upon the national security utilities of space within the doctrines of the EU, France, India, Japan, Russia, and the US has the potential to have both a positive and a negative effect on space security. It can have a positive effect on space security by underscoring the benefits of a secure and sustainable use of space. However, space policies intended to serve national security may have a negative effect on space security if actors, becoming more dependent upon space systems for national security, acquire incentives to develop protection and negation capabilities to protect their own space systems, which can lead to an arms escalation dynamic. This concern was highlighted by recent Russian war games. While the US *Counterspace Operations* document and the Presidential Directive represent a further development in American focus on space control, they also represent a departure from the broadly accepted notion of space as an environment that is open to all and belonging to none.

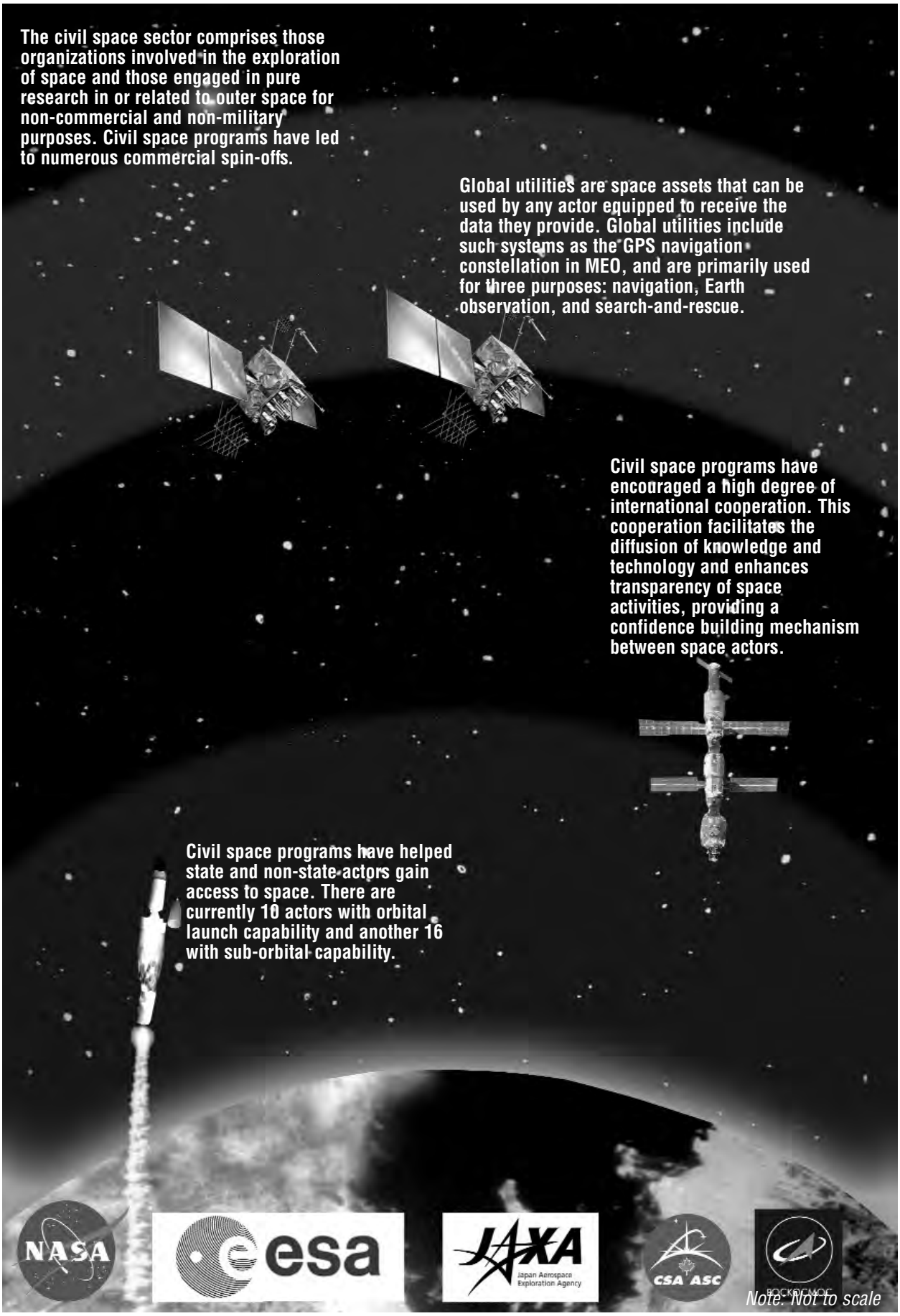
## Space Security 2004 Survey Results

| ***Overall, how have developments related to space security laws, policies, and doctrines in the past year affected space security?*** | | | | | |
|---|---|---|---|---|---|
| Space Security Survey (14 January-21 February 2005) | | | Space Security Working Group Survey (24-25 February 2005) | | |
| Enhanced | 4 | 3% | Enhanced | 0 | 0% |
| Somewhat Enhanced | 26 | 20% | Somewhat Enhanced | 2 | 8% |
| Little or No Effect | 34 | 26% | Little or No Effect | 3 | 12% |
| Somewhat Reduced | 41 | 32% | Somewhat Reduced | 18 | 72% |
| Reduced | 24 | 19% | Reduced | 2 | 8% |
| Total | 129 | | Total | 25 | |



**A majority of Space Security Survey respondents and Space Security Working Group participants assessed that space security had been somewhat reduced or reduced in 2004 with respect to this indicator.**

The most commonly cited argument for this assessment was a strong sense that the apparent drive within US military space doctrine toward space control and counterspace capabilities could lead to the weaponization of space, and encourage other space actors to take countermeasures, such as the development of space systems negation capabilities. Some experts cited progress at COPUOS as a positive development with respect to space security. The deadlock at the CD, coupled with the perception that space-related international legal regimes are poorly enforced, was underscored by other experts as detrimental to space security. Finally, some experts pointed out that international space law has not been able to keep pace with the development of new national civil, commercial, and military space policies and capabilities.


The civil space sector comprises those organizations involved in the exploration of space and those engaged in pure research in or related to outer space for non-commercial and non-military purposes. Civil space programs have led to numerous commercial spin-offs.
Global utilities are space assets that can be used by any actor equipped to receive the data they provide. Global utilities include such systems as the GPS navigation constellation in MEO, and are primarily used for three purposes: navigation, Earth observation, and search-and-rescue.
Civil space programs have encouraged a high degree of international cooperation. This cooperation facilitates the diffusion of knowledge and technology and enhances transparency of space activities, providing a confidence building mechanism between space actors.
Civil space programs have helped state and non-state actors gain access to space. There are currently 10 actors with orbital launch capability and another 16 with sub-orbital capability.
NASA
esa
JAXA
Japan Aerospace Exploration Agency
CSA ASC
ROSKOSMOS
Note: Not to scale

# 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, in particular, national space agencies, e.g. the US National Aeronautics and Space Administration (NASA), the Russian Space Agency, and the European Space Agency (ESA), and their missions, e.g. Soyuz, Apollo, MIR, the Hubble Space Telescope, and the International Space Station (ISS). The civil space sector also includes the key capabilities associated with launch vehicles, developed by, or in cooperation with, civil programs, that enable actors to access space. It also includes international collaborations that facilitate space access for countries without launch capability, through the launch capability of other actors.

The chapter examines these trends and developments in civil space for each space actor, including 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 manned and unmanned civil launches made by each actor; the funding trends of civil programs; and the degree of civil-military cooperation. It also assesses the degree and scope of international civil space collaboration, often seen as a 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. Global utilities include remote sensing satellites which monitor the Earth's changing environment using various sensors, e.g. weather satellites. It includes search and rescue satellites that provide emergency communications for people in distress. Global utilities also include 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, for the purpose of navigation aid, e.g. 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 their number of users. It also assesses trends in conflict and cooperation between actors in the development and use of global utilities.

## Space Security Impacts

Civil space programs can impact space security in several positive ways. First, civil space programs 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. Therefore, changing scope and priorities in these civil space programs can affect an actor's space capabilities. 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 help to drive 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 weapons, and by overcrowding certain scarce space resources such as orbital slots and radio frequencies. Thus, civil-military cooperation can have a mixed impact on space security. On the one hand, such cooperation may help advance the capabilities of civil space programs to access and use space. On the other hand, it may encourage the targeting by adversaries of dual-use civil-military satellites.

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 by broadening the community of actors with an investment in space security and the peaceful uses of space. However, global utilities are also being used for dual-use functions, providing in particular navigation data than can support terrestrial and space military operations (see Space Support for Terrestrial Military Operations, Space Systems Negation, and Space-Based Strike Weapons).

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 which 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.

## Trends and Key 2004 Developments

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

The number of actors with an independent orbital launch capability continues to grow and now includes 10 states (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 it builds the Zenit rockets launched by Sea Launch and has therefore demonstrated an orbital launch capability.

### FIGURE 3.1: Independent orbital launch capability of states[3]

| State/Actor | Year of first orbital launch |
|---|---|
| USSR/Russia | 1957 |
| USA | 1958 |
| France | 1965 |
| Japan | 1970 |
| China | 1970 |
| UK | 1971 |
| ESA[4] | 1979 |
| India | 1980 |
| Israel | 1988 |
| Ukraine[5] | 1999 |

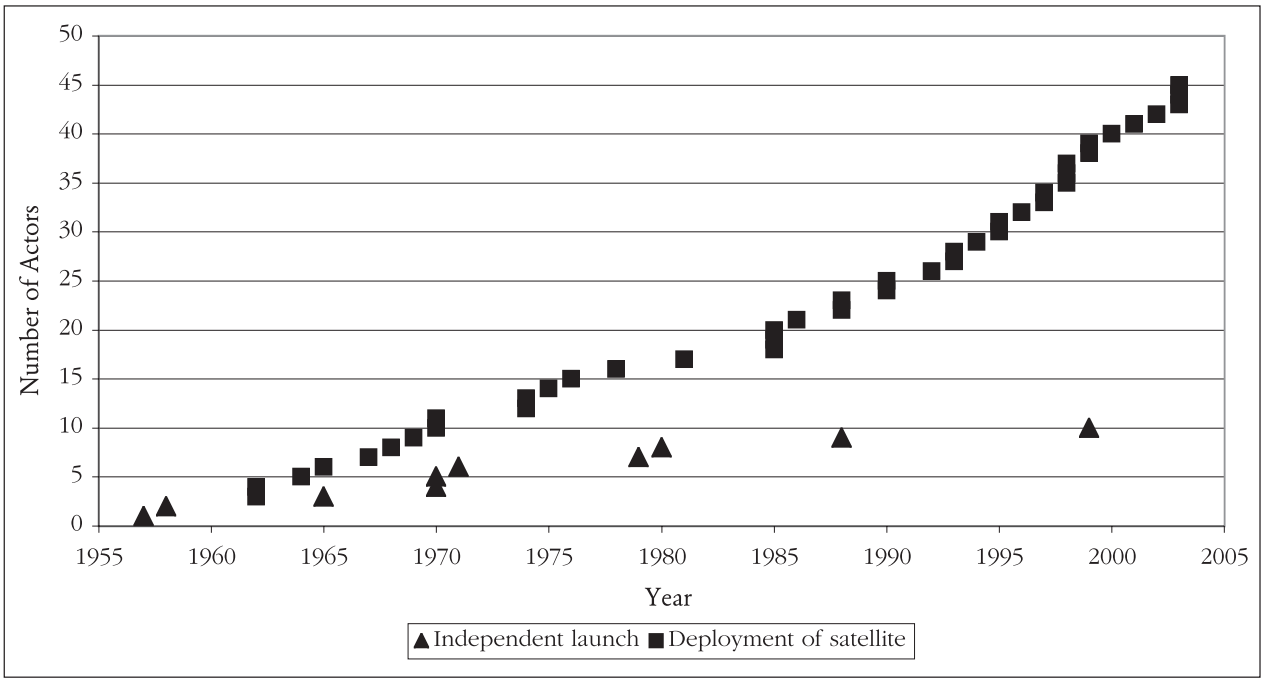
There are a further 18 actors that have sub-orbital capability, which is required for a rocket to enter space in its trajectory, but not achieve an orbit around the Earth. These actors are Argentina, Australia, Brazil, Canada, Germany, Iran, Iraq, Italy, Lybia, North Korea, South Korea, Pakistan, South Africa, Spain, Sweden, Switzerland, Saudi Arabia, and Syria.[6] In addition, Iran and North Korea maintain long-range missile programs that would enable them to develop an orbital launch capability.

By the end of 2003, a total of 45 states had accessed space, either through their own launchers or through the launchers of other states. 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., which specializes in helping countries to develop affordable satellites. Over the past 12 years, Surrey Satellite has assisted seven states (Algeria, Malaysia, Nigeria, Portugal, South Korea, Thailand, and Turkey) in efforts to build their first civil satellites. Four of these seven states have launched their satellites in the last three years.[7]

The USSR was the first space actor to send a man into space in 1961, followed by the US in 1962. With China's first manned launch in 2003, the number of manned launcher states now stands at three. In sum, civil space programs, in

collaboration with military space programs, continue to contribute to an increase in the number of space actors. The general proliferation of space technology is also contributing to this trend.

**FIGURE 3.2: Growth in the number of states accessing space**[8]




## 2004: Iran and South Korea set targets for orbital launch programs; Russian Soyuz 2-1a completes first flight

In October 2004, Iran announced plans to launch a scientific satellite from a military-developed rocket in 2005.[9] In October 2004, South Korea and Russia signed an agreement on the joint development of a commercial launch vehicle planned for launch in 2007.[10] In November 2004, the Russian Soyuz 2-1a successfully completed its first flight. The upgraded Soyuz, developed jointly by Starsem and Arianespace, has a digital control system providing additional mission flexibility.[11] Meanwhile the Angara, Russia's planned heavy launcher, is still awaiting funding.[12]

## 2004: First launch of US Boeing Delta IV-Heavy a partial success

In December 2004, the US Boeing Delta IV-Heavy launcher completed its first launch. The mission was only partially successful due to a shorter than expected burn time on the first stage, making it unable to successfully deploy its satellite payload (see Space Support for Terrestrial Military Operations).[13] While the Delta-IV Heavy launcher was developed primarily for the US Air Force, it will also provide new civil launch capabilities.[14] In June 2004, the US company Mojave Aerospace Ventures launched the first entirely privately-funded manned spacecraft into space on a sub-orbital trajectory to an altitude of 100 kilometers (see Commercial Space).

**FIGURE 3.3: Summary of 28 civil satellite launches completed in 2004**[15]

| Purpose | Number | Mission |
|---|---|---|
| Manned | 2 | •Soyuz (Russia) (Three astronauts)<br>•Soyuz (Russia) (Three astronauts) |
| Re-supply vehicles to space stations | 4 | •Progress (Russia)<br>•Progress (Russia)<br>•Progress (Russia)<br>•Progress (Russia) |
| Planetary probes | 2 | •Rosetta to a comet (EU - ESA)<br>•Messenger to Mercury (US - NASA/Johns Hopkins University) |
| Technology development craft | 6 | •Tansuo-1 (China - University of Harbin)<br>•Saudisat-2 micro-satellite (Saudi Arabia - King Abdulaziz City for Science and Technology)<br>•Unisat-3 micro-satellite (Italy - La Sapienza); Shi Jian 6A and Shi Jian 6B FY-1 (China - Shanghai Academy of Space Flight Technology and Agfanghong Satellite Co.); and Nanosat 01 (Spain - Instituto Nacional de Técnica Aeroespacial) |
| Astrophysics missions | 2 | •Gravity Probe B (US - NASA/Stanford University)<br>•Swift (US - NASA; UK - University College London, University of Leicester; Italy - Agenzia Spaziale Italiana) |
| Remote sensing missions | 7 | •Demeter (France - Centre National d' Études Spatiales (CNES))<br>•Aura (US - NASA)<br>•Tan Ce 2 (China - Aerospace Dongfanghong Satellite Ltd)<br>•FY-2C Weather (China)<br>•Parasol Aeronomy Myriade (France, European Aeronautic Defence and Space Company Astrium, CNES)<br>•Sich-1M Okean O1-N9 Radarsat (Ukraine, NPO Yuzhnoye, National Space Agency of Ukraine (NKAU))<br>•MK-1TS (Ukraine, NPO Yuzhnoye, NKAU) |
| Tele-education missions | 1 | •GSAT-3/Edusat Insat GramSat (India - Indian Space Research Organisation) |
| New rockets | 2 | •Soyuz (2a) (Russia)<br>•Delta IV Heavy (US-Boeing) – Partial failure |
| Sub-orbital missions | 1 | •Maxus 6 (Swedish Space Corporation, ESA) |

## Net assessment

Trends over the last 25 years suggest that a new actor demonstrating independent orbital launch capability is emerging roughly every eight years, mostly through joint civil-military programs. Furthermore, the early 1990s saw more than a doubling of the rate of states accessing space via other states'

launchers, from approximately one to approximately two per year, a rate that has since held steady. [16]

Developments in 2004 associated with the South Korean and Iranian launch programs suggest continued growth in the number of actors independently accessing space over the next few years. This increase will likely have a positive impact on space security through greater diversification of space actors and launch vehicle capabilities. However, it should be noted that an orbital launch capability also provides space actors with a major prerequisite for most types of space systems negation capabilities. Therefore, the proliferation of such dual-use capability can also be a concern for space security.

Finally, the growth in the number of actors accessing space via the launch capabilities of others will continue to exert a mixed effect on space security. On the one hand, such an increase indicates that a growing number of actors will have access to space, and a corresponding stake in its security. On the other hand, increased access to space may eventually lead to crowding and competition over scarce space resources.

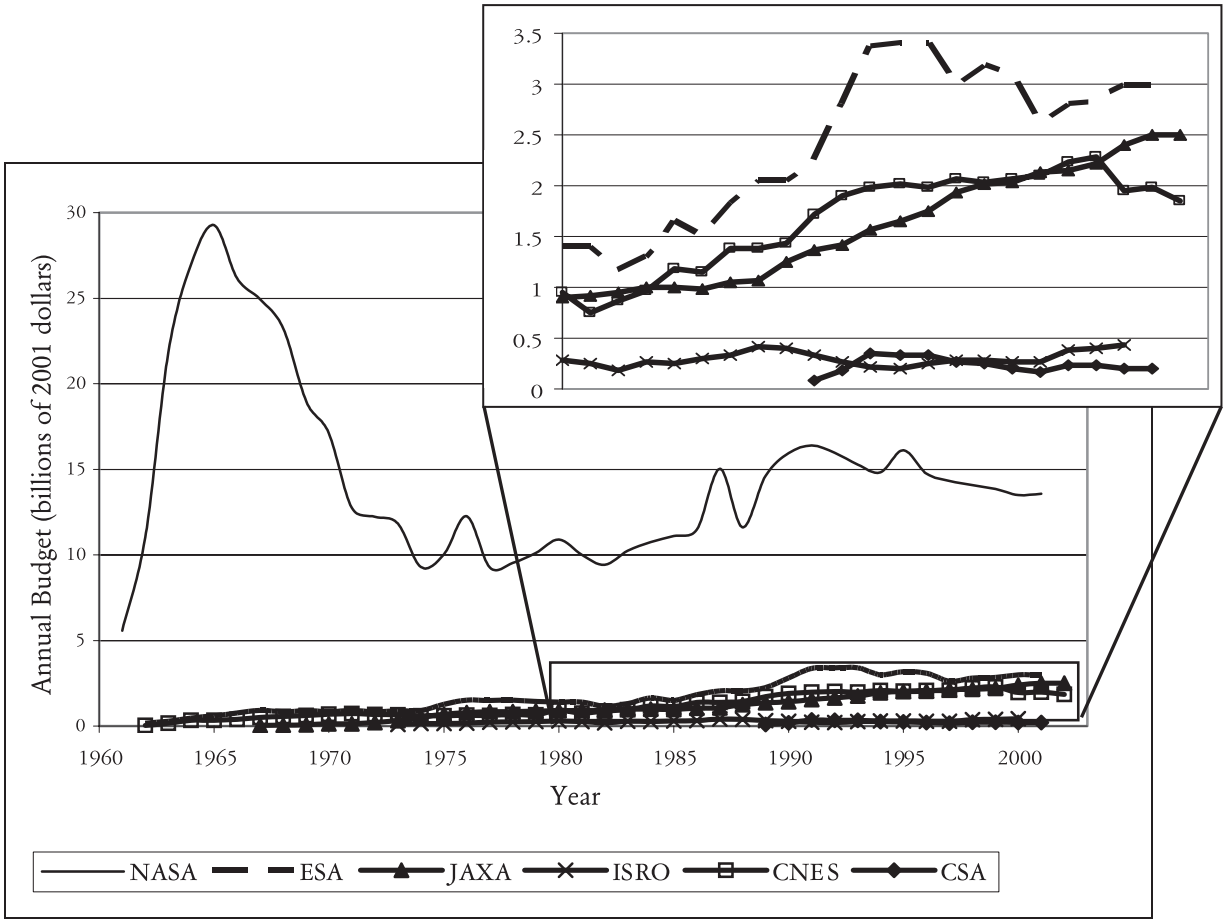
### TREND 3.2: Changing priorities and funding levels within civil space programs

Civil expenditures on space continue to increase in India and China, while generally decreasing in the US, the EU, and Russia. There has been a growth of about five percent per annum in real terms in the Indian civil space program over the decade 1990-2000, a total increase of over 60 percent.[17] Due to the growth in civil program activities, in particular the manned program, the Chinese civil space budget has also grown considerably in recent years.

Although it still dwarfs the civil space budgets of other actors, the NASA budget dropped 25 percent in real terms between 1992 and 2001.[18] The ESA budget dropped nine percent in the same period. This follows a long period of growth for both NASA and the 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.[19]

The Russian Space Agency budget has seen an even sharper decline in the 1990s, but this may not provide an entirely accurate reflection of the status of Russian civil space capabilities. For example, Russia launches more civil satellites than any other state with a budget less than a tenth of NASA's. Russia maintains over 160 military, civil, and commercial satellites on a budget of about $400 million per year, which is less than the cost of a single launch of the US Space Shuttle.[20]

**FIGURE 3.4: Civil space agency budgets**[21]




The USSR/Russia was the most active civil space actor from 1970 to the early 1990s when funding decreases led to a reduction in the number of its civil missions. The trend in the 1990s towards miniaturization in electronics helped reduce the size and weight of civil satellites, which can now perform the same functions as their more bulky predecessors. 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 new technology enabled "smaller, faster, cheaper" space missions.

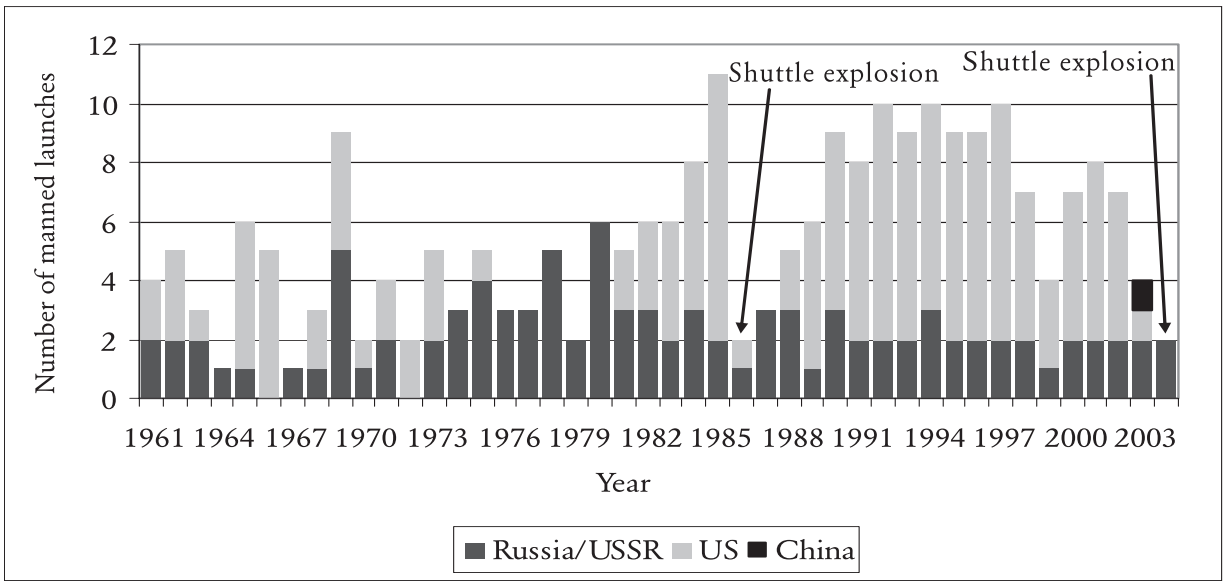
Micro-satellites are now increasingly being used for civil missions, e.g. the multinational Disaster Monitoring Constellation and France's joint military/civil Myriade series of micro-satellites.[22] These developments have also allowed the rest of the world, primarily the EU, China, and Japan, to expand their civil programs to the point where they now together equal the US or Russia's civil efforts.[23]

### *Human spaceflight*

On 12 April 1961, Yuri Gagarin became the first human in space on board a Soviet Vostok 1 spacecraft. Human spaceflight was led in the early years by the USSR, which succeeded in fielding the first woman in space, the first 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 manned spaceflight program, and has since carried about 100 missions with a capacity to carry three humans on each flight.

The first US human mission was completed on 5 May 1961 with the sub-orbital 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 manned space laboratories in 1973, and the USSR developed the MIR space station which operated from 1986 to 2001. The US developed the Space Shuttle in the 1970s, 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.

**FIGURE 3.5: Number of manned launches**[24]




China developed the Shenzhou human spaceflight system in the late 1990s and early 2000s. It completed a successful manned mission in 2003, making it the third state to develop independent human spaceflight capability.[25] The 2003 Space Shuttle Columbia disaster, and the subsequent grounding of US Space Shuttle missions, reduced the total annual number of US manned missions. Russia is the only actor performing regular manned missions, with its Soyuz

spacecraft providing the only lifeline to the International Space Station (see Figure 3.5).

### *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' — large 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 re-shaped into the Russian Aviation and Space Agency (Rosaviakosmos). While this new agency has more centralized powers than previous organizations, the majority of 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 it difficult to obtain accurate comprehensive budget figures for Russian civil space programs.[27] However, in 2002, the Russian government contributed about $265 million to the Russian Aviation and Space Agency.[28]

In Europe, France established the first national space agency, Centre National d'Études Spatiales (CNES) in 1961, which remains the largest of the EU national agencies. Italy established a national space agency in 1989, followed by Germany in 1990. The European Space Research Organisation and the European Launch Development Organisation, both formed in 1962, were merged into the ESA in 1975. The majority of ESA funding is provided by a small group of states with active national space programs. For example, between 1991 and 2000, Germany and France regularly provided between 40 and 50 percent of the ESA's budget.[29]

In China, civil space activities began to emerge 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 civilian space agency in China, and reports through the Commission of Science Technology and Industry for National Defense, to the State Council. Budget figures for China's civil space program are not public, and unofficial estimates range from $175 million to $1.5 billion per year.[30]

In Japan, civil space was initially coordinated by the National Space Activities Council formed in 1960. The Institute of Space and Aeronautical Science within 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.[31] India's civil space agency, the Indian Space Research Organisation, was founded in 1969. Israel's space agency was formed in 1982, Canada's was formed in 1989, and the Brazilian Agencia Espacial Brasileira was formed in 1994.

### *New directions for civil programs*

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 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."[32]

A growing number of civil space projects are now also explicitly focused on social and economic development objectives. The Indian Space Research Organization has developed 10 communications satellites that provide tele-education and tele-health applications, and nine remote sensing satellites for enhancing agriculture, land, and water resource management, and disaster monitoring.[33] Malaysia launched Tiungsat 1 in 2000, a micro-satellite that included several remote sensing instruments for environmental monitoring. In 1998, Thailand and Chile together launched TMSat, the world's first 50-kilogram micro-satellite producing high-resolution, full color, multi-spectral images for monitoring the Earth, and FASat-Bravo, a micro-satellite to study depletion of the ozone layer.[34] In Africa, states such as Algeria, Egypt, Nigeria, and South Africa have, or are in the process of building, satellites to support development.

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 jobs and economic growth.[35] Recent examples of these spin-offs from NASA's programs include scratch resistant lenses, virtual reality equipment, more efficient solar cells, micro-lasers, advanced lubricants, and programmable pacemakers.[36]

## 2004: Ambitious civil space programs announced

In May 2004, China announced its intention to establish a manned space station in Earth orbit within 15 years.[37] On 8 November 2004, it announced plans for a two-person, five-day mission to space in 2005.[38] On 15 January

2004, the US announced a new NASA plan that includes returning humans to the Moon by 2020 and a human mission to Mars thereafter.[39] In November 2004, the US Congress granted NASA its full budget request of $16.2 billion for FY2005, an increase of five percent over FY2004.[40] In a related development, it was announced in March 2004 that NASA and the US military would increase cooperation on the development of new launch vehicles in support of the Moon Mars Initiative.[41]

In August 2004, the ESA released its study on a piloted Mars mission as part of the new Aurora planetary exploration program, and in October, initial funds were granted from the UK and Italy for the initiative.[42] In November 2004, the CNES and members of the European space industry announced plans to develop re-entry vehicles — a critical capability required for the ESA's Aurora program. Two re-entry vehicle projects are being considered. The Pre-X vehicle, initiated by CNES, will be the first in Europe to demonstrate gliding atmospheric re-entry, while the Expert vehicle, a European space industry project, will study ballistic re-entry technologies.[43]

### 2004: China, France, Italy, Spain, and Saudi Arabia launch small or micro-satellites

On 18 April 2004, China launched two small satellites together — the Tansuo 1 and Naxing 1 — which will provide technology for demonstration and surveillance respectively.[44] On 29 June 2004, Russia launched three micro-satellites for three other states: the Demeter seismology satellite for France, and technology demonstration satellites SaudiSat 2 and Unisat for Saudi Arabia and Italy respectively. On 18 December 2004, the ESA launched two micro-satellites — the Nanosat 1 technology demonstration spacecraft for Spain and the Parasol astronomy spacecraft for France — both launched piggy-back with the larger Helios-2 military observation satellite.[45]

### 2004: India launches first dedicated education satellite

Continuing its effort to use satellites for social development, India launched its first dedicated education satellite, Edusat, on 20 September 2004. Built exclusively for the educational sector, Edusat is mainly intended to meet the demand for an interactive, satellite-based distance education system for India. Space projects were also a significant agenda item in the Indo-EU summit, which took place in November 2004.[46] Taiwan launched a remote sensing satellite ROCSAT 2 on 20 May 2004.[47]

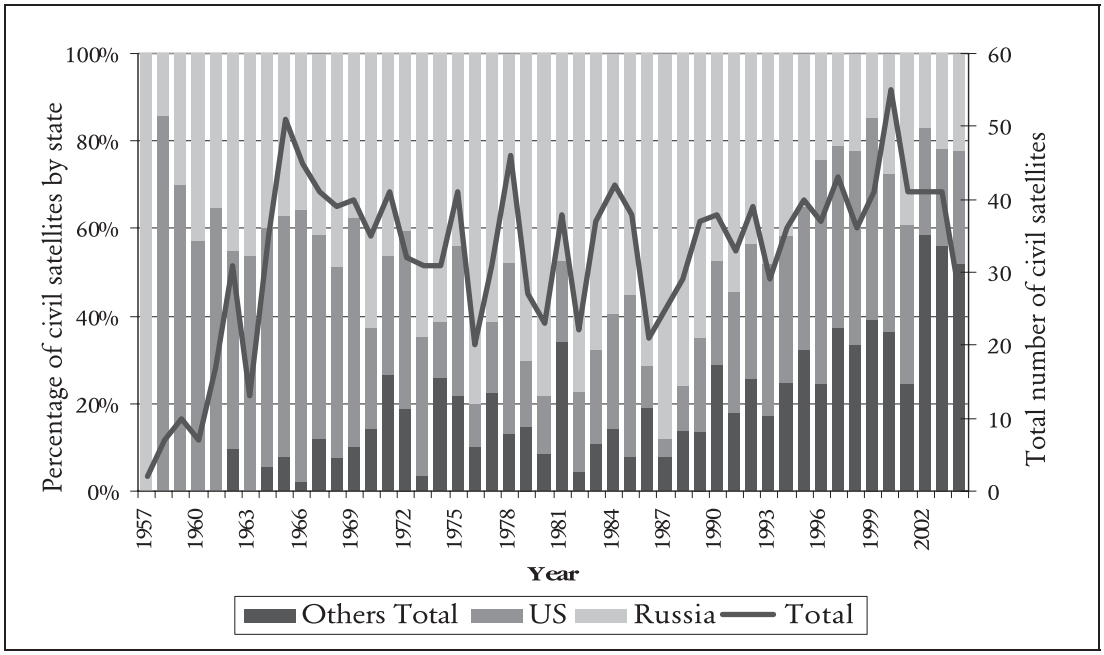
### 2004: Annual number of civil satellites launched continued to decline; new NASA spin-offs

A total of 28 civil satellites which included human spaceflight missions were launched in 2004, continuing a trend towards lower numbers of annual satellite

launches (see Figure 3.6). Of these missions, 18 involved international collaborations, either through an international spacecraft payload or launched by another state, and 10 were developed and deployed by one state. Both new rockets were international collaborations.

NASA announced over 40 technologies in its *Spinoff 2004* publication, including a system that can filter bacteria and viruses from water; a mineral identification tool that enables civil authorities to identify suspicious liquid and solid substances; and a light bulb that provides 40 percent more surface illumination on work and reading surfaces, while reducing eye strain.[48]

**FIGURE 3.6: World civil satellites including human space missions** [49]




## Net assessment

Developments in 2004 tended to reinforce the broader trend of steady growth in the range of civil space actors and civil space applications. This suggests a positive trend for space security as the community of civil space stakeholders continues to grow. Greater use of micro-satellites within civil programs is also largely positive for space security since they enable greater access to, and use of, space by space actors with more modest resources. The growing focus upon space for social development has had a positive impact on space security by reinforcing the norm of the use of space for peaceful purposes, and by linking the maintenance of space security to social and economic development.

The trend towards enhanced civil/military collaboration has the potential to have a mixed impact on space security. On the one hand, the military has helped advance the capabilities of civil space programs to access and use space.

On the other hand, such collaboration raises concerns that dual-use satellites may be targeted by adversaries. Furthermore, such civil-military collaboration or other civil missions with dual-use capabilities, such as the Clementine lunar mission which tested space-based strike weapon technology, may have a negative effect on space security by developing enabling technologies for space-based threats.

### TREND 3.3: Steady growth in international cooperation in civil space programs

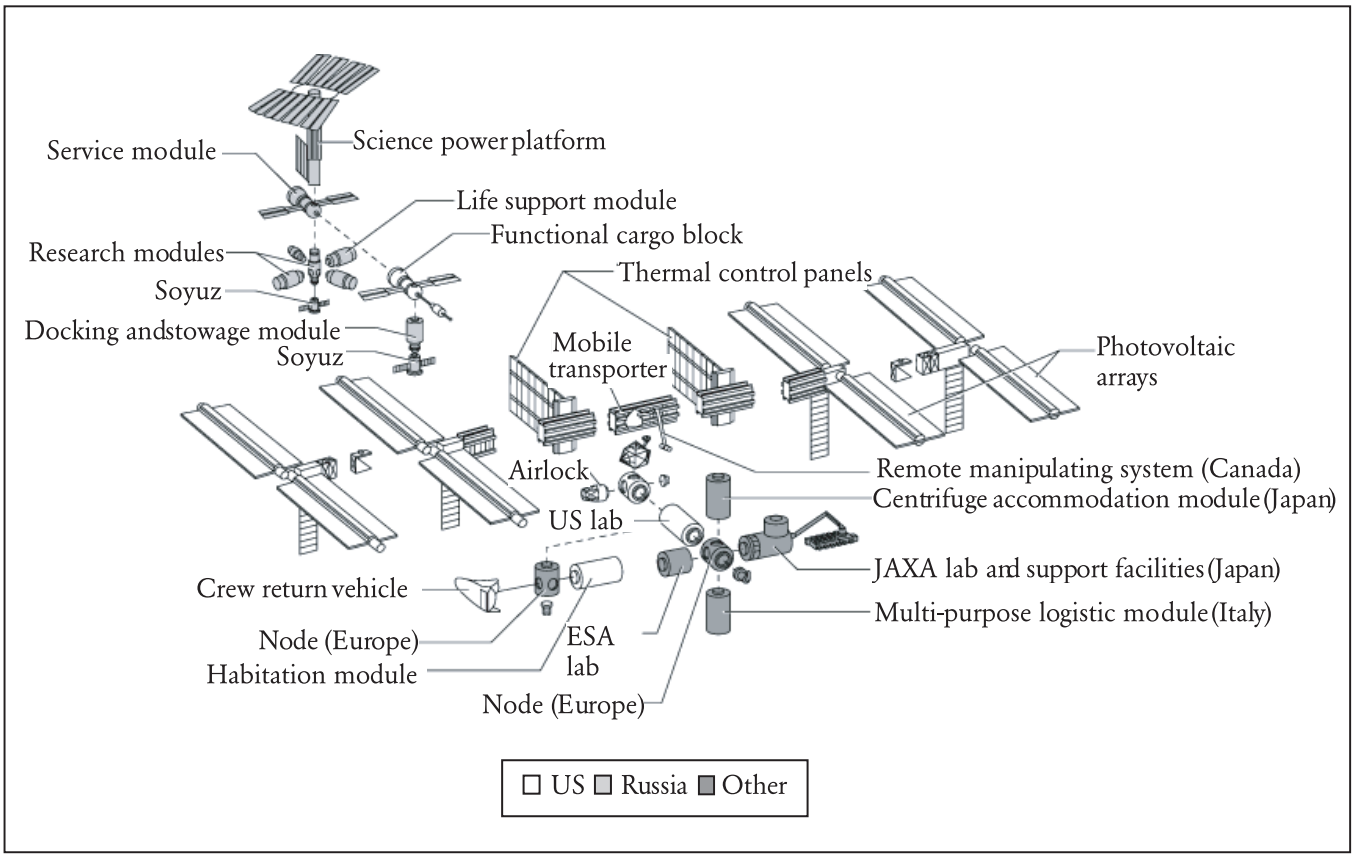
International cooperation has been a defining feature of civil space programs throughout the space age. One of the first scientific satellites, Ariel-1 launched in 1962, was the world's first international satellite, built by NASA to carry UK experiments. The earliest large international cooperation 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 manned modules in July 1975.

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 on board the MIR space station.[50] From 1995 to 1998, there were nine dockings of the US Space Shuttle to the MIR space station, with various crew exchanges.[51] The ESA and NASA have collaborated on many scientific missions, including the Hubble Space Telescope, the Galileo Jupiter probe, and the Cassini-Huygens Saturn probe.

The most prominent current example of international civil space cooperation is the International Space Station, the largest international engineering project ever undertaken. The project partners are NASA, the Russian Space Agency, ESA, JAXA, CSA, and Agencia Espacial Brasileira (see Figure 3.7). The ISS's first module was launched in 1998, and the station is presently still under construction. By the end of 2004 there had been a total of 44 launches to the station carrying components, equipment, and astronauts. The ISS is projected to cost a total of $129 billion.[52]

Space-based global utilities, discussed in more detail in Trend 3.4, represent another area of international cooperation. The EU Galileo satellite navigation system currently involves 15 EU states, two non-EU states, and negotiations are ongoing with several other potential partner states. Algeria, China, Nigeria, Vietnam, Thailand, Turkey, and the UK are collaborating on the Disaster Monitoring Constellation. The project, initiated by China, foresees the deployment of 10 dedicated micro-satellites, four of which have been deployed to date.

**FIGURE 3.7: The International Space Station**[53]




Another recent international civil space 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."[54] The System was initiated in July 2003 at the Earth Observation Summit, which brought together 33 states plus the European Commission and many international organizations. The attending states declared their commitment to the development of a comprehensive, coordinated, and sustained Earth Observation System to collect and disseminate improved data, information, and models to stakeholders and decision-makers.

The "Declaration of the Earth Observation Summit" included a provision to formulate a 10-year Implementation Plan. The anticipated benefits of GEOSS will include disaster reduction, integrated water resource management, ocean and marine resource monitoring and management, weather and air quality monitoring, biodiversity conservation, sustainable land use and management, public understanding of environmental factors affecting human health and well being, better development of energy resources, and adaptation to climate variability and change.[55]

The nature of international space cooperation has changed since the end of the Cold War, as traditional barriers to partnership are being 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.[56] That being said, increased cooperation with the US has been hindered by export control issues (see Commercial Space).

## 2004: Continuing international civil space cooperation

The trend towards international cooperation in civil space programs was maintained in 2004. On 29 April 2004, the *Framework for a 10-Year Implementation Plan* for GEOSS was agreed by representatives from 47 countries meeting in Tokyo.[57] This effort should lead to more capabilities in Earth observation and an increase in the number of actors with access to these capabilities. The Group on Earth Observations welcomed representatives from developing countries to Brussels on 15 October 2004 for an international Earth Observation Partnership Conference. The aim was to bring new collaborators into the process of creating GEOSS.[58] The EU/ESA Global Monitoring for Environment and Security program is part of the GEOSS system.

In May 2004, Russian and EU space officials discussed the possibility of Russia joining the ESA. No formal arrangement was reached, but such a move would represent a major change in the civil space landscape.[59] Subsequently on 6 October 2004, the Prime Ministers of France and Russia signed an agreement to allow the Soyuz rocket to be launched from the ESA spaceport in French Guyana.[60] Also in May 2004, Israel selected India to launch its first astronomy satellite. The $14-million Tel Aviv University Ultra Violet Experiment (TAUVEX) will be the first satellite to observe the universe from an altitude of 36,000 kilometers, and the scientific data will be "shared by researchers of both countries."[61]

## Net assessment

The trend toward greater international civil space cooperation was reinforced by developments in 2004, supporting greater access to space by a larger number of actors. International cooperation has also promoted transparency between space actors through the sharing of expertise and knowledge on each party's civil space program. Due to the often dual-use potential of many civil space programs, such transparency has acted as an important confidence-building measure between space actors, helping to enhance space security. Therefore, the opening of space partnerships in the post-Cold War geopolitical landscape should be seen as a positive trend in this regard.

Collaborative projects such as GEOSS have helped to enhance the space capabilities of a number of space actors. Furthermore, Russian interest in joining the ESA could lead to a major achievement in post-Cold War cooperation. Indo-Israeli cooperation on TAUVEX highlighted the benefits of relying on each actor's comparative advantage. Indeed, without international cooperation, Israel would be unable to attain the desired Geostationary Orbit (GEO) for its satellite. Finally, international cooperation has improved space security by promoting the norm of "international co-operation in the peaceful exploration and use of outer space" as enshrined in the Outer Space Treaty.

## TREND 3.4: Dramatic growth in global utilities as states acknowledge strategic importance of satellite-based navigation systems

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, generating sales revenue of $6.2 billion in 1999.[62] Key global utilities such as the GPS and weather satellites were initially developed by military actors. Today, these systems have grown into space applications that have become almost indispensable to the civil, commercial, and military sectors, as well as most modern economies.

### *Satellite navigation systems*

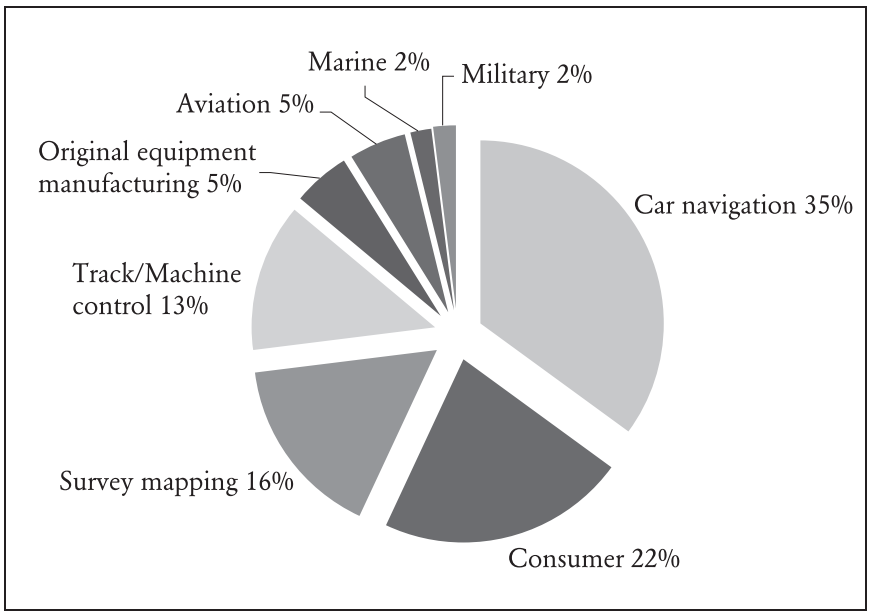
There are currently two large-scale operational satellite navigation systems maintained by states — the US GPS and the Russian GLONASS system. Work on the GPS began in 1978, and it was declared operational in 1993, with a minimum of 24 satellites that orbit in six different planes at an altitude of approximately 20,000 kilometers in Medium Earth Orbit (MEO). A GPS receiver must receive signals from four satellites to fix its location which it can then do with an accuracy of within 20 meters.

Beginning as a military system, GPS applications have diversified and grown to the point that military uses of the GPS only accounted for about two percent of the total GPS market in 2001 (see Figure 3.8). The commercial airplane transportation industry, which carried some 1.6 billion passengers per year in 2000, relies heavily on the GPS.[63] US companies receive about half of GPS product revenues, but US customers account for about one-third of the revenue base. The growth rate of GPS units in use continues to increase, particularly outside the US.[64] Consequently, the number of employees in the GPS industry totaled 30,000 in 1999.

The Russian GLONASS system uses principles similar to the GPS. It is 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.[65] The first GLONASS satellite was orbited in 1982, and

the system became operational with 24 satellites in 1996 with a similar accuracy to that provided by the GPS. While the number of operational GLONASS satellites has fallen below complete operational levels in recent years, it retains some capability and Russia has undertaken to launch sufficient replacement satellites to make the system fully operational again.[66]

**FIGURE 3.8: GPS market breakdown (2001)**[67]




At the end of 2003, China, Japan, and the EU were actively engaged in the research and development of three additional satellite navigation systems.[68] The Chinese Beidou system has been under development since the late 1990s and currently has two satellites. It uses a different principle than that of the GPS or GLONASS, and when fully operational, has two geostationary satellites, one back-up satellite, and requires ground stations for operation. Beidou has the capacity to serve some 200,000 users, but can only be used in and around China.[69] Japan, for its part, began developing the Quazi-Zenith Satellite System (QZSS), which is to deploy a few satellites compatible and interoperable with the GPS in Highly Elliptical Orbit, in order to enhance the regional navigation over Japan.[70]

Perhaps most significantly, the EU and the ESA are jointly developing the Galileo navigation system, which will consist of 30 satellites in a constellation similar to 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.[71] In July 2003, the ESA announced contracts for the procurement of two Galileo technology demonstration satellites, one to the UK's Surrey Satellite Technology Ltd. and one to Galileo Industries, a multinational consortium.[72] The first Galileo satellite is scheduled for launch in 2005.[73] The Galileo project has been opened to international partners. Russia has agreed to launch Galileo satellites, and partnership negotiations

have begun between the EU and a number of other countries, including Australia, Brazil, India, Mexico, and South Korea, to support the development of the system.[74]

The EU intention to use a transmission frequency for its Galileo navigation signals similar to one of the GPS military frequencies has been a source of conflict between the EU and the US. The US argued that the frequency structure between 1559 and 1591 megahertz being demanded by the EU could have prevented American commanders from degrading navigation data in the theatre of war to all but their own forces, as is possible at present.[75] This would mean that the US would be unable to effectively jam enemy signals in a small area, such as a battlefield, without shutting down its entire navigation system. Negotiations began in 2001 to resolve this dispute.[76]

### *Weather*

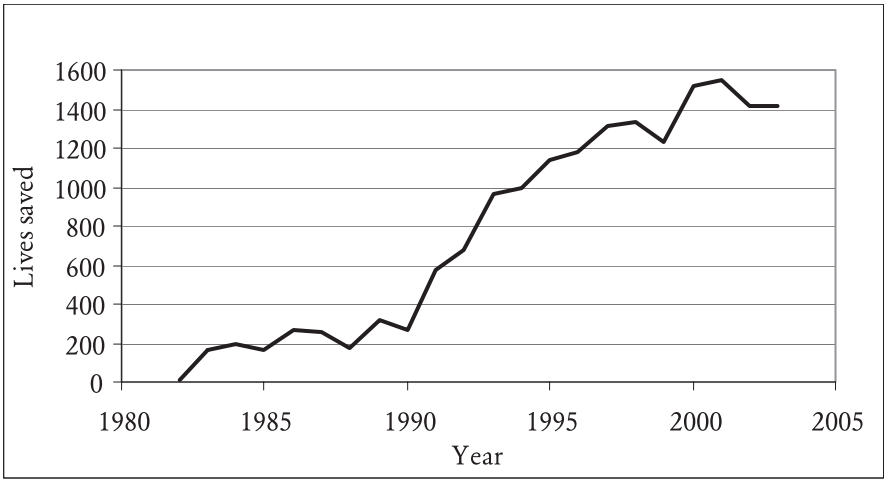
Earth observation satellites are used extensively for a variety of functions, from weather forecasting to disaster warning and emergency response. The European Organization for the Exploitation of Meteorological Satellites has launched eight satellites into GEO since 1972, to provide meteorological data to Europeans. Similarly, the US NOAA, founded in 1970, has launched 34 satellites, primarily into LEO or GEO, to provide US meteorological services.[77]

Earth observation satellites serve a number of other functions, including surveillance of borders and coastal waters, and monitoring of crops, fisheries, and forests, as well as natural disasters such as hurricanes, droughts, floods, volcanic eruptions, earthquakes, tsunamis, and avalanches. Space has become critical for measuring climate change. Several countries, including Algeria, China, Nigeria, Vietnam, Thailand, Turkey, and the UK, are collaborating on the Disaster Monitoring Constellation to deploy 10 micro-satellites dedicated for this use.[78]

### *Search and rescue*

Since 2001, satellite-based search and rescue (SAR) systems have provided emergency communications for people in distress and have been credited with saving the lives of approximately 1,500 people per year.[79] This figure is double that of 1996. Since the 1980s, SAR has been coordinated through the organization COSPAR-SARSAT, the International Satellite System for Search and Rescue Satellites. This organization was founded by Canada, France, the former USSR, and the US through a 1979 memorandum of understanding.

**FIGURE 3.9: Lives saved annually by COSPAR-SARSAT**[80]




## 2004: EU-US Galileo frequency dispute resolved, but issues remain

In January 2004, it was announced that China would not be granted access to the Public Regulated Service government channel, which is Galileo's most secure channel.[81] In February 2004, the US and the EU negotiated an end to the two-year dispute over frequency allocation for the GPS and Galileo systems. The new agreement will ensure interoperability of the two systems, and reserve certain portions of the spectrum for secure military use by the GPS to avoid signal interference.[82] However, some issues appear to remain unsolved. For example, on 23 October 2004, it was reported that the US Air Force was willing to use irreversible action against Galileo satellites if they were used by adversaries.[83] On 24 October 2004, China re-stated its intentions to use Galileo for peaceful purposes.[84] China and the EU have signed a cooperation agreement to share Galileo development costs reportedly for a Chinese contribution of about $300 million.[85]

## 2004: Progress on Galileo development while Japanese QZSS system development stalled

In March 2004, an agreement was reached between the EU and Israel on its participation in the Galileo program.[86] In October 2004, the EU gave the go-ahead to open negotiations with Ukraine on a cooperation agreement on Galileo development.[87] Discussions are under way regarding cooperation with India, Brazil, South Korea, Mexico, and Australia. The European Commission approved a Galileo development program in December 2004, including 2002-2005 program development, 2006-2008 system deployment, and then operation and exploitation. Exploitation costs are estimated at $282 million a year, with an exceptional contribution of the public sector for the first few years of $640 million. Thereafter, these costs will be entirely covered by the private sector.[88] Meanwhile, an internal programmatic dispute continues to deadlock the development of Japan's QZSS navigation system.[89]

### FIGURE 3.10: 2004 Global utility satellites launched

| Function | Number | Mission |
|---|---|---|
| Navigation satellites | 6 | •1 GPS (US - US Air Force (USAF))<br>•1 GPS (US - USAF)<br>•1 GPS (US - USAF)<br>•3 GLONASS (Russia) |
| Global Telecom | 1 | •Amsat Echo (US Radio Amateur Satellite Corporation, US) |

### Net assessment

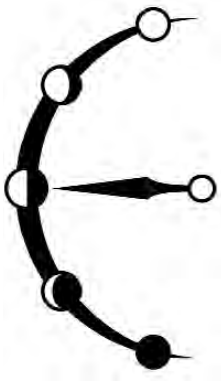
Developments in 2004 reinforced the dramatic growth in global utilities as more actors move to exploit the strategic advantages of satellite navigation systems. It is also noteworthy that while GLONASS and GPS are both operated by the military, Galileo and QZSS are civil programs. This diversification of satellite navigation systems across actors and space sectors promises a degree of system redundancy which could enhance the security of access to global satellite navigation utilities.

The extensive growth and use of global utilities, in particular navigation, search and rescue, and weather satellites, has increased the number of individuals who rely on space. This has had a positive impact on space security by increasing the community of stakeholders in the sustainable use of space and space security.

The EU-US GPS/Galileo frequency dispute demonstrated the potential for competition over space resources and the inherent risks in developing dual-use space systems. The apparent resolution of the dispute suggested the potential for even more dramatic growth in the applications of satellite navigation systems.

## Space Security 2004 Survey Results

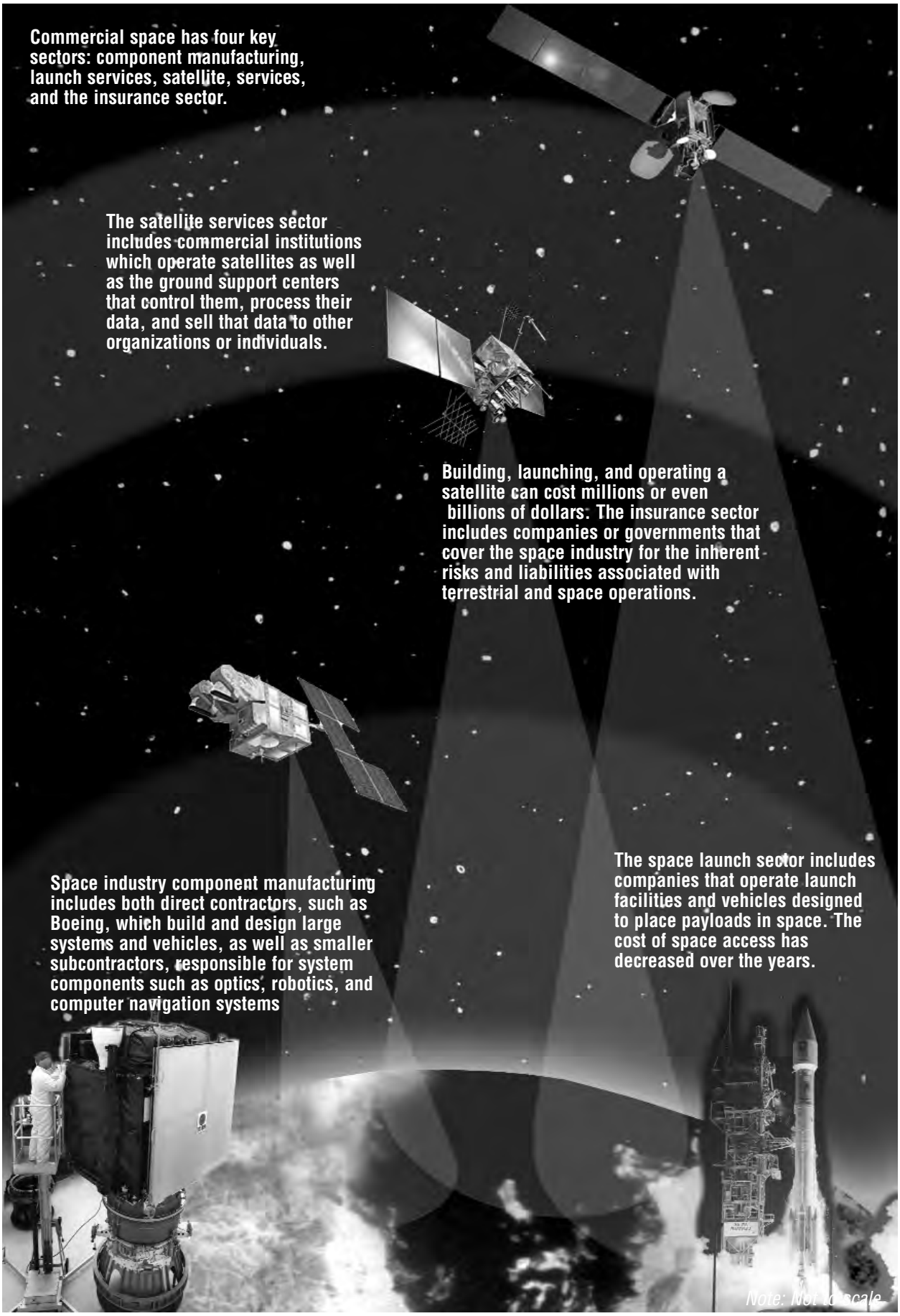
| ***Overall, how have developments related to civil space programs and global utilities in the past year affected space security?*** | | | | | |
|---|---|---|---|---|---|
| Space Security Survey (14 January-21 February 2005) | | | Space Security Working Group Survey (24-25 February 2005) | | |
| Enhanced | 6 | 5% | Enhanced | 0 | 0% |
| Somewhat Enhanced | 49 | 38% | Somewhat Enhanced | 9 | 32% |
| Little or No Effect | 60 | 47% | Little or No Effect | 13 | 46% |
| Somewhat Reduced | 13 | 10% | Somewhat Reduced | 6 | 21% |
| Reduced | 1 | 1% | Reduced | 0 | 0% |
| Total | 129 | | Total | 28 | |



**A significant minority of Space Security Survey respondents and Space Security Working Group participants assessed that there was little or no effect on space security in 2004 with respect to this indicator.**

Respondents who assessed that space security had been somewhat enhanced in 2004 tended to cite the resolution of the GPS/Galileo dispute, as well as new agreements with Ukraine and Israel that will enlarge the Galileo partnership. General growth in the use of global utilities, and corresponding growth in the number of space security stakeholders, was also emphasized as being positive for space security. The role of international civil cooperation in enhancing space security was also frequently noted.

Respondents who assessed that space security had been somewhat reduced in 2004 tended to cite as an issue of concern increased civil-military cooperation — particularly in the US but also in the EU — suggesting that this could encourage some actors to view civil space assets as potential targets for space system negation efforts. Some experts expressed concern about developments associated with the use of nuclear power on civil space missions.


Commercial space has four key sectors: component manufacturing, launch services, satellite, services, and the insurance sector.
The satellite services sector includes commercial institutions which operate satellites as well as the ground support centers that control them, process their data, and sell that data to other organizations or individuals.
Building, launching, and operating a satellite can cost millions or even billions of dollars. The insurance sector includes companies or governments that cover the space industry for the inherent risks and liabilities associated with terrestrial and space operations.
Space industry component manufacturing includes both direct contractors, such as Boeing, which build and design large systems and vehicles, as well as smaller subcontractors, responsible for system components such as optics, robotics, and computer navigation systems
The space launch sector includes companies that operate launch facilities and vehicles designed to place payloads in space. The cost of space access has decreased over the years.
Note: Not to scale

# 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 space insurance sector which underwrites the space industry for the inherent risks and liabilities associated with space system operations.

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 which operate satellites, as well as the ground support centers that control them, process their data, and sell that data to others. The bulk of revenues in the satellite services sector are generated in three main areas: telecommunications, Earth observation, and remote sensing.[1]

The second largest contribution to the growth of the commercial space sector has been provided by satellite and ground equipment manufacturing. This includes both direct contractors which design and build large systems and vehicles, as well as 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. This includes companies that operate launch facilities, that design and manufacture vehicles designed to place payloads in space, and launch component and sub-system manufacturers. The proliferation of states and actors offering commercial space launch services, an increase in market competition, and the development of so-called piggyback launches of micro-satellites have all contributed to both a general decrease in the cost of commercial space access and a corresponding increase in the number of commercial actors accessing space.

Governments play a central role in commercial space activities, as principal contractors for certain services, by supporting research and development, by subsidizing certain space industries, and by underwriting insurance costs. Indeed, the space launch and manufacturing sectors survive largely on government backing. Conversely, because space technology is often dual-use, governments have also tended to constrain these commercial space capabilities though domestic and international export controls.

Several states have begun to consider commercial space a critical infrastructure for national security. In addition, the military sector has taken advantage of a glut of capacity in the commercial market to provide military communications and imagery, reinforcing a trend towards greater dependence upon commercial systems for military applications.

## Space Security Impacts

The commercial space sector is directly related to space security considerations as it provides actors with launchers with which to access space, as well as much of the satellite and ground station manufacturing capabilities which enable actors to operate entire space systems.

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 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 a degree of transparency and trust through international projects that engage multiple actors in several different countries. In addition, the development of the space industry could be a driver for international space governance. To thrive, sustainable commercial markets require a framework of laws and regulations on certain issues of property, standards, and liabilities. For example, the growing role of the commercial space sector has already played a role in modernizing the Liability Convention.

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.

However, growth in space commerce could eventually mean greater competition for scarce space resources such as orbital slots and radio frequency spectrum allocations. Commercial actors could undercut international regulations if they are not properly regulated by national authorities. The dependence of the commercial space sector on military clients, or conversely, the reliance of militaries on commercial space assets, could also adversely impact space security by making the industry overly dependent on one client, or by making commercial space assets the potential target of military attacks.

## Key Trends and 2004 Developments

### TREND 4.1: Continued overall growth in global commercial space industry

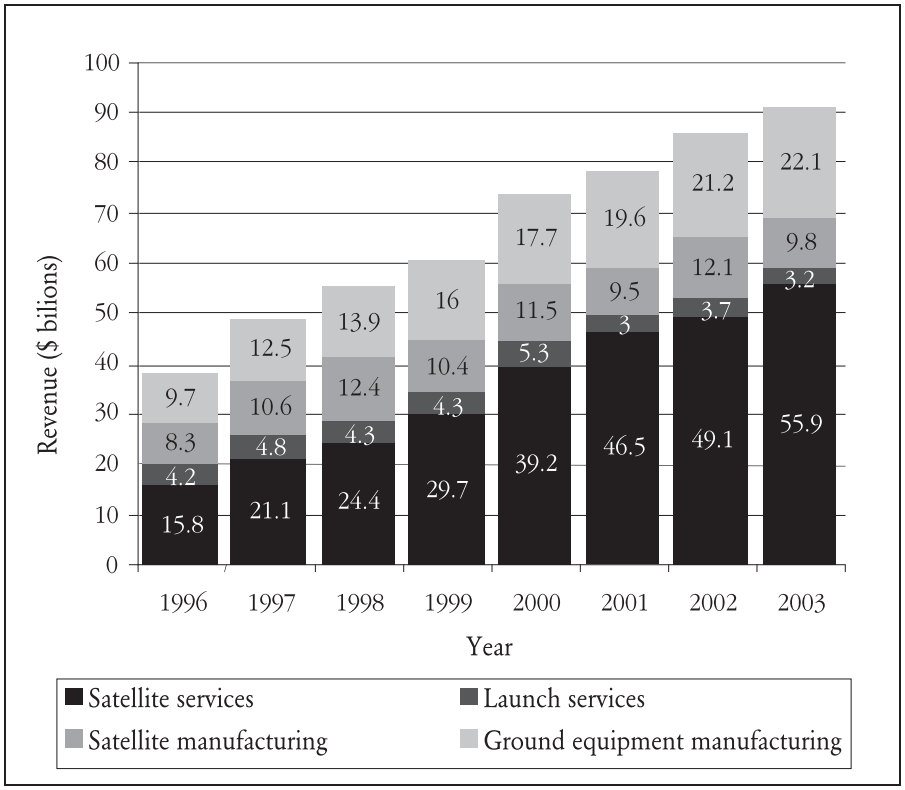
The telecommunications industry has long been a driver of commercial uses of space. The first commercial satellite was the Telstar 1, launched by NASA in July 1962 for the telecommunications giant AT&T.[2] Satellite industry revenues were first reported in 1978, when *US Industrial Outlook* published 1976 COMSAT operating revenues of almost $154 million.[3] By 1980, it is estimated that the worldwide commercial space sector already accounted for $2.1 billion in revenues,[4] and by 2003, the sector collected $91 billion.[5] Not yet included in industry totals for revenues is the small but rapidly growing space tourism industry.

The commercial space sector continues its steady growth. However, the annual rate of growth has been uneven. 2003, for example, saw the slowest annual rate of growth since the mid-1990s. Looking at industry sub-sectors, key recent trends include profits in the manufacturing and launch sectors coupled with significant growth in profits from satellite services. The satellite services sector has tripled in size since 1996, generating $55.9 billion in revenues in 2003, more than 60 percent of the commercial sector's $91 million total revenues (see Figure 4.1).[6]

A number of new companies were founded in the 1980s to take advantage of anticipated growth in the space telecommunications services sector. Telecommunications were de-regulated in many countries during this decade, and previously government-operated bodies such as the International Telecommunications Satellite Consortium and the International Maritime Satellite Organization were privatized.[7] PanAmSat, New Skies, GE Americom, Loral Skynet, Eutelsat, Iridium, EchoStar, and Globalstar were some of the prominent telecommunications companies to emerge during this period. Hughes also entered the market with DirecTV technology, a new satellite television broadcast system.

The 2000 downturn in the technology and communications sectors also cut growth in the commercial space sector, reducing market take-up of satellite telephony, which created a related launcher overcapacity problem. For example, there were 40, 39, 35, 16, 24, and 17 commercial launches from 1998-2003 respectively,[8] and yet by comparison the six primary large boosters available today — Ariane 5, Atlas 5, Delta 4, H-2A, Proton, and Zenit 3SL — have a combined capacity of about 40 commercial launches a year (see Trend 4.2). From a record high of $12.4 billion revenues in 1998, satellite manufacturers worldwide collected only $9.5 billion in 2001, a drop of about 24 percent.

**FIGURE 4.1: World satellite industry revenues by sector**[9]




More recently, the decreasing cost of communications equipment combined with decreasing launch costs have supported significant growth in satellite services such as direct broadcast services. Major satellite telecommunications companies today include PanAmSat, Loral, SES Americom, Intelsat, and News Corporation. Although these companies are for the most part owned outside of the US, they have established subsidiaries to take advantage of the US market, composed largely of government customers.[10]

## 2004: Growth in global commercial space sector continues

Overall growth in the global commercial space industry continued in 2004. The *2004 State of the Satellite Industry* report noted that commercial revenues in 2004 were expected to top $100 billion, with growth driven largely by increasing military expenditures and a growing satellite services sector.[11] By June 2004, the number of Direct-to-Home television subscribers reached 23.4 million, and the number of Direct Broadcast Satellite subscribers stood at 23.1 million.[12] In 2003, nine companies saw stock market gains of 100 percent or better. [13]

China discussed the possibility of having commercial space flights available by 2020,[14] and the Isle of Man announced a zero-tax policy for the space industry.[15] The US Federal Communications Commission reported in January 2004 that cable broadcasters were "losing to satellites" in the competition to

provide television services.[16] US President George Bush's announcement of the new MoonMars Initiative in January 2004 spurred a flurry of interest from the country's major industrial contractors. Although stocks experienced an initial rise after the announcement, they fell back as investors were reportedly disappointed that more NASA funding did not materialize.[17]

### 2004: Military-commercial interdependence sustains growth; sector continues to be shaped by consolidation and privatization

A survey of satellite industry professionals at an International Satellite and Communications Exchange conference in June 2004 indicated that over 200 of the businesses represented had generated a majority of their new business over the previous 12 months from military/defense contracts. Military-commercial interdependence was expected to drive growth "over the next three years, with military/defense services continuing to sustain the market."[18]

Consolidation appeared to be a priority for the Russian space industry, with Russian Federal Space Agency head Anatoly Perminov noting that Russia's 112 companies, 31 industrial facilities, 66 design bureaus, and 15 other organizations required "optimization."[19] While key US aerospace contractors such as Raytheon and Ball Aerospace predicted continued growth into 2005, they believed the pace of hiring would slacken.[20] *Space News* reported that the Launch and Orbital systems unit at Boeing "remains the lone drag on Boeing Co.'s defense units." The unit was expected to lose between $50 million and $100 million in 2004, although the outlook for the next few years was still positive.[21]

In August 2004, Intelsat, a US-based world leader in telecommunications services, was sold to Zeus Holding, a consortium of four private investors, for about $5 billion.[22] Intelsat's privatization will add a major new player to the commercial space industry.

### Net assessment

This continued growth of the commercial space sector can be seen as a positive reflection of space security by indicating relatively secure access to, and use of, space. The booming satellite telecommunications industry affects the lives of millions of people around the world on a daily basis, underscoring the importance of space security.

However, the broader health of the commercial space sector remains dependent upon the telecommunications sector, while the commercial launch and manufacturing sectors continue to face challenges. There is also some concern that the commercial space sector is increasingly able to supply space capabilities to actors adversarial in nature who would otherwise not be able to afford to develop such technology.

## TREND 4.2: Declining commercial launch costs support increased commercial access to space

Commercial space launches currently account for about one-third of the total 60-70 yearly space launches.[23] Russian, European, and American companies remain world leaders in the commercial launch sector, with Russia launching the most satellites, both commercial and overall.[24] Commercial space launches began to grow significantly in the 1980s. At that time, NASA viewed its provision of commercial launches more as a means to offset operating expenses than 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 offering only launches through its Shuttle.

Increasing demand for launch services, and the 1986 Challenger Shuttle disaster which led to a ban of commercial payloads on the Space Shuttle, further encouraged commercial launcher competition. The Ariane launcher, developed under French leadership in the 1980s, captured over 50 percent of the commercial launch market over the period 1988-1997.[25] The Chinese Long March and the Russian proton rocket provided additional competition in the early and mid-1990s. However, about 80 percent of commercial launches to the highly-valued Geostationary Orbit (GEO) were still provided by the three more expensive western launch vehicles, the Ariane, Atlas, and Delta rockets. Near the end of the decade, the Long March was pressured out of the commercial market due to "reliability and export control issues."[26]

Japanese commercial efforts have suffered from technical difficulties, and the Japanese designed H-2 launch vehicle was shelved in 1999 after flight failures.[27] India's Augmented Satellite Launch Vehicle (ASLV) performed the country's first Low Earth Orbit (LEO) commercial launch, placing German and South Korean satellites in orbit in May 1999. However, the Indian commercial launch sector has not received orders since.[28] Brazil is trying to develop an autonomous national launch capability.

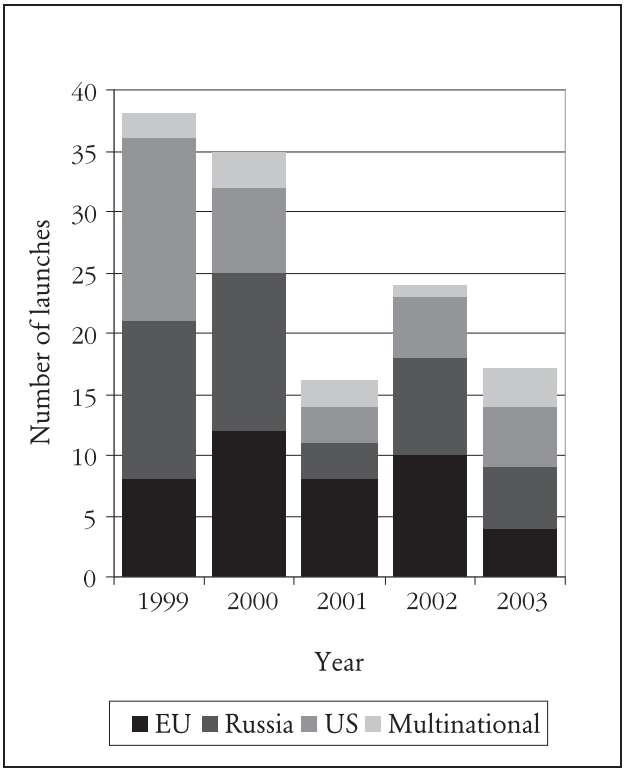
Today's top commercial launch providers include Lockheed Martin and Boeing Launch Services in the US, Arianespace in Europe, Energia in Russia, and two international consortia: Sea Launch and International Launch Service (ILS).[29] Sea Launch is an enterprise comprised of the US' Boeing, Norway's Aker Kvaerner, Russia's RSC-Energia, and Ukraine's SDO Yuzhnoye/PO Yuzhmash, which launches from a sea-based platform located on the equator.[30] ILS is a partnership between Russia's Khrunichev State Research and Production Space Center, US' Lockheed Martin Space Systems, and Russia's RSC-Energia (see Figure 4.2).

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 piggy-back launches — where a small satellite is attached to a larger one so as to avoid

paying for a dedicated launch — in an effort to bring down the cost of space access. It is now also common to use dedicated launches to deploy clusters of two to four smaller satellites on small launchers such as the Cosmos rocket.

Launcher competition and new launch techniques have supported a steady decrease in space access costs. In 2000, payloads could be placed into LEO for as little as $5,000 per kilogram,[31] highlighting the relative ease of reaching this orbit. The cost to place payloads in GEO has declined from an average of about $40,000 per kilogram in 1990 to $26,000 per kilogram in 2000,[32] with prices still falling.

**Figure 4.2: Commercial launch trends**[33]




Greater launcher competition and decreasing launch costs have facilitated steady growth in the number of actors who can access space, either through an independent launch capability or via the launch capability of others (see Civil Space Programs and Global Utilities, and Space Support for Terrestrial Military Operations). The number of states that have a satellite in orbit now stands at 45, almost all of whom have been enabled in some way by the commercial sector.

Whereas 40 years ago only a government body would have been able to acquire satellite imagery of a country, today any individual or organization with the necessary resources can access these services. For example, ORBIMAGE offers

online subscriptions to satellite imagery with one meter resolution, and Space Imaging offers one meter resolution on images that are factory-ordered.[34] Companies such as Surrey Satellite Technology Ltd. and SpaceDev have commercialized private research in the area of space technologies, in particular small satellites. Data and voice services over satellite have themselves become a huge portion of the commercial sector, giving individuals from all over the world, most notably in developing countries, access to these services.

## 2004: SpaceShipOne wins X Prize, becoming the first successful privately-developed manned spacecraft

In June 2004, SpaceShipOne, developed by US Mojave Aerospace Ventures, became the first private manned spacecraft by successfully completing a sub-orbital space test flight to an altitude just over 100 kilometers.[35] In October, SpaceShipOne won the $10-million Ansari X Prize by becoming the first privately funded spacecraft to launch a person and the equivalent payload mass of three people to an altitude of 100 kilometers twice within two weeks.[36] The effort was achieved with a total investment of about $20 million and entirely free of government funding.[37] The X Prize competition involved 24 teams from Argentina, Canada, Israel, Romania, Russia, the UK, and the US, who all invested in research and development of a sub-orbital launch vehicle.[38]

Following this success, British business entrepreneur Richard Branson announced that his new subsidiary, Virgin Galactic, would commit $100 million to the development of commercial spaceflights, to begin in 2007 using SpaceShipOne technology.[39] Capitalizing on the same momentum, Robert Bigelow of Bigelow Aerospace unveiled a new $50-million prize in November 2004, known as America's Space Prize. It calls for contestants to build a space vehicle to take at least five people to 400 kilometers, complete two orbits of the Earth, and repeat the feat within 60 days, before 2010.[40]

## 2004: SpaceX builds a cheaper launcher

US commercial launch vehicle builder Space Exploration Technologies (SpaceX) delivered its first rocket, Falcon I, to Vandenberg Air Force base in 2004 for a launch planned for early 2005.[41] In September 2004, SpaceX was awarded a study contract from the US Air Force and the Defense Advanced Research Projects Agency for the Force Application and Launch from Continental US program's launch vehicle (not to be confused with SpaceX's Falcon rocket).[42] SpaceX hopes to break into the commercial launcher market by showing that "cheaper, more efficient launch vehicle design and operation is possible,"[43] largely by focusing on reusability. If successful, the SpaceX Falcon V booster will be offered for some 60-70 percent less than Boeing's Delta II and their newer Delta IV medium Evolved Expendable Launch Vehicle.[44] SpaceX's initial three contracts all went to the US Department of Defense (DOD),[45] illustrating the continued role that the military plays in developing industry capacity.

US SpaceDev also announced their Dream Chaser program in September 2004, a planned sub-orbital vehicle for manned spaceflights based on NASA's scrapped X-34 program, eventually to be scaled up for orbital flight.[46] Finally, Space Adventures Ltd. confirmed that its third space tourist will fly on a Russian Soyuz spacecraft to the International Space Station, scheduled for April 2005.[47]

## 2004: Concerns over future of Ariane launchers

In December 2004, French officials suggested, for the first time, that the Ariane launch program could come to a halt. The program is currently being sustained by a five-year, $1.2 billion support package slated to end in 2009. European governments appear hesitant to further support the rocket's development.

Furthermore, an agreement was signed in early December 2004 for a loan guarantee from the French government for the European-Russian launch company Starsem. This agreement will see Starsem's vehicle, Soyuz, launching from the Guiana Space Center in Kourou, French Guiana beginning late 2006 or early 2007. To this end, the European Space Agency (ESA) has committed $282 million to the construction of a new launch facility at the site.[48] According to a French official, part of the reason for having the Soyuz launch from Kourou was to maintain autonomous launch capability in case Ariane was not competitive by 2009. Responding to concerns about the lift capabilities of the Soyuz system, Starsem said that while the first version of the Soyuz to launch from the Kourou site would be able to place 2,900 kilogram satellites into GEO, the upgraded Soyuz 2-1b will be capable of lifting 3,200 kilograms to GEO. [49]

## 2004: US Congress passes law giving Federal Aviation Administration (FAA) oversight over commercial human spaceflight

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,"[50] the Act establishes the FAA's authority over sub-orbital space tourism in the US, allowing it to issue permits to private spacecraft operators to send paying customers into space.[51] The bill sparked debates over how far the Office of Commercial Space Transportation should go to protect sub-orbital passengers, delaying its passage for several months.[52]

**FIGURE 4.3: Summary of commercial launches in 2004**[53]

| Function | Satellite name | Buyer | Commercial partners |
|---|---|---|---|
| Communications | AMC-10 (GE10) | US | Lockheed Martin/SES Americom |
| Communications | MBSAT | Japan | Space Systems/Loral/Mobile Broadcasting Corp. |
| Communications | W3A | EU | Eutelsat/European Aeronautic Defence and Space Company (EADS) Astrium |
| Communications | Superbird 6 | Japan | Japanese Communications Corp. |
| Communications | Ekspress AM-11 | Russia | NPO Prikladnoy Mekhaniki/Alcatel/PO Kosmicheskaya Sviaz |
| Communications | DirecTV 7S | US | Space Systems/Loral/DirecTV Inc. |
| Communications | AMC-11 (GE-11) | US | SES Americom/Lockheed Martin |
| Communications | Intelsat 10-02 | UN | EADS Astrium/Intelsat |
| Communications | Apstar 5 | China | Space Systems/Loral. APT Satellite, Partial Failure: incorrect orbit insertion |
| Communications | Aprizesat 2 (LatinSat D) | Argentina | Aprize Satellite |
| Communications | Amsat Echo | US | Radio Amateur Satellite Corporation of North America |
| Communications | Anik F2 | Canada | Boeing Satellite Systems/ Telesat Canada |
| Communications | Amazonas | Spain | EADS Astrium |
| Communications | AMC 15 AS 2100 | US | SES Americom |
| Communications | AMC-16 (GE-16) | US | SES Americom |
| Communications | Ekspress AM-1 | Russia | Russia, NPO Prikladnoy Mekhaniki/Alcatel/PO Kosmicheskaya Sviaz |
| Surveillance | ROCSAT 2 | Taiwan | EADS Astrium/National Space Organization |
| Manned mission | SpaceShipOne Flight 15P | | Mojave Aerospace Ventures |
| Manned mission | SpaceShipOne Flight 16P | | Mojave Aerospace Ventures |
| Manned mission | SpaceShipOne Flight 17P | | Mojave Aerospace Ventures |

## Net assessment

Developments in 2004 tended to reinforce the larger commercial space sector trend toward progressively lower launch costs and greater diversity and overall security in the means to access space. SpaceShipOne's success may have ushered in a new era of space tourism, while US efforts to put in place regulations for this new sector suggest that some challenges may lie ahead regarding the safety of manned access to orbital space through purely private companies.

The continuing increase in the number of actors with access to space and space-derived products continues to enlarge the range of space security stakeholders. This sustained growth may place additional pressures upon scarce space resources. Moreover, the ongoing dependence of many commercial actors on government support continues to underscore the relative fragility of independent and sustainable commercial space access.

### TREND 4.3: Government subsidies and national security concerns continue to play an important role in the commercial space sector

Governments have long played a central, if not indispensable, role in the development of the commercial space sector. Most space-faring states see their space systems as an extension of their national critical infrastructure, and a growing number view their space systems as critical to national security. Complete state ownership of space systems at the beginning of the space age has given way to a mixed system in which many larger commercial space actors receive significant government contracts and various government subsidies such as research and development funds, loan guarantees, insurance coverage, and funding for launch site maintenance. The US space industry reportedly receives 80 percent of the total value of its space contracts from governments. In Europe this figure stands at 50 percent.[54]

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.[55] 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 program, which holds as part of its mandate to ensure the continued existence of the two launch vehicles to assure a degree of redundancy in case of rocket design failure.[56]

In Europe, the Guaranteed Access to Space Program adopted in 2003 has the ESA underwriting the development costs of the Ariane 5, ensuring its competitiveness in the international launch market.[57] The program provides both short- and medium-term support for Arianespace during the development and maturation of the Ariane 5 rocket program. It explicitly recognizes the competitiveness of the European launch industry as a strategic asset, and is intended to ensure sustained government funding for launcher design and development, infrastructure maintenance, and upkeep.[58] Although the program is largely focused on the Ariane 5, it also designates money to support a continued relationship with Russia for the use of the Kourou launch site.

Russia's commercial space sector also continues to enjoy a close relationship with its government, receiving significant government contracts and subsidies for the development of the Angara launcher[59] and launch site maintenance.[60] The Russian space program receives subsidies from the US in the form of

contracts related to the International Space Station (ISS). The fragility 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 Energia to default on loan payments. According to the Russian press, the Russian space industry was to receive the equivalent of only $38 million in subsidies in 2003, not enough to cover existing debts or commitments to the ISS.[61]

### *Insurance*

Governments also play an equally important role in the insurance sector where rising insurance rates have put pressure on governments to maintain insurance indemnification for commercial launchers. Prior to 1998, the typical insurance rate for a launch, plus 12 months of in-orbit coverage, could be purchased for about seven percent of the satellite and launch vehicle value. Since 1998, however, there has been a 146 percent rise in the number of in-orbit anomalies, which insurers claim has forced a 129 percent increase in insurance premiums.[62] This has directly increased the cost of space access and use.

In 2002, the space insurance industry paid out $830 million in claims while it collected just $490 million in premiums.[63] The insurance industry has blamed rising rates on more complex satellites with less manufacturing quality control, while the satellite industry has countered that insurers are simply overreacting. Insurers have begun offering shorter terms, with higher rates and deductibles, and insurance exclusions for events such as terrorism.[64]

In 1988, the US Congress amended the 1984 Commercial Space Launch Act to include an indemnification authority which limited the amount insurance launch providers would be required to pay to $500 million, covering basic damage costs in the event of structure or payload failures. However, the Act also provided for Congress to further appropriate up to an additional $1.5 billion to cover excess liabilities beyond the required insurance.[65]

The US Commercial Space Act of 2003 represented the third extension of this provision, to 31 December 2007, in order to give Congress time to re-evaluate proposed changes to the regime.[66] In contrast, the EU offers full indemnification for its launch service providers, while China, Japan, Russia, and Australia offer "better or comparable indemnification regimes" than the US.[67] To date, the provision has cost taxpayers nothing and has helped to support this nascent industry. However, in the event of a failure, public funds would bear the burden of the cost.

### *Export controls*

Space launchers and intercontinental ballistic missiles use almost identical rocketry capabilities, and many civil and commercial satellites contain advanced technologies with potential military applications. The dual-use

nature of many space capabilities has encouraged states to develop national and international export control regimes aimed at preventing their proliferation. The export control regime with the most direct application to commercial space security considerations is the Missile Technology Control Regime (MTCR) (see Space Security Laws, Policies, and Doctrines).

The MTCR was formed in 1987 as a group of states seeking to prevent the further proliferation of capabilities to deliver weapons of mass destruction by working together on a voluntary basis to coordinate the development and implementation of a set of common export policy guidelines.[68] There are 34 members of the MTCR, including Australia, Brazil, Canada, France, Germany, Japan, the Republic of Korea, Russia, the UK, and the US.[69] In 2003, China formally expressed interest in becoming a member of the MTCR.[70] However, even within the MTCR membership, some export practices sometimes differ from state to state. For example, although the US' "Iran Nonproliferation Act" of 2000 limits the transfer of ballistic missile technology to Iran, Russia is still willing to provide such technology.[71]

From the late 1980s to late 1990s, the US had agreements with China, Russia, and the Ukraine to enable the launch of US satellites from foreign sites. However, in 1998, a US investigation into several successive Chinese launch failures resulted in allegations about the transfer of sensitive US technology to China by aerospace companies Hughes and Loral. Concerns over the possibility that this could happen again sparked the transfer, in 1999, of jurisdiction over satellite export licensing from the Commerce Department Commerce Control List to the State Department's US Munitions List (USML).[72] In effect, the new legislation treated satellite sales like weapons sales, making international collaborations more heavily regulated, expensive, and time consuming.

US exports of USML items are licensed under the International Traffic in Arms Regulations regime, which adds several new 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."[73] 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."[74]

While some point to export controls as an opportunity that other space companies have leveraged to increase their expertise and profits, others say the controls are necessary to preserve US space technology dominance. Paradoxically, export controls have, at times, stimulated states to develop the same technologies indigenously, undercutting export controls and breaking monopolies. For example, after being denied the sale of cryogenic rocket engine components from Russia in 1993 due to pressure from the US, India subsequently successfully developed its own cryogenic engine technology.[75]

### *Commercial space systems as critical infrastructure*

Space systems, including commercial systems, are increasingly being viewed as national critical infrastructure. In the 1990s, the US military began to take advantage of the commercial industry's overcapacity by employing commercial satellite systems for non-sensitive communications and imagery applications. During the 1991 Gulf War, 60 percent of the 100 megabytes per second of bandwidth required by US forces was supplied by commercial providers.[76] During Operation Enduring Freedom in 2001, the US military used 700 megabytes per second of bandwidth, of which 75 percent came from commercial bandwidth.[77]

By November 2003, it was estimated that the US military was spending more than $400 million each year on commercial satellite services.[78] This growing dependence upon commercial services prompted a US General Accounting Office December 2003 report to recommend that the US military be more strategic in planning for and acquiring bandwidth, including consolidating bandwidth needs among military actors to capitalize on bulk purchases.[79]

The broader US Government also makes extensive use of commercial communication satellites. Fixed Satellite Services provide wideband Internet Protocol services, and have provided national security and emergency preparedness services to the Federal Emergency Management Agency and National Communications System. Mobile Satellite Services support civil marine operations, and played a domestic security role in the events following 11 September 2001, as well as during the 2002 Winter Olympics.

### 2004: New European Aeronautic Defence and Space Company (EADS) contracts

In May 2004, Arianespace announced it had contracted EADS Space Transportation to deliver 30 Ariane 5 launchers, valued at $3.8 billion in total, beginning in 2005.[80] The deal, expected to reduce production costs by 30-35 percent compared to the Ariane 4, will also benefit Germany where the Ariane 5 rocket program employs over 30,000 people.[81] In August 2004, EADS signed a deal with the ESA worth $1.26 billion, as part of the European Guaranteed Access to Space program signed into law in February 2004. The deal includes preparations for Europe's Columbus module to the International Space Station, and production of six Automated Transfer Vehicles used to deliver International Space Station supplies. EADS is expected to work with about 30 other space companies to fulfill the contract, including 10 European and several Russian companies.[82]

### 2004: US Government awards major reconnaissance contract

In September 2004, the US National Geospatial-Intelligence Agency awarded a major contract in its NextView program to ORBIMAGE. The award was

unsuccessfully contested by rival company Space Imaging.[83] The Nextview contracts, reportedly worth about $500 million, will have a significant influence upon who will be the major players in the US satellite imaging industry, supporting the development for next-generation US intelligence imaging satellites to ensure they possess better than 0.5 meter resolution.[84]

### 2004: US Government releases report on vulnerabilities of commercial satellite systems

In March 2004, a study of the US National Security Telecommunications Advisory Committee Satellite Task Force noted that the US Government has become increasingly dependent upon commercial satellite systems, noting that:

> The national security and homeland security communities use commercial satellites for critical activities, such as direct or backup communications, emergency response services, continuity of operations during emergencies, military support, and intelligence gathering.[85]

### 2004: China moves to join export control regimes

In February 2004, the MTCR held an initial round of consultations with China regarding its intention to join the regime.[86] However, by the end of 2004, China's membership had not been approved, largely because of concerns raised by some MTCR states that China was not ready to adhere to the necessary standards for membership.[87]

### Net assessment

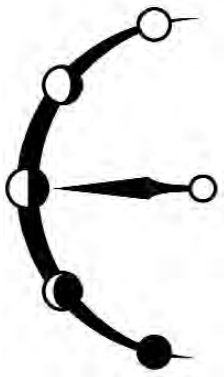
The dependence of governments upon commercial space systems appears to have had a mixed impact on space security. On the one hand, it has encouraged governments to directly support the commercial sector, providing revenues during economic downturns. Moreover, without sustained government support, many space technologies would not have been developed. On the other hand, military uses of commercial space assets could make it more likely that these assets will be viewed as legitimate targets of military attack by adversaries.

While many believe export controls perform important national security functions, they also tend to have a negative effect on space security by constricting the availability of space access material and technology. Furthermore, export controls have at times distorted the commercial space market and made legitimate transnational commercial partnership more difficult.

## Space Security 2004 Survey Results

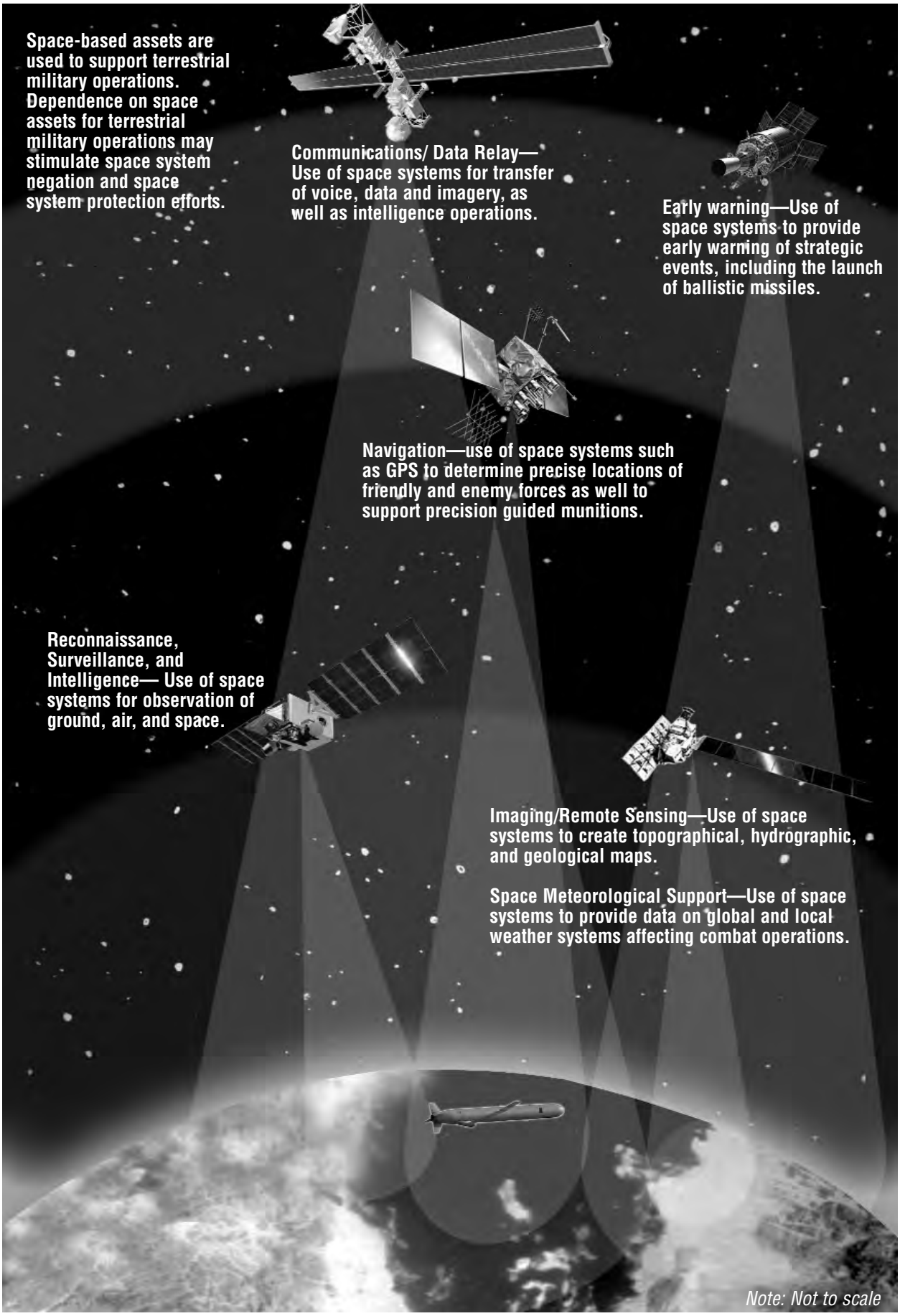
| ***Overall, how have developments related to commercial space in the past year affected space security?*** | | | | | |
|---|---|---|---|---|---|
| Space Security Survey (14 January-21 February 2005) | | | Space Security Working Group Survey (24-25 February 2005) | | |
| Enhanced | 6 | 5% | Enhanced | 0 | 0% |
| Somewhat Enhanced | 43 | 36% | Somewhat Enhanced | 6 | 27% |
| Little or No Effect | 57 | 47% | Little or No Effect | 14 | 64% |
| Somewhat Reduced | 14 | 12% | Somewhat Reduced | 2 | 9% |
| Reduced | 1 | 1% | Reduced | 0 | 0% |
| Total | 121 | | Total | 22 | |

**A significant minority of Space Security Survey respondents and a majority of Space Security Working Group participants assessed that there was little or no effect on space security in 2004 with respect to this indicator.**



A significant minority of experts assessed that the continued growth of the commercial space sector had a positive impact upon space security, often noting that this growth, combined with increasing military-commercial interdependence, would underscore the importance of secure and sustainable access to, and uses of, space. The continued vulnerabilities of commercial space assets and the minimal incentives for commercial actors to protect their satellites were highlighted by a number of experts who assessed that space security had been somewhat reduced with respect to this indicator.

Some respondents noted that growth in the commercial space sector was encouraging the development of new regulatory frameworks which could help to encourage the sustainability of space security. Further, some respondents noted that SpaceShipOne's successful sub-orbital space flight was a positive development related to growing access to space. Some respondents pointed out that, although they felt export controls may have a negative impact on the US commercial space sector, such controls were likely to motivate other space actors to develop their own capabilities, thus increasing secure access for the international community writ large.


Space-based assets are used to support terrestrial military operations. Dependence on space assets for terrestrial military operations may stimulate space system negation and space system protection efforts.
Communications/ Data Relay— Use of space systems for transfer of voice, data and imagery, as well as intelligence operations.
Early warning—Use of space systems to provide early warning of strategic events, including the launch of ballistic missiles.
Navigation—use of space systems such as GPS to determine precise locations of friendly and enemy forces as well to support precision guided munitions.
Reconnaissance, Surveillance, and Intelligence— Use of space systems for observation of ground, air, and space.
Imaging/Remote Sensing—Use of space systems to create topographical, hydrographic, and geological maps.
Space Meteorological Support—Use of space systems to provide data on global and local weather systems affecting combat operations.
Note: Not to scale

# 5 Space Support for Terrestrial Military Operations

This chapter assesses trends and developments in the research, development, testing, and deployment of space systems that support terrestrial military operations. This includes efforts to launch into orbit satellites that provide military attack warning, communications, reconnaissance, surveillance, and intelligence, as well as navigation and weapons guidance applications.

Extensive military space systems were developed by the US and USSR during the Cold War. Satellites offered ideal vantage points from which to monitor the Earth to provide strategic warning of nuclear attack, such as the launch plume of a ballistic missile or the light signature of a nuclear detonation. Satellite communications provided extraordinary new capabilities for real-time command and control of military forces deployed throughout the world. The space age also opened a new chapter in the development of reconnaissance, surveillance, and intelligence collection capabilities through the use of satellite imagery and space-based electronic intelligence collection.

By the end of the Cold War, the US and USSR had begun developing satellite navigation systems that provided increasingly accurate geographical positioning information. Building upon the capabilities of its Global Positioning System (GPS), the US began expanding the role of military space systems, 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 for detection of opposition forces on the ground in all weather at all times.

The US leads in the development of space systems to support military operations, and maintains just over half of all military satellites. Russia maintains the second largest number of military satellites. Together, these two actors tend to dwarf the military space capabilities of all other states. This chapter identifies the development of the military space capabilities of the US and Russia as a distinct space security trend. However, it also examines the efforts of a growing number of other states that have begun the development of their own space systems to support military operations, primarily in the areas of surveillance and communications.

This chapter does not examine military programs pertaining to space systems protection or negation, or space-based strike weapons, which are described in their respective chapters. Additional information on the function of satellite navigation systems as global utilities is provided in the Civil Space Programs and Global Utilities chapter.

## Space Security Impacts

Over half of all space systems to date have been developed to support terrestrial military operations, making the military space sector the primary driver behind the advancement of capabilities to access and use space. In addition to driving the increasing number of actors accessing space, military space has played a key role in bringing down the cost of space access. However, increased access to, and 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 military capabilities and national security.

Space assets have played a strategic and an increasingly tactical role in the terrestrial military operations of certain states. In most cases, space systems have leveraged advanced states' military capabilities through enhanced battlefield awareness, including, as mentioned above, precise navigation and targeting support, early warning of missile launch, and real-time communications. Furthermore, reconnaissance satellites have served as national technical means of verification of international arms control and disarmament regimes. These uses, in addition to the tactical capabilities mentioned above, have driven increasing dependence on space, in particular by the major space-faring states. It is important to note, however, that the impact of space systems on terrestrial military operations and arms control agreements, while related, is distinct from their impact on space security itself.

Growing military uses of space increase both the reliance on, and vulnerability of, a growing number of actors using space. On the one hand, this can have a positive effect on space security by increasing the collective vested interest in space security. On the other hand, the use of space to support terrestrial military operations can have a negative impact on space security if potential adversaries, viewing space as a new source of military threats and an extension of terrestrial battlefields, develop space system negation capabilities to neutralize the advantages those systems provide.

As actors become more dependent upon space systems to support military operations, they acquire greater incentives to develop space system protection and negation capabilities to protect their own space systems, which can lead to an arms escalation dynamic. Finally, some argue that extensive use of space in support of terrestrial military operations blurs the notion of "peaceful purposes" as enshrined in the Outer Space Treaty (see Space Security Laws, Policies, and Doctrines).

## Key Trends and 2004 Developments

### TREND 5.1: US and USSR/Russia lead in developing military space systems

During the Cold War, the US and USSR developed military space capabilities at a fairly equal pace. However, the collapse of the USSR saw a massive drop in Russian military space spending while the US was expanding its military space capabilities. There has been a general decrease in the number of military launches of both states in recent years.

Despite this decrease in the number of dedicated military satellites, US and Russian dependence on military space systems appears to be increasing. While new systems are being orbited at a slower rate, they are being used in conjunction with older Cold War systems. Commercial systems are also playing a rapidly growing military support role. Figures 5.1 and 5.3 provide an overview of US and Russian military space satellites.

#### *United States*

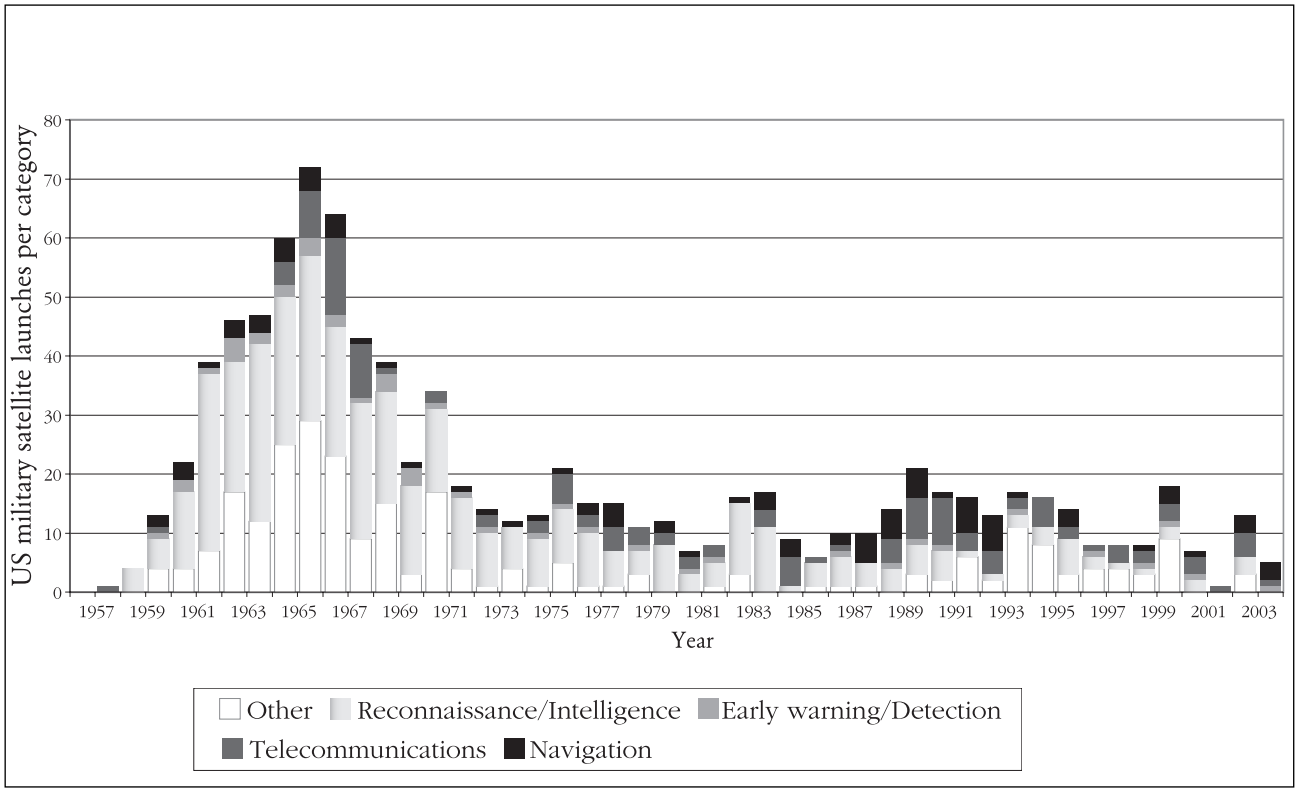
The US has dominated the military space arena since the end of the Cold War. Although spending is only one measure, the US currently outspends all other states combined on military space applications, accounting for 95 percent of total global military space expenditures.[1] At the end of 2004, the US had approximately 135 operational military-related satellites, representing over half of all military satellites in orbit.[2] It continues to place heavy emphasis on upgrading all aspects of its military space capabilities and is, by all major indicators, the actor most dependent on its space capabilities. By comparison, Russia is believed to presently have some 61 operational military satellites in orbit.[3]

The US military has several satellite communications systems. The Military Satellite Communication System (Milstar) is currently one of the most important, providing secure, jam-resistant communications for the US Army, Navy, and Air Force, through five satellites in Geostationary Orbit (GEO). The replacement system for Milstar will be the Advanced Extremely High Frequency satellites, designed to provide assured strategic and tactical command and control communications worldwide.[4] By 2012, the US hopes to deploy the Transformation Satellite Communications System to provide high-speed internet-like information availability to the military, using satellite laser communications technology.[5]

The Defense Satellite Communications System (DSCS) is a hardened and jam-resistant constellation that transmits high-priority command and control messages to battlefield commanders using five satellites in GEO. A planned follow-on to this system is the Advanced Wideband System (AWS) that is expected to increase available bandwidth significantly.[6] The Global Broadcast

System and Ultra High Frequency (UHF) follow-on satellites provide wideband and secure, anti-jam communications, respectively. The Wideband Gapfiller System is intended to bridge the transition between retirement of the DSCS and full deployment of the AWS constellations. The US military also maintains a polar military satellite communications system to assure communications in those regions. In addition to these dedicated systems, space-based military communications use commercial operators such as Globalstar, Iridium, Intelsat, Inmarsat, Pan Am Sat, and Telstar.[7]

**FIGURE 5.1: US military space launches (1957-2004)**[8]




Space-based early warning systems provide the US with critical missile warning and tracking capabilities. The first such system, the US Missile Defense Alarm System, was deployed in a polar orbit beginning in 1960. The 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 satellites needed to four.[9] The US is planning to replace the DSP system with Space Based Infrared High (SBIRS-High) satellites over the next decade, which will provide advanced surveillance capabilities for missile warning and missile defense, as well as "battlespace characterization, and technical intelligence."[10] The anticipated US Space Tracking and Surveillance System (formerly known as SBIRS-Low) will work with SBIRS-High to

provide early warning and to support missile defense responses (see Space Systems Protection).

The first US optical reconnaissance satellites were launched as early as 1959, with the Soviets following suit by 1962.[11] These early imaging satellites had lifetimes on the order of 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.[12] Over the years, resolution of these cameras improved from the realm of 10 meters to current optical resolution of less than a meter. While the precise resolution of today's imaging satellites remains classified, the US is generally thought to have optical satellites with resolutions down to about 10 centimeters.[13] As early as 1976, the US began to fit its imaging satellites with devices which transmit images using electromagnetic communications providing near-real-time satellite imagery.[14] Open sources information suggests that the US maintains about eight imagery intelligence satellites in orbit today, comprising three systems known as Crystal, Misty, and Lacrosse.[15]

Anticipated US Space-Based Radar satellites will be designed to provide tactical support capable of tracking "moving ground targets in operational theatres,"[16] and are slated for initial launch in 2012. The US military also uses several commercial imagery services such as DigitalGlobe, Ikonos, and SPOT Image. For example, Landsat is a dual-use imaging satellite used by the US military for tactical planning.[17] The Defense Meteorological Satellite Program provides environmental data in support of military operations. There are also several dual-use civilian-military meteorology spacecraft, including the Geostationary Operational Environmental Satellite and the Polar-orbiting Operational Environmental Satellite.[18]

Navigation and positioning systems were also one of the first military satellite applications. In 1964 the first navigation system was deployed. It was a US Navy navigation system and it had an accuracy greater than 100 meters. This system and similar follow-on systems 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. The GPS navigation system is used at all levels on the battlefield, from GPS locators for navigation of terrestrial equipment and individual soldiers, to target-identification and precision weapons guidance (see Civil Space Programs and Global Utilities).

Since 2003, the US Air Force (USAF) has promoted a concept entitled Operationally Responsive Spacelift (ORS), focused on reducing satellite costs and deployment times from months to days. This is made possible by new launch capabilities, combined with miniaturization technologies that have dramatically increased the 'capability per kilogram on orbit' equation for satellites.[19] These ORS efforts seek the capability to replace US satellites on short notice,[20] 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 is an ORS demonstration imaging satellite, weighing just 110 kilograms, that will combine existing military and commercial technologies with new commercial launch systems providing "more rapid and less expensive access to space."[21] The satellite will be controlled directly by deployed US commanders.[22]

**Figure 5.2: Characteristics of key US military payloads**[23]

| Current programs (initial launch) | Orbit (satellites on orbit*/full constellation) | Follow-on systems |
|---|---|---|
| Communications | | |
| Defense Satellite Communications System III (1982) | GEO (5) | Advanced Wideband System (2009) |
| Military Satellite Communication System ('Milstar') (1994) | GEO (5) | Advanced Extremely High Frequency (2006) and Transformational Satellite Communications System (TSAT) (2012) |
| Polar Military Satellite Communications (1997) | GEO (1/3) | Advanced Polar System (2010) |
| UHF Follow-on Satellite (1993) | GEO (4) | |
| Global Broadcast System (1998) | GEO (3) | Wideband Gapfiller System (2006) and The Mobile User Objective System (MUOS) (2009) |
| Weather | | |
| Defense Meteorological Satellite Program (1962)avigation | Low Earth Orbit (LEO) (2) | |
| Navigation | | |
| Global Positioning System (1978) | Medium Earth Orbit (MEO) (24) | |
| Early Warning | | |
| Defense Support Program (1970) | GEO (22) | Space Based Infrared High System (2007) and Space Tracking and Surveillance System (2007) |
| Tactical Warning | | |
| | | Space Based Radar (2012) |
| Imaging | | |
| Crystal (1976) | LEO (3) | |
| Lacrosse (1988) | LEO (3) | |
| Misty (1990) | LEO (?) | |

* This number represents the number needed for full system functionality, and does not include on-orbit spares.

The Evolved Expendable Launch Vehicle (EELV) program is a 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 can be used for both commercial and government purposes.[24] In order to meet future government requirements, both the Lockheed Martin Corporation and the Boeing Company are also pursuing so-called Heavy Lift launch capability under the EELV program. Boeing's Delta 4 Heavy will be able to lift 13,130 kilograms into GEO, and is planned for a late 2004 inaugural launch.[25] Lockheed's Atlas V Heavy is "available 30 months from order," but there are no specific plans for its launch.[26]

The growing dependence of the US upon space systems to support military operations has raised concerns about the vulnerability of these assets. 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 (see Space Systems Protection and Space Systems Negation).[27]

### *Russia*

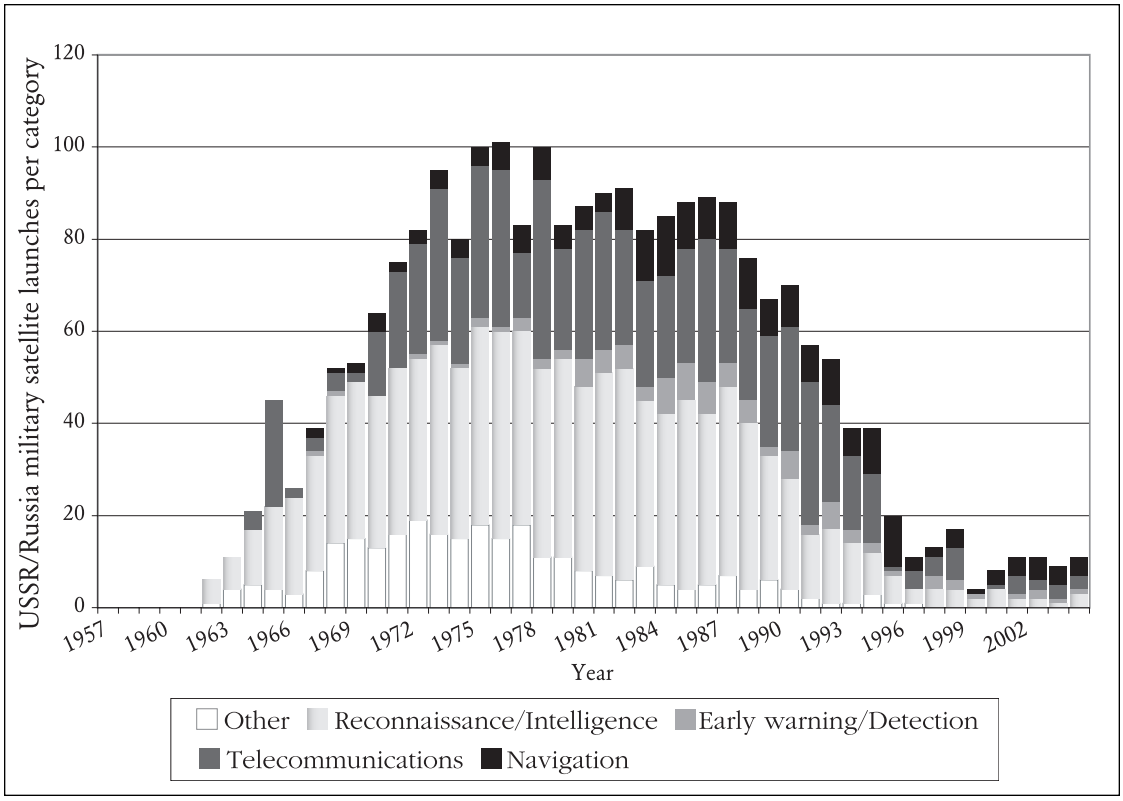
While Russia maintains the second largest fleet of military satellites, unlike the US, these capabilities remain focused primarily on providing strategic support functions. Its current early warning, optical reconnaissance, communications, navigation, and signals intelligence systems were developed during the Cold War, and between 70 and 80 percent of its spacecraft have now exceeded their designed lifespan.[28] However, some of Russia's more critical systems have received replacement satellites over the years, albeit often from Soviet-era equipment, and several Russian military space systems have managed to survive this transition with some operational capacity.

Russia maintains several communications systems, most of which are dual-use. The Raduga constellation of satellites, promoted as a general purpose system, is reported to have secure military communications channels.[29] The Geizer system is designed to have four GEO satellites as a communications relay system for Russian imaging and communications satellites in LEO, but currently has only one operational satellite in orbit.[30] The Strela system began as a military communications system, although civil Gonets satellites were launched to the same orbits, likely augmenting the military satellite system.[31] The Molniya-1 and -3 satellites are in Highly Elliptical Orbits (HEO) and serve as relay satellites for both military and civilian use. There are indications that the maintenance of the Molniya, Strela, and Raduga systems will remain priorities for Russia.[32]

The USSR launched its first early warning Oko satellite in 1972 and by 1982 had fully deployed a system of four satellites in HEO capable of providing warning of the launch of US land-based ballistic missiles.[33] By the end of the 1990s, this system had been replaced by two satellites in HEO and one in GEO, which provide coverage of US ballistic missile fields with reduced reliability.[34] 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 none of these satellites is considered operational today (see Space Systems Protection).[35]

**FIGURE 5.3: USSR/Russia military space launches (1957-2004)**[36]




The USSR began using optical reconnaissance satellites in 1962.[37] By the 1980s, it had begun using electronic transmission of images.[38] Russia's optical imaging satellite capabilities have declined since the Cold War, and it does not currently have the capability to maintain continuous coverage of the Earth.[39] Its two photo electronic reconnaissance systems in operation today are the Yantar-4KS1 Newman system and the Arkon system, which received their most recent new satellites in 2000 and 2002, respectively.[40] Russia maintains two signals intelligence collection satellite systems, neither of which is fully operational. The first system, US-PU/EORSAT, is dedicated to detecting electronic signals from surface ships, while the second, the Tselina, is used for more general signals intelligence purposes. There are indications that Russia is developing a new system, but few details are available.[41]

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 operational today, with an accuracy of about 100 meters.[42] Initially a military system, this constellation has transferred many of its services to civilian purposes. 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.[43] With a full constellation, the navigational system is supposed to have resolution comparable to that of the GPS.[44] While the number of operational GLONASS satellites has fallen below 24, Russia plans to increase the number of satellites in orbit to 17 by 2007, and to 24 by 2010 (see Civil Space Programs and Global Utilities).[45]

As noted in Figure 5.3, Russia has tended to maintain an average annual satellite launching rate slightly higher than that of the US. However, this rate has not been sufficient to keep its military space systems fully operational since they require more frequent replacements. Forced to prioritize, Russia has focused first on its early warning systems, and more recently has moved to renovate the GLONASS navigation system.[46] Russia's extensive experience with military space systems and significant range of conventional and nuclear weapons capabilities make it a significant space security player. Moreover, Russia could draw upon its military space knowledge to assist in the development of the military space capabilities of other states.[47]

### 2004: New US military space systems challenged by delays and inflated costs

The US continued to lead in the development of military space programs in 2004, but many key programs encountered significant cost overruns. SBIRS-High, designed to replace the US DSP early warning satellites, reported 15 percent cost overruns in June 2004, bringing the total projected cost of the system to $9.9 billion.[48] The system's first payload was delivered in August 2004, 18 months overdue.[49] In September 2004, the program's manager warned that the GEO segment of the system could be delayed up to two years.[50] However, in October 2004, the USAF reported that after having completed an analysis of alternatives, it was staying focused on the SBIRS-High system despite the challenges it has encountered.[51]

The budget of the EELV program was increased from $14.4 billion to $31.8 billion in the fall of 2004, after an announcement that it was in deficit.[52] The cost increase was attributed to faulty market forecasts, rather than faulty engineering, planning, or management, raising questions as to whether the USAF could afford program development while it continues to subsidize both Lockheed and Boeing as launch service providers.[53]

### 2004: US Congress cuts funding for Space-Based Radar and Transformational Satellite Communications

The US Space-Based Radar program was cut back to technology development levels in 2004 as the US Congress allocated $75 million in the FY05 budget out of a requested $327 million.[54] The Transformational Satellite Communications

system, a next generation communications system, also had its funding cut significantly by the US Congress, which warned that the Department of Defense "was attempting to move too quickly on the challenging program."[55]

The US Missile Defense Agency announced in February 2004 that it was canceling the Russian American Observation Satellite, an early warning satellite that would have been shared between Russia and the US, citing cost overruns and other priorities.[56] In general, the US Congress was seen to be taking a somewhat hostile approach to space systems in the FY05 budget, criticizing unaffordable technologies and condemning the trend in underestimating costs and time frames for deployment of these systems.[57]

### 2004: Delta 4 Heavy maiden flight experiences premature engine shutdown

On 21 December 2004, Boeing's Delta 4 Heavy launch vehicle carried out its maiden flight from Cape Canaveral. Although Boeing officials deemed the launch a success, all three of the rocket's three main engines shut down early, causing the final orbit achieved to fall short of its intended GEO destination.[58] The launch contained three payloads, including two university-built science nano-satellites piggybacked on the main DemoSat payload, intended for the sole purpose of taking measurements during the flight.[59] Although the original plan had been to auction off the rocket's maiden flight to a commercial payload, lack of market demand compelled USAF to purchase a demonstration launch in order to gather the necessary data for future payloads.[60]

### 2004: Continued emphasis on responsiveness of US space capabilities

In 2004, the US military continued to invest in the development of small satellites and responsive space launch capabilities, as experts noted that one way to address vulnerabilities in space is "to make building and launching American satellites much, much cheaper and easier."[61] The US Congress suggested a $25-million increase in funding for operationally responsive satellites.[62] Following up on a 2003 report from the General Accounting Office, the military noted that it was moving forward with reforms to satellite acquisition procedures "to enhance flexibility, quicken response times and lower costs."[63] However, two small satellites considered to fall within the responsive space program, the TacSat1 and XSS-11, both initially scheduled to launch in 2004, were delayed until 2005 (see Space Systems Negation),[64] and the Responsive Access, Small Cargo, Affordable Launch Vehicle program encountered difficulties.[65]

### 2004: Successes for US military space programs as discussion over separate US Space Forces intensifies

2004 also saw successes for some US military space programs. The 11th UHF Follow-on satellite was handed over to the USAF after successful on-orbit

testing by Boeing in March 2004.[66] The Wideband Gapfiller satellite reported being on track to launch at the end of 2005. The Space Tracking and Surveillance System was noted to be ahead of schedule, and the Next-Generation GPS system reported being on track.[67]

**FIGURE 5.4: Summary of US and Russian military space satellites launched in 2004**[68]

| Satellite name | State | Partners |
|---|---|---|
| **Communications** | | |
| Molniya-1T | Russia | Lavochkin, Russian Space Forces |
| Raduga-1 | Russia | |
| Cosmos 2408 | Russia | |
| Cosmos 2409 | Russia | |
| **Reconnaissance/ surveillance** | | |
| Cosmos 2405 | Russia | Upravlenniye Sputnik Passivny Modifikirovanny, KB Arsena, Russian Navy |
| Cosmos 2406/Tselina-2 | Russia | Yuzhnoye Design Office, Russian Ministry of Defense |
| Cosmos 2410/Yantar-4K1 | Russia | |
| USA 179 Nemesis | US | National Reconnaissance Office |
| **Early warning** | | |
| DSP F22 Block 14 | US | Northrop Grumman Space Technology, National Security Agency |
| **Technology demonstration** | | |
| 3CSat 1 Sparkie Nanosat 2 | US | New Mexico State University, USAF |
| 3CSat 2 Ralphie Nanosat 2 | US | University of Colorado in Boulder, USAF |
| **Navigation** | | |
| GPS | US | USAF |
| GPS | US | USAF |
| GPS | US | USAF |
| GLONASS | Russia | |
| GLONASS | Russia | |
| GLONASS | Russia | |
| GLONASS | Russia | |
| **Launch vehicle test** | | |
| Soyuz 2 | Russia | |
| USA 181 Demosat/ HLVOLSDP | US | USAF, Boeing |

Discussions intensified in 2004 regarding a separate Space Forces within the USAF. The USAF Space Command *Strategic Master Plan for FY06 and Beyond* called for the creation of a "space combat command."[69] In April 2004, the USAF launched a new Space University in cooperation with the University of Colorado at Colorado Springs, focused on providing "an education and training program open to all airmen to advance understanding of how space-based systems can be used in military operations."[70]

## 2004: Russia focuses on GLONASS and signals intelligence

In June 2004, the Russian Space Forces launched the second of a projected four Tselina-2 signals intelligence satellites.[71] In July 2004, the commander of the Russian Space Forces noted that Russia will focus on "maintaining and protecting" its fleet of satellites, including launching the remaining seven satellites needed to complete the GLONASS navigation system by 2008.[72] Later in July, he told a news conference that "a trend toward reducing the number of satellites has been stopped," and that while Russia had been launching satellites with older technology, the time had come for it to begin developing satellites with post-Soviet era technology.[73]

In October 2004, Russian Federation Armed Forces announced that their troops had begun to receive GLONASS navigation units.[74] Russia's space chief claimed in July 2004 that the government had been too slow to fund the Angara rocket as a replacement for the Proton, delaying the final development of the new rocket until 2008 at the earliest.[75]

## Net assessment

The maintenance and further development of extensive military space capabilities by the US and Russia continued in 2004. This has the potential to positively impact space security by providing these two actors with the incentive to maintain secure and sustainable access to space to ensure the utility of these systems. This growing US and Russian dependence upon military space systems could also encourage these actors to develop space protection capabilities to mitigate their vulnerabilities. However, as suggested by the 2001 *Report of the Commission to Assess United States National Security Space Management and Organization,* it could equally encourage the development of space negation capabilities designed to defend space systems through offensive means.

The strategic advantages offered by military space systems could also encourage the US and USSR to develop space negation capabilities to prevent competitors from achieving parity in key space systems to support terrestrial military operations. Conversely, these same advantages provide adversaries with incentives to develop space negation capabilities to exploit the dependence of the US and Russia upon military space systems.

Cost overruns in US military satellite programs, and the overall decline of Russian military space systems, demonstrate the challenge of maintaining the world's most advanced space fleets. However, new US investments in military space systems suggest that the US has no intention of neglecting the maintenance and development of these systems. Russia's acknowledgement of the decline in its satellite systems and announcements that it will be focusing on re-building key systems over the next few years is also a positive sign in this area.

Some experts argue that if Russia's presence in space were strengthened, it could play an important role in mitigating the actions of the US. Others argue the opposite, stating that US military reaction to China's growing space program suggests an arms race dynamic is already driving some US decisions, and that the emergence of a genuine peer competitor in space would have a negative impact upon space security.

### TREND 5.2: More states developing military space capabilities

While the US and USSR/Russia had together launched more than 2,000 military satellites, the rest of the world had only launched between 30 to 40 military satellites by the end of 2003.[76] The UK, NATO, and China were the only other actors to launch dedicated military satellites until 1988, when Israel launched its first military satellite. France's Telecom series of satellites, launched in the mid-1980s was reportedly dual-use.[77] In 1995, France and Chile both launched military satellites.[78] Military satellites launched by these actors have been almost exclusively intended for telecommunications and reconnaissance, the exception being the deployment of military satellite navigation systems by China in 2000.

In the absence of their own dedicated military satellites, some actors have relied upon dual-use satellites, bought existing satellites from others, or purchased data and services from other satellite operators.[79] States allied with either the US or the USSR were also able to benefit from their capabilities. Today, however, 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.

### FIGURE 5.5: States' first military satellites and their function[80]

| Year | State/Actor | Description |
|---|---|---|
| 1958 | US | Telecommunications experimental satellite |
| 1962 | USSR | Reconnaissance |
| 1969 | UK | Telecommunications |
| 1970 | NATO | Telecommunications |
| 1975 | China | Reconnaissance |
| 1988 | Israel | Telecommunications |
| 1995 | France | Technology development for electronic intelligence |
| 1995 | Chile | Communications and remote sensing |
| 2003 | Australia | Telecommunications |
| 2003 | Japan | Reconnaissance |

### *Europe*

European states have developed a relatively modest range of space systems to support military operations. France, Germany, Italy, and Spain jointly fund the

Helios 1 military observation satellite system in LEO, which provides images with a one-meter resolution and supplies images to the EU. The French Ministry of Defense procurement agency runs the program, retains direct control over the management of the ground segment, and delegates the space segment responsibility to the French space agency, the Centre National d'Etudes Spatiales. France, Germany, and Italy were scheduled to launch Helios 2 in 2004, which will offer enhanced resolution as well as day and night capabilities. France, Germany, and Italy are planning to launch six low-orbit imagery intelligence systems to replace the Helios series by 2008.[81]

The UK maintains a constellation of three dual-use Skynet 4 UHF and Supra High Frequency (SHF) communications satellites in GEO.[82] The UK began work in 1998 to develop four Skynet 5 military communications satellites.[83] France also maintains the dual-use Telecomm-2 communications satellite, in addition to the military Syracuse 2 system.[84] Italy's Sicral military satellite provides secure UHF, SHF, and Extremely High Frequency communications for the Italian military.[85] Spain operates the dual-use Hispasat satellite system, which provides X-band communications to the Spanish military.

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) system will collate and disseminate data from satellite systems and is anticipated to be operational by 2008. It will support objectives linked to the European Security and Defense Policy, such as early warning, rapid damage assessment in natural disasters, surveillance, and support to combat forces.[86]

In addition, the Galileo satellite navigation program, initiated in 1999 and jointly funded by the EU and the ESA, will provide location, navigation, and timing capabilities.[87] Galileo is intended to operate principally for civil and commercial purposes, but will have a dual military function. The fact that the ESA, founded with a mandate to launch only peaceful space missions, has recently opened a Space Security Office, is also indicative of the changing military space landscape in Europe.[88] EU states already spend a total of about $1.3 billion per year on military space activities, largely through the national satellite communications and reconnaissance programs discussed above.[89]

### *China*

China does not maintain the same separation between civil and military space programs as do many other states. Officially, its space program is dedicated to science and exploration.[90] Leadership of the space program is provided by the Space Leading Group, whose members include representatives from several government bodies, including three senior officials of bodies that oversee the defense industry in China.[91] Thus, although the Chinese military's role in the space program is unclear, the space program is certainly dual-use in nature.

China began working on space imagery in the mid-1960s, launching its first reconnaissance intelligence satellite in 1975.[92] It has 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."[93] Today, China maintains two Zi Yuan series satellites in LEO for tactical reconnaissance and surveillance.[94] China is believed to be purchasing additional commercial satellite imagery from Russia to suit its intelligence needs.[95]

Chinese military satellite communications are believed to be provided by the Feng Huo series satellite, officially known as ChinaSat-22. Officially referred to as a civilian communications satellite, the ChinaSat-22 is thought to enable "theatre commanders to communicate with and share data with all forces under joint command" through C-band and UHF systems.[96] China also operates a pair of Beidou navigational satellites designed to augment the data received from the US GPS system and to enable China to maintain navigational capability in the face of US efforts to deny GPS services in times of conflict (see Civil Space Progams and Global Utilities).[97]

### *Israel*

Israel operates a dual-use Eros-A imagery system, which is capable of providing images with a resolution of about 1.8 meters.[98] Israel also operates the military OFEQ-5 system, which provides both panchromatic and color imagery at resolutions of less than one meter for reconnaissance and surveillance purposes.[99] The Israeli Ministry of Defense is managing four satellite programs scheduled for completion in 2008. OFEQ-6 and OFEQ-7 will provide more advanced imaging satellites. TechSAR will be a synthetic aperture radar technology demonstrator, and a military version of the Amos-2 commercial communications satellite will also be developed.[100] Israel's programs reflect an interest in exploiting space systems in support of terrestrial military operations, including operational and tactical level missions. This has been demonstrated recently by the change of name of the Israeli Air Force to the Israeli Air and Space Force.[101]

### *South Asia*

India maintains the Technology Experimental Satellite, which provides images with resolution between one and 2.5 meters. India also operates a remote sensing ocean satellite, which was deployed in 1999.[102] Pakistan's space-based capabilities are not assessed to be as advanced as those maintained by India. Pakistan operates the Badar 1 multi-purpose satellite, and is currently developing the Badar 2.[103] While India and Pakistan clearly seem intent on developing space systems capable of supporting military operations, significant progress in this area remains a longer-term objective.

### *East Asia*

Japan operates the commercial Superbird satellite system, which also provides military communications. It has two reconnaissance satellites, one optical and one radar, which it launched in 2003 following growing concerns over North Korean missile launches.[104] A second launch effort later in 2003 resulted in a high-profile failure of its indigenously developed H-2 rocket.[105] The manufacturer of the optical reconnaissance satellite, Mitsubishi, is also a partner in the imaging company IKONOS.[106]

South Korea operates the Kompsat-1 satellite, which provides imagery with a resolution of 6.6 meters "sufficient for [military] mapping although not for military intelligence collection."[107] It also bought 10 Hawker 800 series satellites from the US, which South Korea has operated for signals intelligence since 1999.[108] Finally, South Korea maintains the KITSAT-3 experimental satellite, which was developed domestically beginning in 1995, and delivered in 1999.[109] In December 2003, South Korea announced intentions to increasingly use space for military purposes, and the creation of an Air Force Space Command.[110]

This growth in the number of new actors developing military space capabilities has been facilitated by commercial actors such as the UK's Surrey Satellite Technology Ltd., which has alone enabled nine states in the last 12 years to develop and deploy their first satellite with various communications and remote sensing capabilities, all using foreign launchers (from Russia and Europe in particular).[111] Similarly, by using off-the-shelf components and limiting satellite functions to specific tasks, certain satellite systems are being made smaller and lighter, improving deployment timelines and decreasing total system and launch costs. Not only does this increase the responsive capabilities of the existing space powers, but it also increases the ability of less affluent states to exploit space for military support purposes. Moreover, actors can increasingly obtain commercial space products that have significant capabilities to support terrestrial military applications. A good example of this is the wide availability of meter-resolution satellite imagery from companies such as IKONOS, SpaceImaging, and Keyhole.

## 2004: EU moves forward with Galileo and GMES programs

In Europe, the EU made progress with several states regarding their participation in the Galileo system, resolving conflict over the system's radio frequencies, and engaging new states such as the Ukraine and Israel in the development of the system (see Civil Space Programs and Global Utilities). The European Commission adopted an action plan for the GMES project in February, which details management and funding strategies. Program planners continue to expect operational capacity by 2008.[112]

### 2004: Setbacks for Israel's OFEQ reconnaissance satellite program

In July 2004, it was reported that "tens of millions of dollars" could be cut from Israel's military satellite program. This was expected to affect the OFEQ-6 and OFEQ-7 remote sensing satellites, the TecSAR synthetic aperture radar technical demonstration planned for 2006, and the Milcom-1, a secure, encrypted communications satellite intended for launch in 2007. An unnamed source within the Israeli defense industry was cited as saying that the cuts could effectively "put an end to most of Israel's satellite programs."[113]

The launch of Israel's OFEQ-6 reconnaissance satellite failed in its third stage on 6 September 2004, leaving Israel, according to some, with a strategic reconnaissance gap at a time when it is concerned about activities in Iran. The day after the failure, the Israeli Army announced that it intended to replace the satellite.[114] In February 2004, it was reported that Israel was contemplating leasing its OFEQ-5 satellite with a resolution of 0.5 meters. Israeli officials were quoted as saying that "sharp cuts in the Defense Ministry and the close strategic relations with New Delhi have led to an Israeli review of its policy" of not providing foreign access to its satellites.[115]

### 2004: Progress in French signals intelligence satellites

In December 2004, France launched four 120-kilogram signals intelligence satellites into a constellation know as Essaim. The Essaim program will cost approximately $123 million over three years, and is expected to test signal collection in several frequency bands over targeted areas. The satellite constellation will also test the ability to keep the satellites at specified distances from one another in orbit.[116] France also announced in 2004 that its Pleiades high-resolution optical imaging satellites are to be built without components originating from the US that are on the US State Department's list of satellite technologies requiring special export licenses (see Commercial Space).[117]

### 2004: China launches reconnaissance satellites; Japan, Thailand, Egypt, and Taiwan show increasing interest in similar capabilities

China launched a total of 11 satellites in 2004 — more than in any other year — of which three could be considered to have military reconnaissance applications.[118] The Japanese Prime Minister announced in August 2004 that he had requested $638 million for the launch of three 'information collection' satellites by March 2007. Two of the satellites were said to be optical, while the third is to collect radar imagery.[119] In a separate announcement, the Japanese government unveiled plans to launch an advanced spy satellite with a resolution of 0.5 meters by 2010.[120]

In July 2004, Thailand signed a multi-million dollar deal with the European Aeronautic Defence and Space Company (EADS) Astrium to provide Thailand's

first Earth observation satellite, expected to be used for intelligence and defense purposes.[121] In March 2004, it was reported that Egypt had authorized the launch of its first reconnaissance satellite, to be launched within two years, although Egyptian officials insisted the satellite was for civilian purposes.[122] *Jane's Defense Weekly* reported in January 2004 that the US was encouraging Taiwan to obtain a synthetic-aperture radar satellite in order to address intelligence "blind spots" over China.[123]

**FIGURE 5.6: Summary of non-US/Russia military satellites launched in 2004**[124]

| Satellite name | State | Partners |
|---|---|---|
| **Communications** | | |
| Estrela do Sul 1 | Brazil | Loral Skynet do Brasil |
| **Reconnaissance/ surveillance** | | |
| FSW-19/FSW-3 2 | China | |
| FSW 20 | China | |
| ZY-2C | China | |
| Ofeq-6 (failed) | Israel | |
| Helios 2A | France | European Aeronautic Defence and Space Company (EADS) Astrium, Délégation Générale pour l'Armement (DGA) |
| Essaim 1 | France | |
| Essaim 2 | France | |
| Essaim 3 | France | |
| Essaim 4 | France | |
| ELINT Myriade | France | EADS Astrium, DGA |

## Net assessment

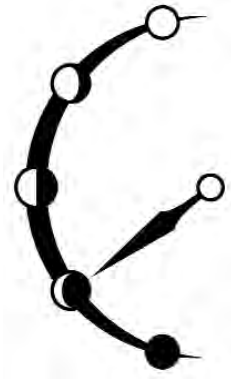
Developments in 2004 reinforced the trend in the growing number of new states developing military space capabilities to support terrestrial military operations. This growth in actors accessing and using space is potentially positive for space security to the extent that it expands the number of stakeholders with interests directly engaged by space security dynamics. As relatively weaker space actors, these states may see the advantages of a rules-based approach to resolving space security dilemmas. However, the proliferation of actors using space support for terrestrial military operations could well stimulate a corresponding interest in space negation capabilities designed to offset the advantages military space systems offer.

The Galileo-GPS agreement in 2004 was a test run for what will be the increasingly recurrent issue of military systems' interoperability and reliability in coming years. More so than most other types of satellite systems, interference with satellite navigation systems could quickly degrade into international instability or conflict. The emergence of a second global navigation system highlights the positive and negative aspects of redundancy in space systems. On

the one hand, the development of system redundancy will help ensure the secure and sustainable use of space assets. On the other hand, systems with similar capabilities can end up competing for the same resources.

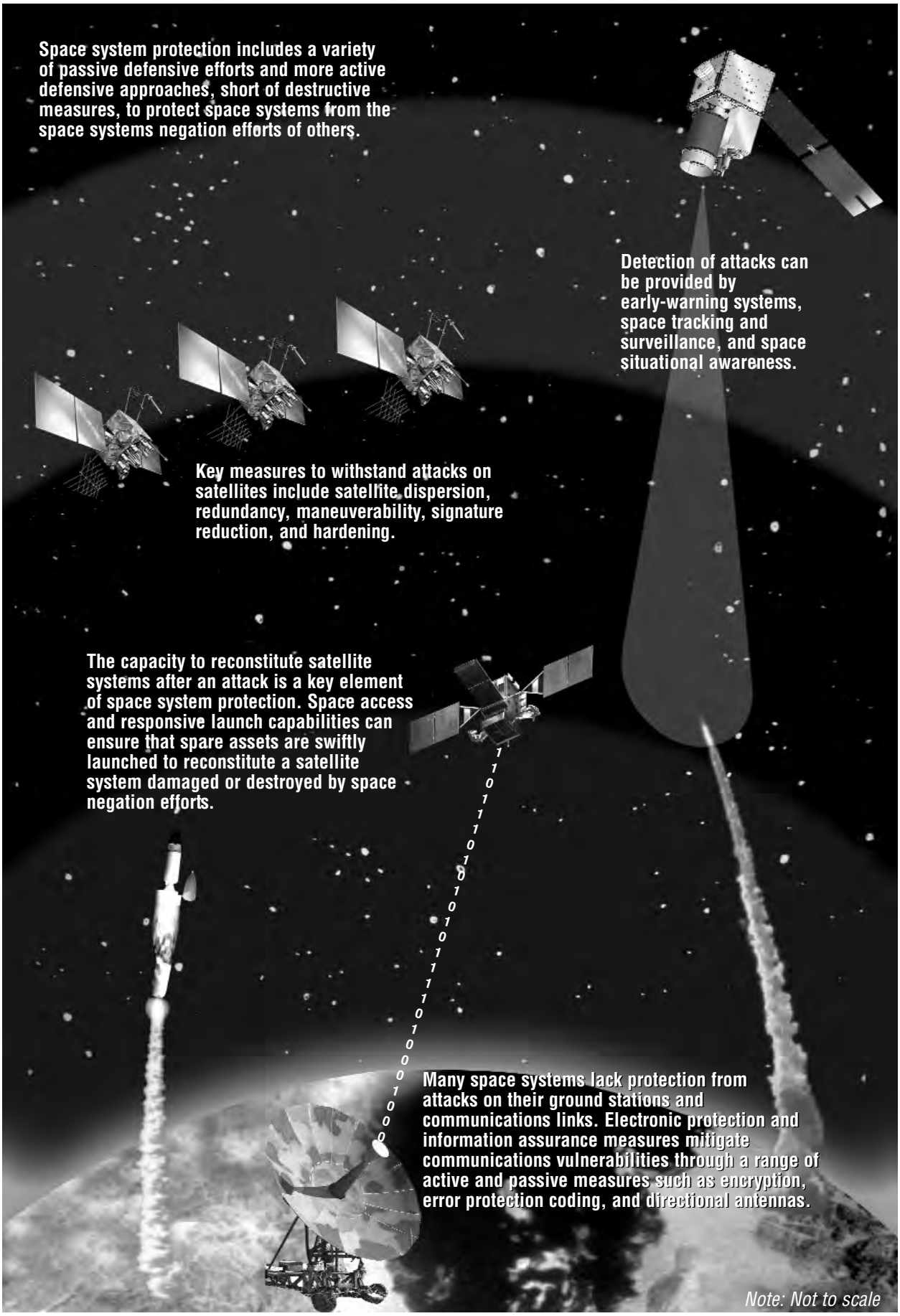
## Space Security 2004 Survey Results

| ***Overall, how have developments related to space support for terrestrial military operations in the past year affected space security?*** | | | | | |
|---|---|---|---|---|---|
| Space Security Survey (14 January-21 February 2005) | | | Space Security Working Group Survey (24-25 February 2005) | | |
| Enhanced | 6 | 5% | Enhanced | 0 | 0% |
| Somewhat enhanced | 24 | 18% | Somewhat enhanced | 3 | 11% |
| Little or no effect | 33 | 25% | Little or no effect | 8 | 30% |
| Somewhat reduced | 51 | 39% | Somewhat reduced | 15 | 56% |
| Reduced | 16 | 12% | Reduced | 1 | 4% |
| Total | 130 | | Total | 27 | |



**A majority of Space Security Survey respondents and Space Security Working Group participants assessed that space security had been somewhat reduced, or reduced, in 2004 with respect to this indicator.**

The most common supporting argument for this assessment was that the growing importance of military space systems, combined with perceptions of their vulnerabilities, was driving a new space systems protection-negation dynamic which was undermining the sustainability of space security. While it was clear that a majority of expert respondents assessed that space systems had improved terrestrial military operations, a lack of transparency and trust between key military space actors remained a significant problem.


Space system protection includes a variety of passive defensive efforts and more active defensive approaches, short of destructive measures, to protect space systems from the space systems negation efforts of others.
Detection of attacks can be provided by early-warning systems, space tracking and surveillance, and space situational awareness.
Key measures to withstand attacks on satellites include satellite dispersion, redundancy, maneuverability, signature reduction, and hardening.
The capacity to reconstitute satellite systems after an attack is a key element of space system protection. Space access and responsive launch capabilities can ensure that spare assets are swiftly launched to reconstitute a satellite system damaged or destroyed by space negation efforts.
Many space systems lack protection from attacks on their ground stations and communications links. Electronic protection and information assurance measures mitigate communications vulnerabilities through a range of active and passive measures such as encryption, error protection coding, and directional antennas.
Note: Not to scale

# 6 Space Systems Protection

This chapter assesses trends and developments related to the research, development, testing, and deployment of capabilities to protect space systems from the potential negation efforts of other actors. These 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.

Both active and passive means can be used to provide three main types of space system protection: capabilities to detect space negation attacks; physical and electronic capabilities 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, for example anti-satellite (ASAT) systems, are considered by some as protection measures, these capabilities are addressed by the Space Systems Negation and Space-Based Strike Weapons chapters.

The ability to detect, identify, and locate the source of space negation attacks through surveillance and space situational awareness capabilities is critical to space protection, since it is important to know whether the failure of a space system is being caused by technical or environmental factors or the deliberate actions of an attacker. The ability to detect an actual attack is often a pre-condition for effective protection measures such as electronic counter-measures or simply maneuvering a satellite out of the path of an attacker.

The capability to protect satellite ground stations, communications links, and satellites themselves is dependent upon the nature of the space negation threat that such systems face. Negation capabilities are examined in more detail in the Space Systems Negation chapter, but in general terms they can include: cybernetic attack 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.

In the wake of a space negation effort, a critical space systems protection capability is the ability to recover from the attack in a timely manner by reconstituting damaged or destroyed components of the space system. Capabilities to repair or replace ground stations and re-establish satellite communications links are generally available, while 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 Impacts

Many space systems remain unprotected from a range of threats, assessed by some to include, in order of decreasing likelihood: (1) electronic warfare such as jamming satellite communications; (2) physical attacks on satellite ground stations; (3) dazzling or blinding of satellite sensors; (4) pellet cloud attacks on low-orbit imaging satellites; (5) attacks in space by micro-satellites; (6) hit-to-kill anti-satellite weapons; and (7) high-altitude nuclear detonations (HAND).[1] Growing awareness of the vulnerabilities of space systems has led actors to develop space system protection capabilities to detect, withstand, or recover from an attack. Assisted by the proliferation of space systems protection techniques and technologies, both the range of actors employing protection systems and the depth of their capability are increasing.

Space systems 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 security of access to, and use of, space. The ability to survive an attack can also help to deter negation attempts. Actors may refrain from what could prove to be futile and costly attacks on well protected space systems.

As noted in the Space Systems Negation chapter, the space security dynamics of space negation and protection are closely related. The use of protective measures to address space system vulnerabilities can, at times, offer a viable alternative to using offensive means to defend space assets. Given concerns surrounding space debris, passive defensive measures may offer more sustainable approaches to space protection challenges.

It is currently difficult to distinguish between satellite failures caused by environmental factors or a deliberate attack. This has led some experts to argue that greater space situational awareness is critical to improvements in space security.[2] However, the inherently dual-use nature of many space capabilities complicates this protection-negation dynamic. For example, it is largely impossible to distinguish a rocket carrying a satellite from one carrying a nuclear warhead.

Under some conditions, protection systems can have a negative impact on space security. Like many defense-oriented systems, they can stimulate an arms escalation dynamic by motivating adversaries to develop weapons to overcome protection systems. Robust protection capabilities could also reduce an actor's fear of retaliation, reducing their threshold for using space negation capabilities. Finally, space systems protection can in some instances increase the cost of space access and use, which can reduce the number of actors with secure use of space.

## Space Security Trends and Key 2004 Developments

### 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

As noted above, the ability to detect space negation attacks is critical to space protection since many satellite failures are caused by technical or environmental factors. Mounting effective protection efforts very often depends upon effective warning of attack, as well as a clear understanding of the parameters of the attack itself. Detecting attacks on satellite ground stations is not addressed in any detail within this trend assessment since this capability is available to almost all actors with some measure of conventional military capabilities. A general assessment of the capabilities of key space actors to detect a space negation attack is provided in Figure 6.1.

#### *Detecting rocket launches*

During the Cold War, the USSR and the US developed significant space-based early warning systems designed to detect ballistic missile and space rocket launches. These systems also provided some capabilities 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 an existing satellite. No other actors beyond the US and Russia currently have such capabilities, although France is due to launch two early warning satellites, Spirale-1 and 2, in 2008.[3]

The USSR launched its first space-based early warning Oko satellite in 1972 and had fully deployed the Oko system by 1982. To maintain a continuous capability to detect the launch of US land-based ballistic missiles, the system maintained 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. These four satellites have since been lost, and replaced by two satellites in HEO and one Geostationary Orbit (GEO) satellite. The system continues to operate in this configuration, which provides coverage of US intercontinental ballistic missile fields, albeit with reduced reliability.[4]

In 1991, Russia began launching US-KMO, a next generation early warning satellite system, using a mixture of GEO and HEO satellites. Since then, there have been six additional launches, and the program has been plagued by satellite malfunctions. Despite these setbacks, Russia seems determined to continue its development of US-KMO. In 1998, it completed construction of a new command and control station necessary to support the operation of satellites to be deployed over the Pacific.[5]

From the beginning of the space age, the US military has emphasized space protection as one of the key pillars of its space doctrine.[6] 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. The DSP system consists of four GEO satellites which, since its inception, have been progressively replaced with a total of 22 satellites of increasing capabilities.

The US is now building the Space-Based Infra-Red System (SBIRS)-High, and the Space Tracking and Surveillance Systems (STSS) to replace the DSP capabilities. These systems are capable of detecting and tracking ballistic missiles, and thus also ground-based kinetic-kill ASATs. In addition to ground stations, the SBIRS-High project will consist of four GEO satellites, a spare satellite, and additional sensors on two classified HEO satellites.[7] A Lockheed Martin-Northrop Grumman team was awarded a $2.16-billion contract to build SBIRS-High in 1996. By September 2002, this contract was valued at $4.18 billion, not including the cost of three of the five GEO satellites."[8]

The STSS under development by the US Missile Defense Agency aims to track missiles through all three phases of flight using a system of 20-30 sensor-satellites in Low Earth Orbit (LEO). In January 2002, the Congressional Budget Office estimated the cost through to 2015 at $14-17 billion.[9] In December 2004, the General Accounting Office estimated STSS cost through to 2011, before most of its satellites will be launched, to be $4.2 billion.[10]

### *Detecting ASAT attacks*

Most actors have a basic capability to detect a ground-based electronic attack, such as jamming, by sensing the interference signal of the attacker or by noticing the loss of communications with the system under attack. In the case of jamming, it is reasonable to assume that any actor operating a satellite will detect an interruption of signals from the satellite and most will be capable of detecting the interference signal itself. Many actors will also have the capability to use multiple sensors to geo-locate the source of jamming signals, which helps to determine whether the interference is intentional or not. In the case of spoofing, it is also reasonable to assume that all actors operating a satellite have some capability to detect an attack, since basic electronic error code checking routines are relatively simple to implement.

Directed energy attacks, such as laser dazzling or blinding, or microwave attacks, move at the speed of light, making it very difficult to obtain advance warning of such attacks. These attacks can be detected either by the loss of a data stream from optical or microwave instrumentation, or in the case of blinding, by detecting the energy beam prior to damage. One can also place on

board satellite-specific laser sensors which either detect the key laser frequencies or optical powers. Such capabilities could trigger a variety of protection means, such as automated mechanical shutters, which may be able to prevent damage depending on the sophistication of the attacker. Only US satellites are known to have such capabilities, and only Russia, France, 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 check whether a satellite is put into an orbit which could allow it to intercept/attack another satellite, thus gaining advance warning of a possible ASAT approach. Both the US and Russia have a limited ability to do this through their space surveillance capabilities (see The Space Environment). Better still would be the ability to constantly observe the motions of all satellites and look for hostile maneuvers amongst any of them towards others. No space actor currently has such capabilities.

Another approach would be to place sensors on every satellite that would allow the detection of nearby satellites and negation efforts. While no actor has fully developed these capabilities, the US Radio Frequency Threat Warning and Attack Reporting (RFTWARS) program aims to develop a light-weight, low-power radio frequency sensor suite to attach to individual satellites to provide situational awareness.[11] The US is also developing capabilities for individual spacecraft to detect enemy space negation attempts 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 to enable the timely employment of defensive responses. It is anticipated that this can be accomplished by utilizing or leveraging existing technologies, data, and sensors.[12]

The detection of a HAND can be undertaken by using gamma ray/X-ray/neutron flux or optical flash detectors in Earth 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 of satellites to detect nuclear tests in order to monitor compliance with the 1963 Limited Test Ban Treaty. Subsequently such instruments were integrated on to the DSP early warning satellites and the Global Positioning System (GPS) satellites.[13] The USSR integrates nuclear detonation warning sensors onto its GLONASS satellites. Beyond these capabilities, actors in direct line of sight would clearly see a HAND, but not likely in time to activate protection measures, such as shutting down sensitive satellite electronics to protect them from electromagnetic pulse effects.

**FIGURE 6.1: Capabilities of key actors to detect an attack on a *satellite system***

| Category | Attack capability | China | EU | India | Israel | Japan | Russia | US |
|---|---|---|---|---|---|---|---|---|
| Electronic | Jamming | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Conventional | Space-based ASAT | | | | | | ■ | ■ |
| | Ground-based ASAT | | □ | | | | ■ | ■ |
| Directed energy | Laser dazzling /blinding | ? | ? | | | | ? | ■ |
| Nuclear | HAND | ■ | ■ | ■ | ■ | ■ | ■ | ■ |

**Key:**
■ = Some degree of capability
□ = Under development
? = Unclear from open source literature

## 2004: US launches DSP satellite and allocates money for RAIDRS

Developments in 2004 were largely consistent with this trend. On 14 February 2004, the US launched its 22nd DSP satellite into GEO, the ninth third-generation DSP vehicle. This maintains US capability to detect the launch of what could be ground-based kinetic ASAT attacks. The RAIDRS attack detection system program received $6.6 million in FY2004 and requested $16.4 million for FY2005.[14]

## 2004: US begins restricting availability of satellite orbital information

On 24 November 2004, the US Defense Authorization Act included restrictions on the provision of satellite orbital information to other actors (see The Space Environment).[15] While this move appeared to be aimed at improving the security of US space systems, this will make it more difficult for space actors other than the US to maintain space situational awareness. This could also motivate other actors to devote greater attention to developing and establishing their own space surveillance networks.

## Net assessment

Overall, the progressive development of capabilities to detect space negation attacks suggests an enhancement of space security. US and Russian early warning satellites providing surveillance of launch sites have long been assessed by experts as providing important crisis stability capabilities with related positive impacts upon space security. However, in contrast, space surveillance capabilities remain somewhat underdeveloped. Even the most advanced US capabilities in this area are currently based on a spot check system, and not continuous scanning. Russian space surveillance systems have even more limited capabilities (see The Space Environment).

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

As noted above, satellite ground stations and communication links are the most likely targets for space negation efforts since they are vulnerable to a range of widely available conventional and electronic warfare threats. However, it is also the case that satellite communications can usually be restored and ground stations rebuilt for a fraction of what it costs to replace a satellite. Military satellite ground stations and communications links are generally well protected, whereas civil and commercial assets tend to have fewer protection features.

The vulnerability of civil and commercial space systems raises concerns, since a number of military space actors are becoming increasingly dependent upon commercial space assets for many applications. Many commercial space systems have just one operations center and one ground station,[16] leaving them potentially vulnerable to some of the simplest 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. Responding to these types of concerns, in 2002, the US General Accounting Office recommended that "commercial satellites be identified as critical infrastructure" (see Commercial Space).[17]

#### *Electronic protection*

Most, if not all, space actors are capable of providing effective physical protection for their satellite ground stations, should they wish to do so, within the general boundaries of their relative military capabilities. Thus, this chapter focuses upon 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 in both peace-time and during a conflict (see Space Systems Negation).

Satellite communications links require specific electronic protection measures to safeguard their utility. Unclassified information on these capabilities is difficult to obtain. However, 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 that increases the amount of interference which can be tolerated before communications are disrupted; (3) directional antennas that reduce interception or jamming vulnerabilities, or antennas which utilize natural or man-made barriers as protection from line-of-sight electronic attacks; and (4) shielding and radio emission control measures that reduce the radio energy which can be intercepted for surveillance or jamming purposes.[18]

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 which communicate data in short series of signals, or across a range of radio frequencies, to keep adversaries from 'locking-on' to signals in order 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 (4) nulling antenna systems (adaptive interference cancellation) which monitor interference and combine antenna elements to direct a beam back in the direction of the interference, designed to null or cancel the interference.[19] This latter technique is considered to be the most comprehensive anti-jamming technique yet developed.[20]

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, and some of these capabilities are now also available to other states with more advanced military communications systems. For example, US/NATO Milstar communications satellites use multiple anti-jamming technology, employing both spread-spectrum modulation and antenna side-lobe reduction. Adaptive interference cancellation is being developed for next generation satellites.[21] Through its Global Positioning Experiments project, the US is attempting to solve the problem of GPS jamming by developing airborne pseudo-satellites which provide higher powered GPS signals that can overpower jammers.[22]

### 2004: China and US developing 'jam-proof' satellite communications systems

In March 2004, China announced that its first anti-jamming satellite, a communications satellite, will be launched in 2005. A principle driver for this development was the October 2003 incident in which the Falun Gong blocked signals from the Sino Satellite Communications System (SINOSAT), preventing Chinese viewers from watching broadcasts of China's first manned space mission.[23]

### 2004: Advanced US nulling antenna completes testing

US (Northrop Grumman) completed testing of its uplink phased array antenna (nulling antenna) for the Advanced Extremely High Frequency defense communications satellites. This technology is among the most advanced and effective currently available to protect satellites from intentional and unintentional communications interference.[24]

### 2004: US Government report on protecting commercial satellites emphasizes ground-based threats

In March 2004, the US President's National Security Telecommunications Advisory Committee (NSTAC) published a study on current threats to commercial space assets. It emphasized that the key threats to the commercial satellite fleet are on the ground, in the form of attacks on ground facilities, from hacking computers, or possibly, but less likely, jamming. [25]

### Net assessment

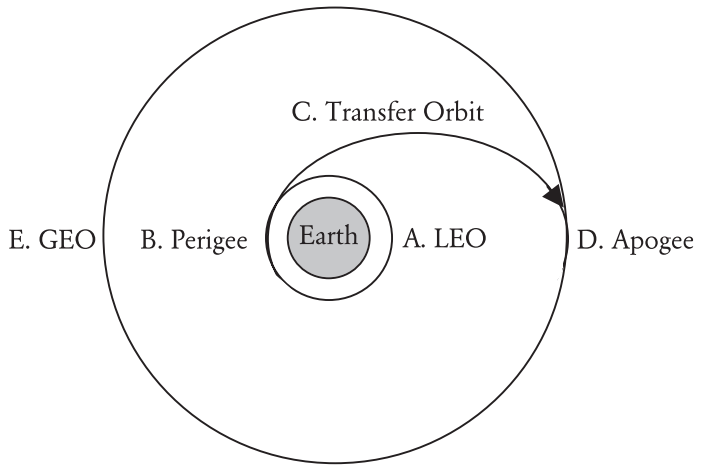
The continued vulnerability of ground stations and communications links to space negations efforts raises a number of space security concerns. The US NSTAC report underscored the degree to which the vulnerability of commercial space systems is also becoming a concern for some actors. Therefore, recent efforts by China and the US to examine and address ground stations vulnerabilities and improve the resistance of communications links to jamming can be seen as positive shift in this trend.

## TREND 6.3: Protection of satellites against some direct threats is improving, largely through radiation hardening, system redundancy, and greater use of higher orbits

Beyond attacks on satellite ground stations and communications links, the next most significant space systems protection challenge is the defense of satellites from direct attack with conventional, nuclear, or directed energy weapons. Here the primary source of protection for satellites is derived from the difficulties associated with attacking into and through the unique space environment. Conventional or nuclear weapons need to be launched into, and maneuvered through, space to fairly specific locations before they can attack satellites. Directed energy weapons must overcome atmospheric challenges and be effectively targeted on satellites, which are often at great distances and moving at very high speeds. A general assessment of the capabilities of key space actors to provide protection against direct threat satellites is provided in Figure 6.3.

A total of 28 actors are assessed to have a sub-orbital launch capability which could allow them to launch a conventional or nuclear payload into LEO for a matter of a few minutes before it would descend back into the Earth's atmosphere. A total of 10 actors have an orbital launch capability, with 9 of these actors having demonstrated the capability to reach GEO. The fact that LEO can be reached in a matter of minutes, and that GEO takes about a half a day to reach by completing a Hohmann transfer orbit (see Figure 6.2), underscores the unique protection dynamics associated with different orbits.[26] Not surprisingly, military systems are increasingly being placed into higher orbits such as Medium Earth Orbit (MEO), or GEO itself.

**FIGURE 6.2: The Hohmann Transfer Orbit**




A Hohmann transfer orbit is the most fuel-efficient way to transfer from one orbit to another. To transfer a vehicle traveling in Low Earth Orbit (LEO-Point A) around the Earth, to a higher Geostationary Orbit (GEO-Point E), at Point B (the so-called point of perigee), an engine thrust from the vehicle enlarges the orbit. The vehicle will then move in the transfer orbit (Point C). At the so-called point of apogee (Point D), an engine thrust is used to further enlarge the orbit. This time, the vehicle will enter into GEO, thus completing the transfer. The duration of the transfer from LEO to GEO is about 12 hours.

The distances and speeds involved in satellite engagements can also be exploited to enhance satellite protection. Lower altitude orbits make it more difficult to detect satellites using 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 around 800 kilometers altitude, the predictability of orbits is limited to an error of approximately one kilometer, using readily available models. Conversely, higher operational orbits raise the power demands for terrestrial radars, leaving only optical systems capable of tracking satellites in altitudes beyond 5,000 kilometers. The selection of 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.

### *Protection against conventional weapons*

Efforts to protect satellites from conventional weapons such as kinetic hit-to-kill, explosive, or pellet cloud forms of attack begin with the assumption that it is more or less impossible to provide physical hardening, or armor, against such attacks because of the very high relative velocities of objects in orbit. However, as noted above, the protection of satellites from conventional weapons threats is assisted by the difficulties of attacking into, and maneuvering through, space. For example, attacks of the Soviet co-orbital ASAT system of 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. This can be exploited by the defending targeted satellite through evasive maneuvers which force an interceptor to expend valuable fuel and more time to re-orient its line of attack. While such maneuvers would 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 the face of natural orbital disturbances. Moreover, such a maneuver needs only to be large enough to avoid the weapons effects or target acquisition range of the interceptor.[27] No satellites are known to be designed to carry fuel specifically for such evasive maneuvers. The extra fuel for such a maneuver might represent 10-20 percent of the satellite cost.[28]

In addition, an interceptor is vulnerable to deception by decoys deployed from a target. This is particularly the case when the interceptor's sensors assume tracking functions apart from the general tracking systems. For example, the interceptor's radars could be deceived by the release of a cloud of metal foil known as 'chaff,' or its thermal sensors could be spoofed by devices imitating the thermal signature of the satellite.

These defender advantages can be enhanced through a number of general space protection measures, including use of higher orbits, dispersion, autonomy, redundancy, reconstitution, signature reduction, and the use of decoys or evasive maneuvers. Dispersion is a well-established practice within terrestrial conflict that can be applied to satellite operations. Redundancy in satellite design and operations offers a number of protection advantages. Since on-site repairs in space are not currently cost-effective, satellites tend to employ redundant electronic systems to avoid single point failures. Many GEO communication satellites are also bought in pairs and separately launched into orbit to provide system-level redundancy. Over the longer term, in-orbit repair and robotic servicing capabilities will likely further improve the survivability of space systems.

In general, to date there is little redundancy of commercial, military, or civil space systems, when compared to terrestrial military spheres. This is especially true of the space-based components, due to the large cost per-kilogram of launch. Commercial satellites are, however, increasingly exploiting slack in the commercial telecommunications systems to allow for distribution and redundancy even compared to military systems.

With greater dependency on space systems, the motivation for redundancy is increasing. China, the EU (in partnership with others), and Japan are each 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 to some degree, since the loss of one satellite might reduce service reliability but not destroy the entire system. Second, these different but often interoperable systems create redundancy of entire navigation systems, so that the same actor may be able to rely upon two separate systems (see Civil Space Programs and Global Utilities).

Higher orbits can also be utilized to take advantage of lengthier 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 has begun to recognize and utilize the benefits of higher orbits, and slowly other space actors are following suit.

### *Protection against nuclear attack*

Since all current nuclear weapons-capable states also have sub-orbital space access, the capability to carry out a HAND attack is at least within the capability of this group of actors. While unhardened satellites are quite vulnerable to the effects of nuclear weapons, there are three general measures that can be used to protect satellites from nuclear weapons: radiation hardening; electromagnetic pulse (EMP) shielding; and, scintillation and blackout avoidance.[29]

Radiation hardening measures enable 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 for many satellites are particularly vulnerable to radiation effects, and can be replaced by nuclear reactors, thermal-isotopic generators, or by 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.[30] 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 which will prevent transmission of EMP radiation to interior components; (3) the use of grounding straps and surge arresters to maintain surfaces at the same electrical potential; and (4) the use of microwave filters to 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 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 global 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 nuclear survivability of the USSR's space capabilities from nuclear attack. Both the US and Russia have significant protection from HAND on their military assets. Military satellites of the UK and France also have radiation and EMP hardening. It is not clear from open sources whether or not China, India, or Israel employ such measures.

Most commercial spacecraft have to install radiation-hardening to guarantee lifetimes (typically 15 years), and include automated switch-off and recovery modes which protect systems from natural radiation events, such as solar flares. Most commercial satellites are not specifically protected from EMP effects that would result from a HAND. However, some components in commercial spacecraft are radiation-hardened by virtue of using components developed for military specifications, which may provide some limited protection. Any physical protection normally results in an increased cost and "it seems unlikely that the space industry would harden its satellites without significant prompting and subsidization from government entities."[31] 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 the satellite costs, while hardening against the EMP effects of a nuclear detonation can be up to 10 percent of the satellite costs.[32]

Beyond hardening, the US is also pursuing technologies to reduce the damaging long-term radiation belts caused by 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.[33] Such measures would reduce the probability of satellite malfunction in a HAND's aftermath.

### *Protection against a directed energy attack*

The simplest form of directed energy weapons make use of a ground-based laser directed at a satellite to temporarily dazzle, or disrupt, sensitive optics, such as optical imaging systems on a reconnaissance satellite, or other sensors, such as the infrared Earth sensors which are part of the attitude control system of most satellites. The attacker must be in the line of sight of the instrument, which limits opportunities for such attacks 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 are available to address these threats including: (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.

Highly advanced lasers capable of damaging other satellite subsystems through heating or shock require higher powers still. 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 that can be damaged by lasers.[34] The use of higher orbits provides significant protection from this type of attack since the destruction of a non-imaging satellite in GEO by laser heating could be prevented by modest shields because of the distances involved.[35] 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 the satellite's receivers.

In general, the US currently leads the way in both systems protection policy and technology to protect from directed energy attack. Commercial satellites, however, lack protection from laser or microwave attack. Beyond the US, only

the EU and Russia are assessed to employ means, such as higher orbits or spectral filtering on reconnaissance satellites, to provide protection from directed energy attacks.

**FIGURE 6.3: Protection capabilities of key actors to *withstand* an attack on a satellite system**

| Category | Attack capability | China | EU | India | Israel | Japan | Russia | US |
|---|---|---|---|---|---|---|---|---|
| Electronic | Jamming | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Conventional | Space-based ASAT | | □ | | | | ■ | ■ |
| | Ground-based ASAT | | □ | | | | ■ | ■ |
| Directed energy | Laser dazzling / blinding | ? | ■ | | | | ? | ■ |
| Nuclear | HAND | ? | ■ | | | | ■ | ■ |

**Key:**
■ = Some degree of capability
□ = Under development
? = Unclear from open source literature

## 2004: EU-US agreement on Galileo-GPS enhances prospects for global navigation system redundancy

Developments in 2004 continued to improve space systems protection. The interoperability of the GPS and Galileo systems agreed in an EU-US summit in February 2004 will ensure redundancy for users who will be able to combine signals from either system in a single receiver, and system level redundancy so long as the actors are allied.[36] Arianespace announced in October 2004 that it plans to celebrate the 50th anniversary of the launch of Sputnik by launching "a cluster of 50 nano-satellites for the International Astronautical Federation in 2007," demonstrating another step towards greater European capability to provide space systems redundancy.[37]

## 2004: US developing stealth satellite

The US National Reconnaissance Office is developing a satellite called Misty-3, which reportedly employs signature reduction technologies to make it less visible to other actors' space surveillance equipment.[38] It has been proposed that the stealth satellite technology may be similar in principle to that which the Strategic Defense Initiative Office (now the Missile Defense Agency) filed a patent for in 1994.[39] The satellite has run in to major cost overruns: "the previously undisclosed effort has almost doubled in projected cost—from $5 billion to nearly $9.5 billion."[40]

### 2004: US Government report emphasizes remote nature of direct attacks on satellites

In March 2004, the US President's National Security Telecommunications Advisory Committee report emphasized the difficulty of attacking the space-based components of space systems, noting that "attacks on satellites themselves could cause tremendous damage, but those types of attacks are less likely because they would be more expensive, technical, and difficult to execute." It also suggests that the threats to commercial assets are even more remote, arguing that, "Federal agencies must decide which additional mitigation techniques to require and whether their missions make it necessary to actively address the less likely and more expensive threats."[41]

### Net assessment

Overall, this trend towards increased protection for space systems through radiation hardening, system redundancy, and the greater use of higher orbits, can be seen as generally positive for space security, helping assure the secure uses of space in the face of space negation threats. However, these measures can also increase the cost of space access, sometimes quite dramatically, making it more difficult for certain actors to adopt these protection capabilities.

Furthermore, the drive for system redundancy can place greater pressures upon the allocation of space environment resources, potentially increasing competition over these scarce resources. Finally, it is noteworthy that while the transfer of assets to higher orbits may offer greater protection against ground-based attacks, the longer-term negative consequences of a direct conventional attack on satellites at these higher orbits could be quite significant, since space debris that is created at higher orbits is essentially permanent.

### TREND 6.4: Russia and the US lead in capabilities to rapidly rebuild space systems following a direct attack on satellites

In the wake of a space negation attack, the capability to rapidly rebuild space systems is critical to the protection of space utilities. It is assumed that any actor capable of operating a satellite is able to recover from an electronic attack since such attacks do not, in most cases, cause permanent damage. It is also assumed that all space actors have the capability to rebuild satellite ground stations. This assessment therefore 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. A general assessment of the capabilities of key space actors to recover from this type of attack is included in Figure 6.4.

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. Indeed, the general approach of the USSR/Russia has been to launch less expensive and sophisticated satellites more often to maintain its space system capabilities. Soviet-era pressure vessel spacecraft designs, still in use today, hold promise over Western vented satellite designs that require a period of out-gassing before the satellite can enter service.[42] This gives Russia, in principle, the capacity to deploy redundancy in its space systems at a lower cost. It should equally allow quicker space access to facilitate the reconstitution of systems. A significant fraction of current Russian launches, however, are of other nations' satellites, and Russia struggles to maintain existing military systems in operational condition. Thus, in practice, little redundancy is leveraged through this launch capability.[43]

**Figure 6.4: Protection capabilities of key actors to rapidly *recover* from an attack on a satellite system**

| Category | Attack capability | China | EU | India | Israel | Japan | Russia | US |
|---|---|---|---|---|---|---|---|---|
| Electronic | Jamming | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Conventional | Space-based ASAT | | | | | | ■ | ■ |
| | Ground-based ASAT | | | | | | ■ | ■ |
| Directed energy | Laser dazzling | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| | Laser blinding | | | | | | ■ | ■ |
| Nuclear | HAND | | | | | | | □ |

**Key:**
■ = Some degree of capability
□ = Under development

The US is leading in the development of next generation responsive space launch capabilities. The US Air Force Space Command's *Strategic Master Plan FY06 and Beyond* notes that, "An operationally responsive spacelift capability is critical to place timely missions on orbit assuring our access to space."[44] There are several programs underway that address this concern. The US Force Application from the CONtinental US (FALCON) program includes a Small Launch Vehicle sub-program, which is attempting to develop a rocket capable of placing 100-1,000 kilograms into LEO on 24-hours notice for under $5 million.[45]

The US Responsive Access, Small Cargo, Affordable Launch program aims to develop a responsive system to deliver 50-130 kilograms into LEO at any time, for under $20,000 per kilogram.[46] The US Space Maneuver Vehicle (SMV) is envisioned as a small, powered, reusable space vehicle, operating as an upper stage on top of a reusable launch vehicle or as a reusable satellite bus with a variety of available payloads. An operational SMV might include up to 550 kilograms of payload with a sub-72-hour turnaround time between missions.[47]

The US is also pursuing technologies to recover from a HAND. The aforementioned US High Frequency Active Auroral Research Program discussed in Trend 6.3, in addition to aiding the ability of satellites to withstand the long-duration radiation belt effects of a HAND, also allows the US to increase the probability of any replacement satellites being able to survive a normal lifetime in the face of persistent HAND effects.

In addition to developing responsive space launch capabilities, actors attempting to recover from a HAND attack must also be capable of addressing the challenges associated with operating in a space environment that may be hostile to satellites due to enhanced radiation in some orbits. While some actors may be able to simply use higher orbits, the capability to operate in an enhanced radiation environment is limited to actors such as the EU, Russia, and the US that have developed radiation-hardened satellites.

## 2004: Progress in Russian and US responsive lift capabilities

2004 saw developments which could affect the rapid reconstitution of space systems. On 18 February 2004, Russia conducted a large military exercise which included plans "to launch military satellites from the Baikonur cosmodrome in Kazakhstan and the Plesetsk launch pad in northern Russia – a simulation of the replacement of satellites lost in action."[48] The Plesetsk launch successfully carried a Lavochkin-built communications satellite into HEO, while the success of the Baikonaur launch is unclear, since it appears that no satellite was successfully orbited.[49]

On 17 September 2004, contracts worth a total of $41 million were signed between the Defense Advanced Research Projects Agency (DARPA) and Airlaunch, Lockheed Martin, Microcosm, and SpaceX to "mature their launch vehicle designs" and "conduct an early, responsive launch demonstration" for 'Phase II' of the FALCON technology development program.[50] On 5 October 2004, the company SpaceX, which plans to enable responsive space lift capabilities, "transferred the Falcon I flight vehicle (not to be confused with the DARPA FALCON program) to its launch complex at Vandenberg Air Force Base." The Falcon I is scheduled to be ready for launch in early 2005.[51]

On 9 January 2004, Russia and Kazakhstan signed an agreement to extend Russia's lease on Baikonur launch site until 2050. "Baikonur currently launches all missions to the International Space Station. The site ensures Russian redundancy of launch sites and is Russia's only facility for launching manned space flights."[52]

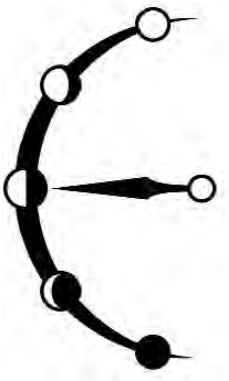
## Net assessment

Developments in 2004 tended to reinforce the existing trend of US and Russian leadership in the development of responsive launch capabilities. These

capabilities have the potential to improve space security for these actors by helping to assure the continued use of space through the timely reconstitution of space systems. However, it should be noted that certain responsive launch technologies are also dual-use capabilities that can be used to support space systems negation efforts, and in this sense have the potential to exert a negative effect on space security.

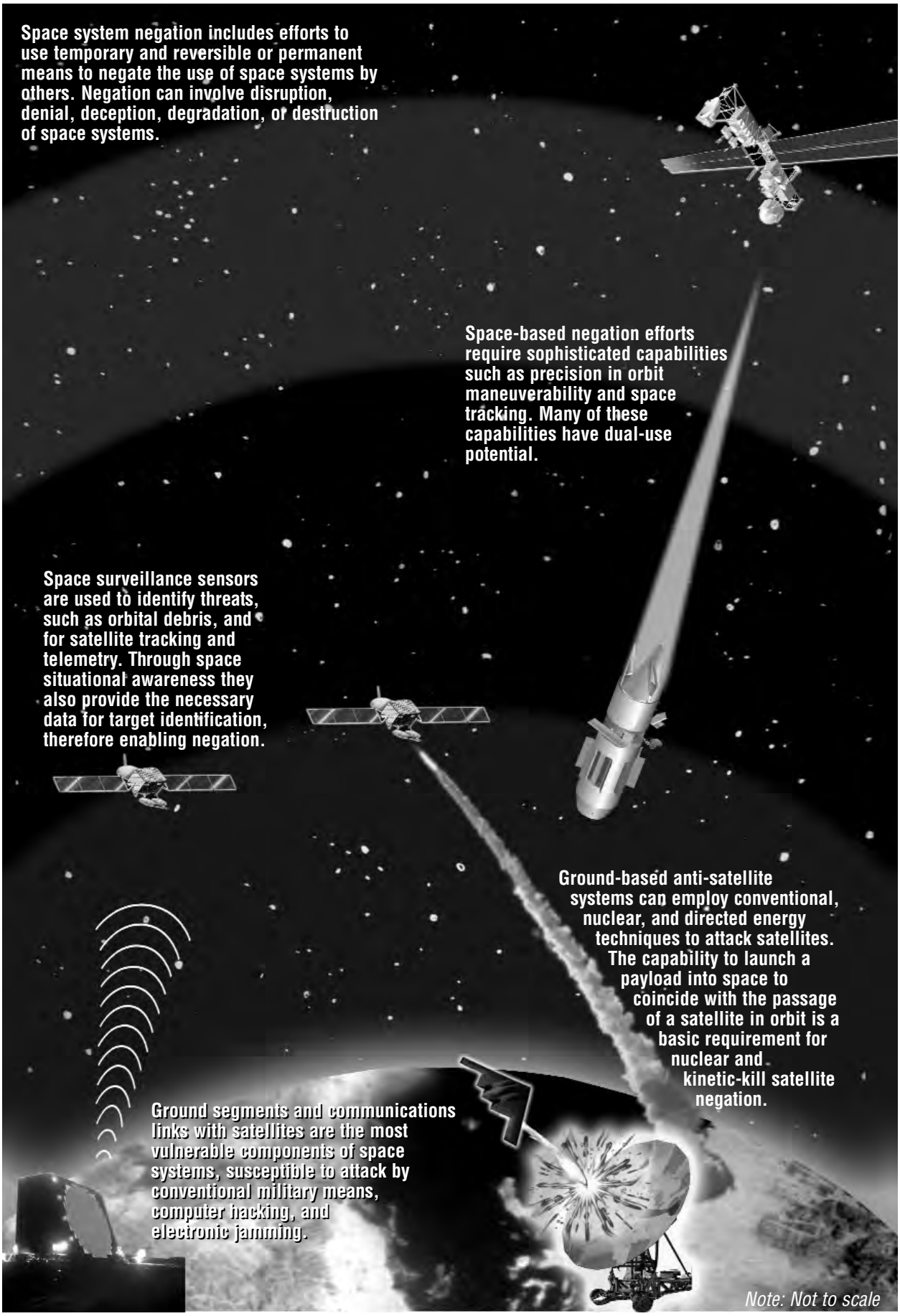
## Space Security 2004 Survey Results

| ***Overall, how have developments related to space system protection in the past year affected space security?*** | | | | | |
|---|---|---|---|---|---|
| Space Security Survey (14 January-21 February 2005) | | | Space Security Working Group Survey (24-25 February 2005) | | |
| Enhanced | 1 | 1% | Enhanced | 0 | 0% |
| Somewhat Enhanced | 24 | 21% | Somewhat Enhanced | 12 | 44% |
| Little or No Effect | 68 | 59% | Little or No Effect | 11 | 41% |
| Somewhat Reduced | 17 | 15% | Somewhat Reduced | 4 | 15% |
| Reduced | 6 | 5% | Reduced | 0 | 0% |
| Total | 116 | | Total | 27 | |



**A majority of Space Security Survey respondents assessed that there was little or no effect on space security in 2004 with respect to this indicator, while the largest number of Space Security Working Group participants assessed that space security had been 'somewhat enhanced.'**

Several expert respondents made the point that this positive assessment was justified by a growing awareness of the need for protection capabilities, coupled with enhanced capabilities to resist jamming of communications links. A number of expert respondents argued that threats to satellites were being inflated. Most agreed that there was insufficient effort being focused on efforts to protect satellite ground stations from attacks, where vulnerabilities are greatest. Experts frequently noted concerns associated with a nuclear attack in space related to the announcement by North Korea that it now possesses nuclear weapons.


Space system negation includes efforts to use temporary and reversible or permanent means to negate the use of space systems by others. Negation can involve disruption, denial, deception, degradation, or destruction of space systems.
Space-based negation efforts require sophisticated capabilities such as precision in orbit maneuverability and space tracking. Many of these capabilities have dual-use potential.
Space surveillance sensors are used to identify threats, such as orbital debris, and for satellite tracking and telemetry. Through space situational awareness they also provide the necessary data for target identification, therefore enabling negation.
Ground-based anti-satellite systems can employ conventional, nuclear, and directed energy techniques to attack satellites. The capability to launch a payload into space to coincide with the passage of a satellite in orbit is a basic requirement for nuclear and kinetic-kill satellite negation.
Ground segments and communications links with satellites are the most vulnerable components of space systems, susceptible to attack by conventional military means, computer hacking, and electronic jamming.
Note: Not to scale

# 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 by other space actors. It also assesses the development of space situational awareness capabilities, including space surveillance, a key enabling factor for space systems negation, since tracking and identifying targeted objects in orbit is a prerequisite to most negation techniques.

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 against satellites themselves. Negation can be achieved through the application of cybernetic or electronic interference, conventional, directed energy (laser), or nuclear capabilities, used to carry out what are often referred to as the five Ds – deception, disruption, denial, degradation, and destruction.

Many space negation capabilities flow from the application of widely proliferated military capabilities and practices. These include conventional attack on ground stations, hacking into computer systems, jamming satellite communications links, or using false radio transmissions or simple camouflage techniques to conceal the location of military assets from space surveillance.

Space negation capabilities which involve attacks on satellites themselves require more sophisticated capabilities. With the exception of ground-based laser dazzling or blinding, a basic launch capability is required to directly attack a satellite, as are space surveillance capabilities 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 concepts include precision-guided kinetic-kill vehicles, conventional explosives, and specialized systems designed to put lethal clouds of metal pellets on the same orbital path as 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 longer-term effects to the Van Allen radiation belts which would adversely impact upon most satellites in Low Earth Orbit (LEO).[2]

## Space Security Impacts

Space systems negation capabilities are directly related to space security since they provide the ability to restrict the secure access to, and use of, space by other actors. This suggests that the space security 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 within military affairs, this space security negation-protection dynamic raises arms race and crisis stability concerns, as actors compete for the strategic advantages that space negation capabilities appear to offer.

Space negation-protection arms race dynamics could push actors to develop progressively more destructive negation means in order to overcome enhanced satellite defenses, eroding important distinctions that are currently made between military uses of space judged to be consistent with international law, and the more contested legitimacy of efforts to place weapons in space.

USSR 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 Space Security Laws, Policies, and Doctrines). Recent space war games have also underscored the crisis management challenges generated by space negation efforts focused on 'blinding' the strategic communications and attack warning capabilities of an adversary.[3]

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, micro-satellites 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.

Finally, it is noteworthy that the application of some destructive space negation capabilities, such as kinetic-kill ASATs, would generate space debris with the potential to inflict indiscriminate damage on other space systems and undermine the sustainability of space security over the longer term. Similarly, a HAND is also indiscriminate in its effects and would generate long-term negative impacts on space security. These concerns have led some experts to argue that space negation efforts may have a positive impact on space security, for example, if such efforts pre-empt the target actor from using space systems to inflict widespread and long-term damage to the space environment.

## Key Trends and 2004 Developments

### 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, both of which are susceptible to attack from widely accessible weapons and technologies. An attack on the ground segments of space systems with conventional military forces is conceivably the most likely space negation scenario. 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.

A number of electronic jamming incidents targeting media broadcasts by communications satellites have been reported in recent years, with the interruptions in US service blamed on Iran working within Cuba,[4] Turkey blocking Kurdish news broadcasts,[5] and the Falun Gong group in China.[6] 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, as the equipment was reportedly commercially acquired from a Russian company, Aviaconversiya Ltd.[7] Although these jammers interfere with the GPS signal in a limited area on the Earth and not the GPS satellites themselves, they do constitute space negation because they disrupt satellite communications.

The US appears to be the leader in developing advanced technologies to temporarily negate space systems by disrupting or denying access to satellite communications. Department of Defense (DOD) budget requests over the past several years have shown a steady allotment of funds for negation programs under the Counterspace line item, defined as having offensive purposes "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."[8]

Some $10.6 million was allocated in FY2003 to the Counter Satellite Communications System (CounterComm), intended to use electronic interference to jam satellite communications.[9] In 2003, funding for CounterComm was moved from the Advanced Component Development and Prototypes budget area under Space Control Technology, to the Engineering and Manufacturing Development budget line under Counterspace Systems, signaling a move beyond research and development with a view to having an operational system in FY2005.[10]

The US Space Control Technology budget has been steadily funded to "continue development and demonstration of advanced counter-communications technologies and techniques (…) leading to future generation counter-communications systems and advanced target characteristics."[11] The mission description for this program element notes that, "Consistent with DoD policy, the negation efforts of this program focus only on negation technologies which have temporary, localized, and reversible effects."[12]

### 2004: US deploys system to temporarily negate satellite communications

The trend of US leadership in developing technologies for temporary negation continued with the October 2004 report that a CounterComm system had been declared operational at the United States Air Force (USAF) 76th Space Control Squadron in Colorado. The system is designed to be mobile and "provide disruption of satellite communication signals in response to United States Strategic Command requirements."[13] A USAF spokesperson described the system's capacity: "A reversible effect ensures that during the time of need, the adversary's space-based capability to threaten our forces is diminished."[14]

### 2004: Release of US *Presidential Directive on Space-Based Positioning, Navigation and Timing Systems*

In December 2004, the US released a *Presidential Directive on Space-Based Positioning, Navigation and Timing Systems* which addresses security concerns regarding GPS uses. The Directive calls for development of capabilities to "deny to adversaries position, navigation, and timing services from the Global Positioning System, its augmentations, and/or any other space-based position, navigation, and timing systems, without unduly disrupting civil, commercial, and scientific uses of these services outside an area of military operations, or for homeland security purposes."[15] This new Directive is consistent with previous US efforts to develop the capability to negate the utility of GPS signals when it is deemed necessary to do so.

### Net assessment

The development and proliferation of space negation capabilities focused on attacks on ground stations and satellite communications links underscores the unique vulnerabilities of these key elements of space systems. The jamming of GPS signals during Operation Iraqi Freedom and interference with satellite communications during peace-time appears to be establishing a new set of practices which could have a negative impact on the sustainability of space security.

## 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 asteroid detection. 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. Canada, France, Germany, and Japan are all actively expanding their ground and space-based space surveillance capabilities.

The US is unique in the degree to which it explicitly links space surveillance with its space control doctrine and desire to achieve 'space situational awareness.' The 2001 *Quadrennial Defense Review Report* noted 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."[16] Space Control is defined by the 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."[17]

While the US Space Surveillance Network is the primary provider of space surveillance data to all space users, it has limited capabilities to provide real-time data collection. To address these limitations, the Space Situational Awareness Integration Office was created in 2002 within the USAF Space Command, with responsibilities to oversee the integration of space surveillance in order to achieve space situational awareness.[18] The utility of space-based surveillance assets to support these efforts was demonstrated by the US in the late 1990s through the Space Visible Sensor experiment.[19] Since then, the US has been planning to develop a 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."[20]

### 2004: US space-based space surveillance programs advance

In 2004, the US awarded Boeing and Ball Aerospace a $189-million contract to produce a "Pathfinder" SBSS satellite, set for launch in 2007.[21] However, Congress expressed some frustration over the slow progress on SBSS development, cutting $27 million of the $66 million requested for SBSS in FY2005. While program officers warned of a potential slip in the launch date because of these cuts, no loss in program capability was anticipated.[22]

In August 2004, the US began seeking proposals for its Orbital Deep Space Imager program.[23] Designed to operate in Geostationary Orbit (GEO), the objective of this system is to "provide a predictive, near-real time operating picture of space to enable space control operations."[24] The Rapid On-Orbit Anomaly Surveillance and Tracking system was provided with $5 million in FY2004 to proceed with development of light-weight optics, telescope and spacecraft design in order to provide low-cost space situational awareness capabilities.[25] The Deep View program received $9.5 million for FY2004 to develop a powerful W-band radar capable of detecting small objects in orbit.[26] The Space Surveillance Telescope program received $8.9 million in FY2004 to continue development of a ground-based optical system designed to identify faint objects in orbit.[27]

### Net assessment

The extent to which US advanced space surveillance systems are used to support space control capabilities raises concerns about the reactions of other space actors to these programs. Efforts to emulate US leadership in this regard would suggest a decline in space security as more actors compete for capabilities to effectively track and negate the satellites of other space-faring states.

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

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

***Conventional weapons*** – Launching a payload to coincide with the passage of a satellite in orbit is the fundamental requirement for a conventional ASAT capability. A total of 28 actors have demonstrated sub-orbital launch capabilities, with 10 of these actors possessing an orbital launch capability. With basic tracking capabilities, a payload of metal pellets could be launched into the path of a satellite by a modified Scud missile.[28] Kinetic hit-to-kill technology requires more advanced sensors to find the target and the capacity to maneuver an interceptor into its path. Targeting satellites from the ground using any of these methods is more cost-effective and reliable than space-based options.

**FIGURE 7.1: History of ground-based ASAT programs**[29]

| System | Actor | Development phase | Description of program |
|---|---|---|---|
| Bold Orion air-launched ballistic missile | US | 1959, single test | Air-launched ballistic missile passed within 20 miles of the US Explorer VI satellite |
| SAtellite INTerceptor (SAINT) | USAF | 1960-1962, idea abandoned in the late 1960s | 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 Army | 1962-1964 | Nike-Zeus nuclear-tipped anti-ballistic missile system employed as an ASAT against orbital vehicles |
| Program 437 | USAF | 1963-1975 | Nuclear-armed Thor ballistic missile launched directly into the path of the target |
| Co-orbital (IS) ASAT | USSR | 1963-1972, 1976-1982 | Conventional explosives launched into orbit near target, detonated when within range of one kilometer |
| Polaris submarine launched ASAT | 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 | Sary Shagan and Dushanbe laser sites reported to have ASAT programs[30] |
| Air-Launched Miniature Vehicle | USAF | 1982-1987[31] | 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[32] |
| MIRACL Laser | USAF | 1989-1990, tested in 1997 though not recognized as an ASAT test | Megawatt-class chemical laser fired at satellite to disable electronic sensors |
| Ground-Based Kinetic Energy ASAT | US Army | 1990-2004 | Kinetic-kill vehicle launched from the ground to intercept and destroy a satellite |

The US Army invested in ground-based kinetic energy ASAT technology in the late 1980s and early 1990s. Although the Army's Kinetic Energy (KE) ASAT program was terminated in 1993, some related research continued, and Congress granted funding for the KE ASAT in FYs 1996, 1997, 1998, 2000, 2001, and 2004.[33] In 2002 it was reported that program administrators estimated an on-orbit demonstration of the moth-balled system would cost $60 million.[34] Congress appropriated $7.5 million for the KE ASAT for FY2004 through the Missile Defense Agency's Ballistic Missile Defense Technology budget.

The US has intensified its efforts to deploy a ground-based ballistic missile defense system, with the budget for missile defense growing from $4.8 billion for FY2001 to $9.1 billion for FY2004.[35] The foundational technology of the current US ballistic missile defense system is the Exoatmospheric Kill Vehicle (EKV), a kinetic-kill vehicle to be launched from a ground-based interceptor missile.

Designed to employ infrared sensors to detect and collide with a ballistic missile in space during its mid-course flight, some experts assess that, with limited modification, the EKV could act as an ASAT.[36] With an interceptor capable of launching a kill-vehicle as high as 6000 kilometers, this system would likely have the capacity to attack satellites in LEO.[37]

***Nuclear weapons*** – A nuclear weapon detonated in space generates an electromagnetic pulse that is highly destructive to unprotected satellites.[38] The impact of a HAND was demonstrated during the US Starfish Prime test in 1962, which detonated a nuclear weapon at an altitude of 400 kilometers, damaging about one-third of satellites (both US and non-US) in LEO. 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. The current status of the system is unclear.[39]

China, the EU, India, Israel, Japan, Russia, Ukraine, and the US all possess space launch vehicles capable of launching a nuclear warhead into orbit, although placing weapons of mass destruction in orbit is prohibited by the Outer Space Treaty. North Korea, Iran, Pakistan, and Saudi Arabia possess medium-range ballistic missiles that could launch a mass equivalent to a nuclear warhead into outer space without achieving orbit.

There are eight states assessed to be nuclear-weapons capable, including China, France, India, Israel, Pakistan, Russia, the UK, and the US. North Korea has declared itself to be in possession of nuclear weapons.[40] Iran is suspected by some of pursuing a nuclear weapons program and has an active long range missile program.[41]

***Directed energy weapons*** – The ASAT potential of high-energy lasers has been extensively explored by the US and to a lesser degree by the USSR. As many as 30 states may already have the capability to use low-power lasers to degrade unhardened sensors on satellites.[42] In 1997, the US Mid-Infrared Advanced Chemical Laser (MIRACL) was test-fired against a satellite in a 420-kilometer orbit, damaging the satellite's sensors. Reportedly, it was not the mega-watt MIRACL laser, but a 30-watt laser used for alignment that actually damaged the target satellite's sensors.[43] This suggests that even a commercially available low-watt laser could be used to 'dazzle,' or temporarily disrupt, a satellite functioning from the ground.[44]

The Counter Surveillance/Reconnaissance System (CSRS), recently funded within the US counterspace program was reportedly designed to employ lasers to temporarily disrupt surveillance satellites by dazzling sensors. Official but sparse descriptions of the system note that CSRS would be a mobile system intended to temporarily counter space-based surveillance reconnaissance capabilities.[45] The program cost $20.4 million in 2003, and was expected to be operational in 2008.[46]

US directed energy weapons research is primarily supported through a USAF program element entitled Laser and Imaging Space Tech, for projects "examining satellite objects to assess vulnerability to laser radiation."[47] The US Space-Based Laser program, long conceived of as a constellation of as many as 20 space-based lasers to support boost-phase ballistic missile interception, was effectively canceled by the Missile Defense Agency in 2002.[48]

The Airborne Laser currently under development is central to plans for future Boost Phase Ballistic Missile Defense. Merging a mega-watt class chemical oxygen iodine laser with a Boeing 747-400 aircraft, the system is designed to destroy ballistic missiles in the early boost-phase.[49] This technology is also assessed to have ASAT capabilities. 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**

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

**Key**: ■ = Enabling capability

## 2004: US kinetic-kill vehicle technology developments

In August 2004, the first US EKVs – the kinetic-kill interceptors for the ground-based missile defense system – were delivered to Fort Greely, Alaska.[50] The EKV will use infrared sensors to detect ballistic missiles in mid-course and maneuver into the trajectory of the missile to ensure a hit to kill.[51] This technology could be applied to satellites in LEO, which have predictable paths and a closing speed similar to a ballistic missile in mid-course.[52] Earlier in 2004, Lockheed Martin was awarded a $760-million, eight-year contract for the development and demonstration of a miniature kill vehicle system.[53] The objective is to develop smaller, lighter, and cheaper kill vehicle technology to respond to decoys. These developments continue the trend toward increased availability of capabilities for ground-based space negation.

## 2004: First light for US Airborne Laser

A partnership between the Missile Defense Agency, USAF, Boeing, Lockheed Martin, and Northrop Grumman, the Airborne Laser project passed a significant test in 2004 when it achieved 'first light' in a November 2004 ground-based test of the chemical oxygen iodine laser.[54] Although the laser was not paired with the aircraft for testing, the successful laser test signaled the go-ahead for renewed aircraft flight testing. On 3 December, and again on 9 December 2004, a Boeing 747-400 freighter began a series of tests for flight re-certification, required because of modifications to the aircraft.[55] This system could have ASAT capability with modest modification, and signals a continuation of the trend of increasing availability of ground-based directed energy technologies with ASAT potential.

## 2004: Counter Surveillance/Reconnaissance System (CSRS) program cut

While the FY2005 budget request for CSRS was $53 million, both the US House and Senate advocated zero funding. Reasons for the funding cut are not clear, but the Senate Conference Report adds the note: "Subsequent to submission of the budget, the Air Force decided to cancel this program."[56] Reports suggest that the system would "use directed energy to temporarily blind or dazzle commercial or government owned imaging satellites."[57]

## 2004: Other actors develop enabling technologies for ground-based ASATs

Other actors, both commercial and governmental, have made recent advances in acquiring access to space, and thus the basic enabling technology for both ground-based direct ascent and space-based ASATs. In June 2004, SpaceShipOne of the American company Mojave Aerospace Ventures, became the first private manned spacecraft by successfully completing a test flight into

space on a sub-orbital trajectory. Repeating the test flight in October, SpaceShipOne won the $10-million Ansari X Prize, as the first privately funded company to launch the equivalent of three people to an altitude of 100 kilometers (generally recognized as the boundary of space) within two weeks (see Commercial Space).[58]

Early in 2004, the Iranian Defense Minister was quoted by news agencies announcing Iran's intentions to launch a satellite into orbit using indigenous launch capacity based on its extensive missile program.[59] Later reports suggested the launch vehicle would be a modified Shahab-3 missile carrying a 20 kilogram experimental satellite to an orbit of 250 kilometers.[60]

## 2004: Publication of US Air Force doctrine *Counterspace Operations*

Iraq's 2003 attempt to use GPS jammers during Operation Iraqi Freedom was considered by some as the first time an adversary challenged US dominance in space.[61] The August 2004 US Air Force Doctrine Document 2-2.1, *Counterspace Operations*, responded with recommended counterspace approaches, described as "preclud[ing] an adversary from exploiting space to their advantage (…) using a variety of permanent and/or reversible means."[62]

*Counterspace Operations* describes the planning and execution for such operations, including legal considerations and targets. On-orbit satellites; communications links; ground stations; launch facilities; command, control, communication, computer, intelligence, surveillance, and reconnaissance systems (C4ISR); or third-party providers are identified as potential targets for offensive counterspace operations. Among the tools for offensive counterspace operations, the document lists direct ascent and co-orbital ASATS, directed energy weapons, and electronic warfare weapons. USAF Doctrine Documents are part of a hierarchy of policy, doctrine, and strategy, including the foundational Air Force Doctrine Documents. Thus, *Counterspace Operations* must be considered in relation to Joint Publication 2-14, *Joint Doctrine for Space Operations* (see Laws, Policies and Doctrines).

## Net assessment

Developments in 2004 have reinforced the trend towards the development and proliferation of ground-based capabilities to attack satellites. The continuation of programs such as the US airborne laser and the actual deployment of US missile defense EKVs with dual-use ASAT capabilities raised significant space security concerns. The publication of US Air Force *Counterspace Operations* doctrine also reinforced efforts to legitimize the use of US space negation capabilities to deny other actors the freedom to access and use space.

This progressive development of US space negation capabilities combined with increasingly explicit USAF space negation doctrines could not only push the

US towards a more aggressive space negation posture, but could also provoke other states to aggressively develop their space negation capabilities. Furthermore, as past space systems negation tests have shown, even the testing of conventional or nuclear negation methods have the potential of causing longer term and indiscriminate damage to the fragile space environment.

### 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 negation technologies could be beneficial for a variety of civil, commercial, or non-negation military programs. However, as dual-use technologies, micro-satellites, 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 which are also enabling technologies for the development of space-based kinetic kill ASATs is provided in Figure 7.3.

Space-based weapons targeting satellites with conventional explosives, referred to as 'space mines,' could employ micro-satellites to maneuver near a satellite and explode within close range. Relatively inexpensive to develop and launch, and with a long lifespan, micro-satellite technology serves many useful purposes, but has dual-use potential as inexpensive space-based weaponry. China is investing in micro-satellite programs, a development that has been cause for some speculation about its interest in acquiring ASATs.[63] To date this work has not, however, been linked to a dedicated ASAT program.

The proliferation of micro-satellite technology has seen a wide array of new state, commercial, and academic actors engaging in satellite research and development. The partnership between China and Surrey Satellite Technology Ltd. of the UK saw the 2000 launch of the Tingshua-1 micro-satellite and companion Surrey Nanosatellite Application Platform (SNAP) nano-satellite to test on-orbit rendezvous capabilities.[64] China has pledged to contribute micro-satellites to the Disaster Monitoring Consortium, together with Algeria, Nigeria, Thailand, Turkey, Vietnam, and the UK (see Civil Space Programs and Global Utilities).[65] Canada's Microvariability and Oscillations of STars (MOST) micro-satellite hosts a space telescope and was a technology demonstrator for future space surveillance efforts.[66] A number of states employ micro-satellites for scientific remote-sensing and surveillance purposes, with no evidence of links to space weapons programs.

The US has a variety of ongoing programs developing advanced technologies that would be foundational for a space-based conventional ASAT program,

including maneuverability, docking, and on-board optics. The Experimental Spacecraft System (XSS) employs micro-satellites to test proximity operations, including autonomous rendezvous, maneuvering, and close-up inspection of a target. For example, XSS-10 was launched in 2002 and performed maneuvers within 40 meters of another satellite.

**FIGURE 7.3: Enabling capabilities of key actors for space-based kinetic-kill ASATs***

| | Space Actor | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Capability** | **China** | **EU** | **India** | **Israel** | **Japan** | **Russia** | **Ukraine** | **US** |
| **Space launch vehicles** | | | | | | | | |
| Land – Fixed[67] | X | X | X | X | X | X | X | X |
| Land – Mobile | L[68] | | L[69] | L[70] | | X[71] | L[72] | X[73] |
| Sea | L[74] | L[75] | | | | X[76,77] | X[78] | X[79] |
| Air | | | | | | D[80] | | X[81] |
| **Space tracking (uncooperative)** | | | | | | | | |
| Optical (passive) | X[82] | X[83] | | | X[84] | X[85] | | X[86] |
| Radar | X[87] | X[88] | | | X[89] | X[90] | | X[91] |
| Laser[92] | X | X | | X | X | X | X | X |
| **Autonomous rendezvous** | | | | | | | | |
| Cooperative | | D[93] | | | | X[94] | | D[95] |
| Uncooperative | | D[96] | | | | F[97] | | D |
| **Proximity operations** | | | | | | | | |
| Cooperative | | D[98] | | | | | | X[99] |
| Uncooperative | | D[100] | | | | | | X[101] |
| High-g, large-$\Delta$V upper stages | X | X | D | | X | X | X | X |
| Micro-satellite construction | X | X | D | X | D | X | D | X |

**Key:**
X = Existing capability
F = Flight tested capability
D = Under development
L = Latent capability

*This figure highlights enabling technologies for space-based kinetic-kill negation capabilities. This 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 is also the objective of NASA's Demonstration of Autonomous Rendezvous Technology spacecraft, relying on the Advanced Video Guidance Sensor and GPS to locate its target.[102] The

Defense Advanced Research Projects Agency (DARPA)'s Orbital Express program will develop on-orbit refueling and reconfiguring, servicing necessary for maneuvering a space-based ASAT.[103] These programs make use of smaller, lighter components and are consistent with a growing US emphasis on responsive space programs.

The German space agency's on-orbit servicing program is testing proximity operations and on-orbit maintenance of satellites. Germany's Technology Satellite for demonstration and verification of space systems 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." Its Spacecraft Life Extension System project plans a satellite 'tugboat' to keep satellites in-orbit beyond their intended lifespan.[104]

## 2004: Delays in US demonstrations of key enabling technologies for space-based ASATs

In 2004, the trend toward developing space-based ASAT technologies was mitigated by testing delays in several US programs slated to test key enabling technologies, particularly autonomous proximity operations and space-based kinetic-kill vehicles. The Demonstration of Autonomous Rendezvous Technology satellite, a NASA program with autonomous navigation capacity using an Advanced Video Guidance sensor and GPS, was scheduled for an October launch. A series of technical difficulties led to the postponement of the launch, planned for no earlier than March 2005.[105] The November 2004 launch of the Air Force's Experimental Spacecraft System-11 (XSS-11), the follow-on to the XSS-10, was intended to undertake a series of close-proximity tests, but was delayed without explanation.[106]

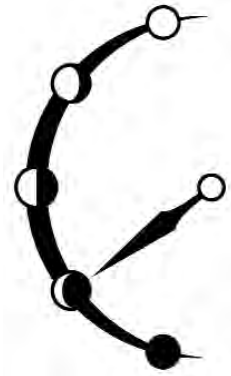
The Near-Field Infrared Experiment (NFIRE), designed to employ a kill vehicle to encounter a ballistic missile at close range with a sensor to record the findings, was scheduled to be tested in June 2004. The test, intended to "get a close-up view of a burning Intercontinental Ballistic Missile at conditions that are truly real world,"[107] was subsequently postponed. Despite opposition in the US House of Representatives, Congress maintained funding for the program.[108] Indications are that the kinetic-kill component of NFIRE, which has an inherent space-based ASAT capacity, has been cut from the program by the Missile Defense Agency (MDA).[109] There remains money in the MDA 2005 budget for the space-based interceptor test bed (tentatively scheduled for a 2011-2012 deployment) to test ballistic missile interception using small, light-weight kill vehicles from a space-based platform.[110]

### Net assessment

To the extent that they support the development of space systems negation capabilities, the development of dual-use capabilities, such as the German Technology Satellite or the US XSS-10, could have a negative impact on space security. Therefore, cuts in such programs as NFIRE, could be considered to have a positive impact on space security. The lack of transparency regarding the dual-use capabilities of some systems, such as micro-satellites, has tended to negatively impact space security by fueling speculation on the potential use of such systems for space negation functions.

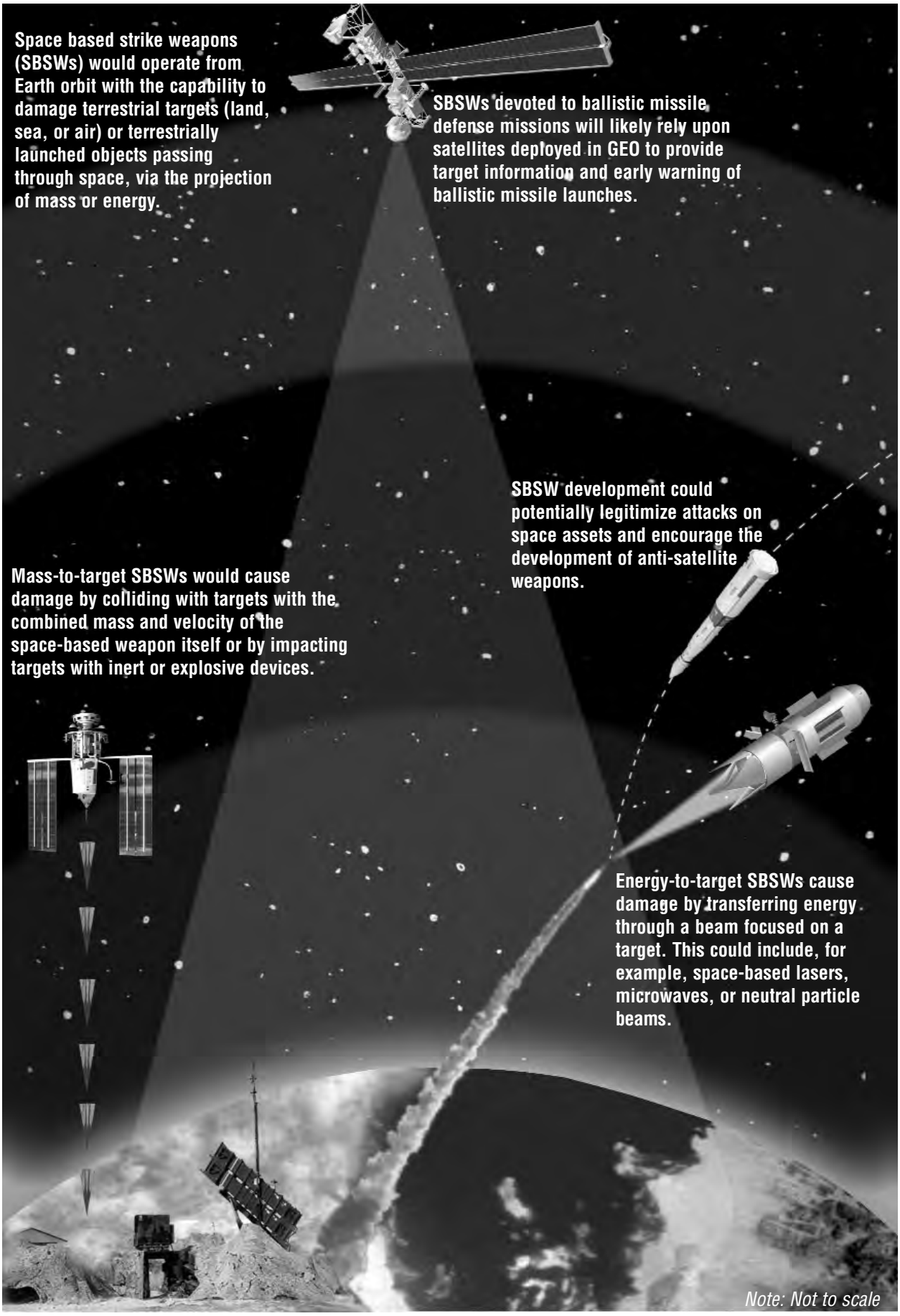
## Space Security 2004 Survey Results

| ***Overall, how have developments related to space system negation in the past year affected space security?*** | | | | | |
|---|---|---|---|---|---|
| Space Security Survey (14 January-21 February 2005) | | | Space Security Working Group Survey (24-25 February 2005) | | |
| Enhanced | 1 | 1% | Enhanced | 0 | 0% |
| Somewhat Enhanced | 13 | 11% | Somewhat Enhanced | 0 | 0% |
| Little or No Effect | 41 | 34% | Little or No Effect | 5 | 20% |
| Somewhat Reduced | 47 | 39% | Somewhat Reduced | 19 | 76% |
| Reduced | 17 | 14% | Reduced | 1 | 4% |
| Total | 119 | | Total | 25 | |



**A majority of Space Security Survey respondents and Space Security Working Group participants assessed that space security was somewhat reduced or reduced with respect to this indicator in 2004.**

Deployment of the US Counter Satellite Communications System was frequently cited as a significant development, as was continued pursuit of enabling technologies for permanent negation of space systems, including those developed through US ballistic missile defense programs. Several participants acknowledged the current US emphasis on temporary and reversible negation techniques, but noted that retaining the option of using space negation systems, particularly kinetic-kill weapons, negatively impacts space security. Some respondents noted that budget limitations on many US programs for negation enabling technologies limited the potential negative impact of these systems.


Space based strike weapons (SBSWs) would operate from Earth orbit with the capability to damage terrestrial targets (land, sea, or air) or terrestrially launched objects passing through space, via the projection of mass or energy.
SBSWs devoted to ballistic missile defense missions will likely rely upon satellites deployed in GEO to provide target information and early warning of ballistic missile launches.
SBSW development could potentially legitimize attacks on space assets and encourage the development of anti-satellite weapons.
Mass-to-target SBSWs would cause damage by colliding with targets with the combined mass and velocity of the space-based weapon itself or by impacting targets with inert or explosive devices.
Energy-to-target SBSWs cause damage by transferring energy through a beam focused on a target. This could include, for example, space-based lasers, microwaves, or neutral particle beams.
Note: Not to scale

# 8 Space-Based Strike Weapons

This chapter assesses trends and developments related to the research, development, testing, and deployment of space-based strike weapons (SBSW). SBSW are systems operating 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 weapons, often referred to as anti-satellite (ASAT) weapons, are addressed in the Space Systems Negation chapter.

Mass-to-target SBSW cause damage by colliding with a target with the combined mass and velocity of the very space weapon, or by impacting a target with inert or explosive devices. One mass-to-target SBSW concept is the US missile defense Space-Based Interceptor (SBI) which is designed to accelerate towards and collide with a ballistic missile as it passes through space at the top of its trajectory. Another mass-to-target SBSW concept is the long-rod penetrator, an orbital uranium or tungsten rod that would be decelerated from orbit and re-enter the Earth's atmosphere at high velocity to attack ground targets.

Energy-to-target SBSW, often called directed energy weapons, transfer energy through a beam designed to generate heat or shock sufficient 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 SBSW concept is the US missile defense Space-Based Laser (SBL). This SBL concept would attempt to use a satellite to direct an intense laser beam at a missile during its launch phase, attempting to heat it to the point where it would explode. This would require the SBL satellite to carry 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.

While no SBSW systems have yet been tested or deployed in space, the US and USSR did devote considerable resources to the development of key SBSW capabilities during the Cold War. Currently, the US continues to develop an SBI within the context of its missile defense program. In addition to assessing the status of these dedicated SBSW programs, this chapter also assesses efforts of space actors to develop key prerequisite technologies required for SBSW, even if they are not being pursued for SBSW purposes. It is generally assessed that only the most advanced space-faring states could overcome the technical hurdles to deploy effective SBSW within the foreseeable future.

## Space Security Impacts

SBSW capabilities can be used to directly impact all aspects of space security. An actor with an SBSW capability, such as a space-based interceptor, could use such a system to deny or restrict another actor's ability to access space by attacking their satellite and human space launch vehicles. Moreover, since some space-based interceptors may also be capable of attacking satellites in Low Earth Orbit (LEO), these SBSW systems could also be used to restrict or deny the use of existing space assets in LEO.

An actor with the capability to attack terrestrial targets from space would be able to threaten and even attack other actors with very little warning. This would undermine the existing legal and normative framework which restricts the uses of space to peaceful purposes. It would also directly threaten space security since actors would no longer enjoy freedom from space-based military threats.

The deployment of space weapons would most likely encourage the development of ASAT weapons and legitimize attacks on space assets, undermining existing legal and normative restrictions and prohibitions upon such attacks. Moreover, the testing and deployment of SBSW and ASAT systems in response to SBSW development would likely generate space debris, potentially undermining the sustainable use of space for all actors over the longer term.

Some have argued that SBSW may be necessary to protect their space systems from attack. Indeed, the protection of satellites and the missile defense potential of SBSW are two of the most commonly cited justifications offered in support of SBSW development. For example, as noted in the Space Systems Negation chapter, it has been argued that SBSW could be used to protect the security of space assets against nuclear space negation attacks that might inflict long-term and disproportionate damage to the space environment. While such arguments appear to offer some justification for SBSW development, they tend to ignore the fact that there are more cost-effective methods of accomplishing these objectives that also present fewer risks to space security.

## Trends and Key 2004 Developments

### TREND 8.1: While no SBSW has yet been tested or deployed in space the US is continuing the development of a space-based interceptor for its missile defense system

There have been no known integrated SBSW systems tested or deployed in space.[1] While space negation systems have been developed, such as the US and USSR ground-based and airborne ASAT systems conceived between the 1960s

and 1990s (see Space Systems Negation), there has not been any testing or deployment of space-to-Earth or space-to-missile systems.

The most advanced SBSW work during the Cold War was primarily focused on the development of mass-to-target weapons. In the 1960s, the USSR developed the Fractional Orbit Bombardment System (FOBS). This system was designed to deliver a nuclear weapon by launching it into LEO at about 135 to 150 kilometers, and then de-orbiting it after flying only a fraction of one orbit to destroy an Earth-based target.[2] A total of 24 launches were undertaken between 1965 and 1972 to develop and test the USSR FOBS, 17 of which were successful.[3] The system was phased out in January 1983 in compliance with the Strategic Arms Limitation Treaty II, under which deployment of FOBS was prohibited. It is believed that no nuclear weapons were orbited through the FOBS efforts.

The US and USSR were both developing energy-to-target SBSW systems in the 1980s, although today these programs have largely been halted. The US held underground tests of a nuclear-pumped X-ray laser in 1985 for the SBL. It also performed a Relay Mirror Experiment in 1990 which tested ground-based laser re-directing and pointing capabilities for the SBL.[4] In 1987, the USSR's heavy-lift Energia rocket launched a 100-tonne 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 orbital insertion failed.[5]

The USSR's neutral particle beam experiments were reportedly halted in 1985. The US SBL program was halted in 2000, and the SBL office closed in 2002.[6] However, some research and development continues for SBL through the US Missile Defense Agency (MDA). For example, over $120 million was allocated to Department of Defense (DOD) Directed Energy Programs in FY2003,[7] and other larger classified budgetary programs are suspected of continuing work on directed energy technologies.[8]

Under the Strategic Defense Initiative (SDI) in the 1980s, the US invested several billion dollars in research and development of an SBI concept called Brilliant Pebbles. While the SDI never developed and deployed a fully operational SBSW, the US did test the targeting and propulsion systems for the SBI. Research and development efforts in the US for SBI capabilities declined in the 1990s, but have been revived since 2000 through the MDA. The current US SBI concept was developed as a contribution to missile defense by providing a capability to intercept missiles as they pass through space at the height of their ballistic trajectory. Like ground-based ASAT systems, SBI capabilities could arguably also be used for offensive attacks on satellites in LEO.

One of the first key tests of US SBI-enabling technologies was the 1994 Clementine mission. This was a lunar mission to test lightweight spacecraft designs "at realistic closing velocities using celestial bodies as targets."[9] The US

Near-Field Infrared Experiment (NFIRE), scheduled for launch in 2006, was projected to include the key capabilities required for an SBI, including appropriate sensors, propulsion, and guidance units.[10] The US has also completed a phase one study for the Micro-Satellite Propulsion Experiment (MPX) which would include two two-stage anti-missile propulsion units — a key requirement for an SBI capability.[11]

Longer-term US plans include the deployment of a test-bed of three to six integrated SBI by 2011-2012, following tests in 2010-2011.[12] While such a system would have limited operational utility, it would constitute the first deployment of a weapons system in outer space. A summary of completed and planned US SBI-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 | Details |
|---|---|---|---|---|
| **Clementine** | Complete | 1994 | DOD & NASA | Testing lightweight sensors at realistic closing velocities using the moon and asteroids as targets |
| **NFIRE** | Under development | 2006 | MDA | Integrated SBI with lightweight sensors and propulsion unit |
| **MPX** | Planned | N/A | MDA | Two two-stage anti-missile propulsion units |
| **SBI test-bed** | Planned | 2010-2012 | MDA | Three to six integrated SBIs as a test-bed for a full SBI system |

Although much of the budget detail for SBI development is classified, the scale of funding for this effort can be estimated by examining allocations to a few key programs. For example, approximately $50 million per year is currently being spent on the development of the NFIRE satellite. A typical technology development and demonstration satellite of this type would cost about a few hundred million dollars for research, development, deployment, and operation. Therefore, while the annual SBI budget is only estimated to be about $100 million within a broader MDA budget of $10 billion, even at these funding levels, the timeline for developing the technical capabilities for SBI appears to be decreasing.

While the development of an integrated SBI vehicle may be possible within years as opposed to decades, building an SBI system with global coverage remains a significant challenge. A truly global system would require hundreds or even thousands of SBI vehicles in orbit, requiring a launch capacity about five to 10 times greater than the current US launch capacity.[13] An examination of the technical feasibility of an SBI system conducted by the American Physical Society estimated that launch costs alone for a system covering latitudes that included Iran, Iraq, and North Korea would likely exceed $44

billion.[14] The US Congressional Budget Office estimated the full cost of an SBI system with a similar coverage of the globe, but with the capability to intercept only slower, liquid-fueled ballistic missiles, would be $27-40 billion for a system that presumed considerable advances in mass reduction of kill vehicle components, and $56-78 billion without such advances.[15]

In summary, there have been no SBSW tested or deployed in space to date, although Cold War era SBSW 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 SBSW programs, especially the energy-to-target types. More recently, the US has pursued the development of SBI, although challenges remain to its completion.

## 2004: US MDA cuts NFIRE Kill Vehicle Interceptor

In February 2004, the MDA requested $68 million for FY2005-2006 for the development and deployment of the NFIRE satellite, due for launch in 2006 with both a sensor package and a kill vehicle.[16] The former would test lightweight infrared sensors for missile tracking. The latter was planned to complete intercept maneuvers using two test missiles, which it would approach at a range of 20 kilometers and 3.5 kilometers, demonstrating necessary attitude control, high-G thrust maneuvering, and autonomous missile tracking.[17] In the budget justification document, the MDA noted the FY2003 accomplishments relating to the development of NFIRE, including the integration and testing of "kill vehicle subcomponents in preparation for an FY2004 Development Testing."[18] The MDA planned developments in 2004 (with a budget allocation of $44 million) to include "Complete Kill Vehicle Ground Based Testing, Assemble, Integrate and Ground Test Flight Kill Vehicle and Initiate procurement for two (2) Multi Stage Boost Targets."[19]

In May 2004 the US Senate Armed Services Committee authorized funding for NFIRE, but added the condition that the test be conducted in a way to avoid intercepting the target.[20] In June 2004, however, the US House of Representatives cut funding for NFIRE.[21] By August 2004, the House of Representatives and the Senate settled to maintain funding for NFIRE at the requested amount. However, in August 2004, the MDA stated, citing technical difficulties, that the kill vehicle main thruster had been removed and the launch date was pushed back from the first to the last quarter of 2006, with test missile flybys moved to 2007.[22] Presently, NFIRE is planned to perform a test with a 20-kilometer flyby of one or two missiles to simulate a kill operation rather than separating from the mother spacecraft and performing an intercept operation on missiles further away from the mother craft. The kill vehicle sensor package, primarily intended for close up autonomous tracking, will remain on-board.[23]

## Net assessment

Despite past SBSW efforts such as the US Brilliant Pebbles program and Soviet particle beam experiment, the non-deployment of such weapons has had a positive effect on space security. It has kept the Earth free from space-based threats and has, through state practice emphasizing restraint, strengthened the international norm against the testing or use of SBSW. This trend continued in 2004. However, past Soviet and American programs did develop much of the prerequisite technologies for any eventual testing or deployment of SBSW, which remain a concern with respect to space security.

If carried out, the deployment of SBI would give the US the potential to deny other actors' secure access to space, since an SBI that can attack a missile can also attack a rocket carrying a satellite. This could potentially have a negative impact on space security by leading to an arms escalation dynamic. Furthermore, it would diminish freedom from space-based threats and break the current taboo against the deployment of weapons in space.

Some 2004 developments are cause for concern in this regard. Despite budget cutbacks, research into NFIRE suggests that the US MDA considers itself to be about two years of technological development away from being able to test what could be considered an integrated SBSW system. In related US developments, the MDA released a report in August 2004 that showed that the SBI effort could pose a debris threat to satellites in LEO, and that detailed discussions with civilian agencies regarding this issue have not been undertaken (see The Space Environment).[24]

## TREND 8.3: A growing number of countries develop an increasing number of SBSW precursor technologies, outside of SBSW programs

Due to the potentially significant effects of SBSW systems upon space security dynamics, it is important to assess the status of various prerequisite technologies that could enable the development of SBSW capabilities. The SBSW prerequisite technologies described below are simply dual-use. They are not related to dedicated SBSW programs, but are part of other civil, commercial, or non-SBSW military space programs. While there is no evidence to suggest that states pursuing these enabling technologies intend to use them for SBSW systems, they do bring these actors technologically closer to such a capability.

The advanced enabling capabilities listed in Figure 8.2 are those required for SBSW systems over and above basic space access and use capabilities, such as orbital launch capability, orbital transfer capability, satellite manufacturing, satellite telemetry, tracking and control, and mission management. Figure 8.2 also indicates which of these capabilities are required for major individual SBSW systems. This analysis is based on the characteristics of these weapons systems as widely described in the literature.[25]

**FIGURE 8.2: Advanced SBSW prerequisite capabilities**

| | Conventional | | | Nuclear | Directed energy | |
|---|---|---|---|---|---|---|
| **Capability** | SBI | Long-rod penetrators | 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 | ■ | ■ | ■ | ■ | ■ | ■ |
| Micro-satellite construction | ■ | | | | | |
| High-power laser systems | | | | | ■ | |
| High-power generation | | | | | ■ | ■ |
| Large deployable optics | | | | | ■ | |
| Precision attitude control | | | | | ■ | ■ |
| Precision re-entry technology | | ■ | ■ | ■ | | |
| Nuclear weapons | | | | ■ | | |

**Key:**
■ = Required
▲= Needed but not necessarily on the primary SBSW craft(s)

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 which require such capability. The EU has almost completed the development of this capability for its Automated Transfer Vehicle which will dock at the International Space Station.[26]

*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 Δ-V thruster* capability that enables a change in velocity required to maneuver in orbit to reach the target is needed for several different SBSW concepts. This is a relatively common capability that has been demonstrated by all actors with rocket technology, including the 10 states which have demonstrated orbital space access and the 18 that have demonstrated sub-orbital space access.

Accurate *global positioning* capabilities required for all SBSW concepts are possessed primarily by the US (with its Global Positioning System) and Russia (with 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, or the Japanese Quazi-Zenith Satellite System (see Civil Space Programs and Global Utilities). It is also noteworthy that many actors could make use of the global positioning afforded by the US and Russian systems, although access to the more accurate military frequencies of the satellite navigation systems is restricted. *Missile homing sensors* which provide real-time directional information during the missile homing phase required for SBI and SBL concepts, are a capability common to most advanced military powers, including the US, Russia, the EU, and Israel which have developed such systems for their ground-based missile defense capabilities. Japan is also currently developing this capability.[27]

Relatively extensive *global missile warning and missile tracking* capabilities, also required for SBI and SBL concepts, were developed by the US and the USSR during the Cold War (see Space Support for Terrestrial Military Operations). Early warning of missile launches is currently provided by the US Defense Support Program satellites and the Russian Oko satellites, and both states are currently working on upgrades and/or replacements for these systems. The US Space-Based Infrared System (SBIRS)-High and Space Tracking and Surveillance System are the most advanced in this regard (see Space Systems Protection). No other states currently have such capabilities, but France is developing two satellites called Spirale-1 and -2 for this purpose, that are due for launch in 2008.[28]

*Launch on demand* capabilities needed to maintain an effective global SBI system are provided by rockets with an operational readiness of less than one week. Russia currently leads in this capability with the shortest average period between launches, but it is not yet a true launch on demand system. The US is developing responsive launch capability through its FALCON – Force Application and Launch from CONUS (CONtinental US) program. Some commercial actors, in particular Space-X, are aiming to be able to provide more responsive and less expensive space launch, but no other states have such capabilities (see Space Systems Protection).[29]

*Micro-satellite construction,* which reduces the weight and increases the responsiveness of space-based interceptors, is also a key enabling capability for an effective SBI system. China, the EU, Israel, Russia, and the US have all launched micro-satellites, and several other states have launched a micro-satellite through the launch capability of another state. India is also developing micro-satellite capability.[30]

*High-power laser systems*, suitable 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 program. *High-power generation* systems for space, suitable for the SBL concept, in particular nuclear fission reactors which use thermoelectric converters to produce electricity, have been developed and deployed both by the US and Russia. For example, the US System for Nuclear Auxiliary Power-10A mission launched in 1965 had a 45 kilowatt thermonuclear fission reactor.

Between 1967 and 1988, the USSR launched 31 low-powered fission reactors in Radar Ocean Reconnaissance Satellites.[31] 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, have been developed by a number of states, including China, the EU, Russia, and the US, for military reconnaissance or civil astronomical telescope missions.[32] India, Israel, and Japan are all currently developing such capabilities (see Civil Space Programs and Global Space Utilities).

*Precision re-entry technology*, needed for long-rod penetrator and space-based munitions delivery concepts, has been developed by only those states that have developed a human spaceflight capability – China, Russia, and the US. The EU has this capability under development with its Applied Re-entry Technology program and through the joint US National Aeronautics and Space Administration-European Space Agency Crew Return Vehicle (X-38).[33] The Japan Aerospace Exploration Agency has some experimental re-entry vehicle programs.[34] Nuclear weapons-capable states have also developed precision re-entry technologies for their nuclear warhead re-entry vehicles.

Figure 8.3 provides an overview of the SBSW prerequisite capabilities possessed, or under development, by key space actors, as discussed above. Only actors with orbital access are included, since this is a prerequisite for all SBSW systems.

## 2004: Developments related to SBSW-enabling technologies outside the context of SBSW programs

On 22 March and 18 October 2004 respectively, Israel and the Ukraine joined the EU Galileo project providing the basis for their future access to a key high-precision satellite navigation capability.[35] French micro-satellites were launched in the joint civil-military Myriade micro-satellite program on 28 June and 19 December 2004 respectively.[36] On 24 October 2004, China announced a civilian space telescope mission which will demonstrate precision attitude control capabilities.[37] On 27 October 2004, France's Centre National d'Études Spatiales announced the development of a new re-entry vehicle program for civil space purposes (see Civil Space Programs and Global Utilities).[38] Finally, on 18 February 2004, Russia conducted a large military exercise which included launch on demand space plans "to launch military satellites from the Baikonur cosmodrome in Kazakhstan and the Plesetsk launch pad in northern Russia – a simulation of the replacement of satellites" lost in combat.[39]

**FIGURE 8.3: SBSW-enabling capabilities of key space actors**[40]

| | China | EU | India | Israel | Japan | Russia | Ukraine | US |
|---|---|---|---|---|---|---|---|---|
| **Advanced capabilities** | | | | | | | | |
| Precision position maneuverability | | □ | | | | ■ | | ■ |
| High-G thrusters | | | | | | | | □ |
| Large Δ-V thrusters | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| Accurate global positioning | □ | □ | □ | □ | □ | ■ | □ | ■ |
| Anti-missile homing sensors | | ■ | | ■ | □ | ■ | | ■ |
| Global missile tracking | | | | | | ■ | | ■ |
| Global missile early warning | | □ | | | | ■ | | ■ |
| Launch on demand | | | | | | ■ | | □ |
| Micro-satellite construction | ■ | ■ | □ | ■ | □ | ■ | | ■ |
| High-power laser systems | | | | | | | | □ |
| High-power generation | | | | | | (■) | | □ |
| Large deployable optics | ■ | ■ | □ | □ | □ | ■ | | ■ |
| Precision attitude control | □ | ■ | □ | □ | ■ | ■ | | ■ |
| Precision re-entry technology | ■ | ■ | | | | ■ | | ■ |
| Nuclear weapons | ■ | ■ | ■ | ■ | | ■ | | ■ |
| **SBSW** | | | | | | | | |
| Space-based laser | | | | | | (□) | | (□) |
| Space-based interceptors | | | | | | (□) | | □ |
| Long-rod penetrators | | | | | | | | |
| SB munitions delivery (conventional) | | | | | | | | |
| Neutral particle beam | | | | | | (□) | | (□) |

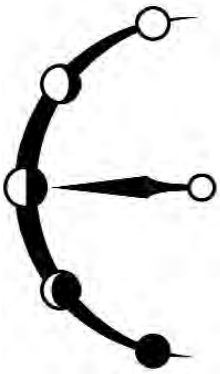
**Key:**
■ = Some capability[41]
□ = Capability under development
(□) = Past development
(■) = Past capability but discontinued

## Net assessment

The development of dual-use capabilities which also provide enabling technologies for SBSW systems continued in 2004 although there was no evidence that states were developing such capabilities for SBSW purposes. While the integration of such technologies into an SBSW capability could be very difficult and take many years, their development does bring states closer to an SBSW capability should a future decision be made to pursue it.

## Space Security 2004 Survey Results

| ***Overall, how have developments related to space-based strike weapons in the past year affected space security?*** | | | | | |
|---|---|---|---|---|---|
| Space Security Survey (14 January-21 February 2005) | | | Space Security Working Group Survey (24-25 February 2005) | | |
| Enhanced | 2 | 2% | Enhanced | 0 | 0% |
| Somewhat Enhanced | 8 | 7% | Somewhat Enhanced | 7 | 30% |
| Little or No Effect | 59 | 50% | Little or No Effect | 12 | 52% |
| Somewhat Reduced | 34 | 29% | Somewhat Reduced | 4 | 17% |
| Reduced | 16 | 13% | Reduced | 0 | 0% |
| Total | 119 | | Total | 23 | |



**A majority of Space Security Survey respondents and Space Security Working Group participants assessed that there was little or no effect on space security in 2004 with respect to this indicator.**

One of the most common comments supportive of a more negative assessment was related to the potential of SBSW to stimulate an arms escalation dynamic, in particular by encouraging the development of space systems negation capabilities by other states. Another frequently mentioned concern expressed by experts was related to the apparent determination of the US MDA to pursue the development and deployment of interceptors for a space-based anti-ballistic missile system. Others noted that the scale of US spending on SBSW was relatively modest. Many respondents welcomed the decision by the MDA to remove the kill vehicle on NFIRE, noting that this was a positive development with respect to space security.

# Endnotes

## Chapter 1

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## Chapter 3

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> there have been a number of reports in the press that have portrayed SSTL's commercial satellite business with PR China in a very misleading light (…) SSTL has carried out two micro-satellite projects for PR China. Both projects are entirely civil in nature and both have been executed strictly within export controls specifically approved for each project by the UK government (…) No propulsion technologies or know-how has been provided by SSTL to China and therefore the satellites supplied by SSTL are not able to be used either as 'ASAT' anti-satellite devices nor as a basis to develop such devices as claimed by some press reports.

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[41]The capabilities in each prerequisite technology can vary a great deal. The filled square only indicates that there is some capability.

# Annex A: Methodology

## Introduction

The objective of *Space Security 2004* and other volumes in the Space Security Index series is to provide an annual, evidence-based, and integrated assessment of the status of space security. So far the Space Security Index has completed three of phases of development: generation of a definition of space security; completion of *Space Security 2003* as a pilot project designed to test our methodology for assessing space security; and the completion of *Space Security 2004*, our first annual evaluation of space security using the methodology that will be used for subsequent annual volumes.

## Defining Space Security

The objective of the first phase of this research project (December 2002-August 2003) was the development of a working definition of space security and a set of indicators capable of providing a comprehensive overview of the key influences on space security.[1] The work of developing a definition of space security was undertaken by an 18 member Space Security Working Group (SSWG) convened by the International Security Research and Outreach Programme maintained by the Foreign Affairs Canada and the Eisenhower Institute in Washington DC.

To assist in the development of a working definition of space security as well as indicators of space security, the SSWG completed two sets of expert questionnaires and met as a group for discussions in Washington DC in March 2003. The work of the SSWG was reviewed by a second group of prominent space experts in April 2003. By August 2003, agreement had been achieved on the following definition of space security for the purposes of the study: ***secure and sustainable access to and use of space, and freedom from space-based threats.***

The key elements of this working definition were informed by a range of considerations including consistency with relevant major international legal instruments such as the United Nations Charter, the Outer Space Treaty, the Liability Convention, and the Environmental Modification Convention. Also considered were relevant United Nations General Assembly resolutions, the laws of armed conflict as well as key elements of selected arms control and disarmament treaties. This working definition informed the development of 12 space security indicators within three main categories: the space environment; intentions of space security actors; and capabilities of space security actors.

## Space Security 2003 Pilot Project

The objective of the second phase of this project (September 2003-March 2004) was to complete a pilot project to evaluate the status of space security in 2003 using the working definition of space security and the 12 space security indicators. This effort was undertaken by a 26 member SSWG including individuals with a range of expertise on space issues. This Space Security Survey was also completed via the web by a larger group of 115 space security experts from 15 states. Participants were asked to provide both quantitative and qualitative assessments of space security and were assured anonymity of their responses.

SSWG members were provided with a series of research papers which examined each of the 12 indicators in some detail based on open source materials. Following a review of the Space Security Survey results, research papers, and a roundtable discussion, SSWG members were asked to complete another Space Security Survey designed to assess the status of each space security indicator for 2003. This work was reviewed by a second group of prominent space experts in May 2004.[2] The results of this exercise led to the publication of the pilot project: *Space Security 2003* in December 2004.[3]

## *Space Security 2004*

*Space Security 2004* was developed using a similar process to that used during the 2003 pilot project with the number of indicators reduced from 12 to eight to reduce overlap of issues between indicators. The 2004 Space Security Survey was open for participation between 17 January and 11 February 2005. Invitations to participate in the Survey along with a set of background briefing notes, were sent to over 600 international space security experts. Efforts were made to provide invitations to national space experts from the civil, commercial, and military space sectors in a manner that was broadly representative of the international space community. A total of 136 experts from 17 states completed the 2004 online survey.[4] The results of the 2004 Space Security Survey were reviewed by a 2004 Space Security Working Group during a conference hosted by the Institute of Air and Space Law at McGill University in Montreal on 25-26 February 2005. A list of participants at the McGill meeting is included in Annex B. The quantitative assessments and qualitative comments provided by the 2004 Space Security Survey respondents and the Space Security Working Group were used to inform the development of *Space Security 2004*.

[1] Space itself has no agreed definition in international law. For the purposes of this research, it is understood to begin at an altitude of 100 kilometers above the surface of the Earth and to mean primarily orbital space, i.e. the region of near-earth space above 100 kilometers that includes low Earth orbit (100-1,500 kilometers) and extends to medium Earth orbit (5,000-10,000 kilometers) and geostationary Earth orbit (36,000 kilometers).

[2] "Space Security 2003," Research Report Prepared for the International Security Bureau of the Department of Foreign Affairs and International Trade, Ottawa, Canada, March 2004. Online: http://www.eisenhowerinstitute.org/programs/globalpartnerships/fos/newfrontier/SpaceSecuritySurvey%202003.pdf.

[3] *Space Security 2003*, (Washington DC: The Einsenhower Institute, 2004). Online: http://www.spacesecurity.org/SSI2003.pdf.

[4] States included: Australia, Austria, Brazil, Canada, China, Germany, France, India, Japan, Luxembourg, Malaysia, Netherlands, New Zealand, Russia, Switzerland, the UK, and the US.

# Annex B: Expert Participation

**Space Security Working Group (SSWG) Meeting**
**Institute of Air and Space Law, McGill University, Montreal, Canada**
**25-26 February 2005**

## 1. Space Security Working Group Participants[1]

Philip Baines, Senior Policy Advisor on Science, Non-Proliferation, Foreign Affairs Canada.

Joe Bock, Executive Director, Secure World Foundation.

Simon Collard-Wexler, Senior Research Officer, International Security Research and Outreach Programme, Foreign Affairs Canada.

Jessy Cowan-Sharp, Space Generation Foundation Committee.

Richard DalBello, President, Satellite Broadcasters and Communications Association.

Paul Dempsey, Director, Institute of Air and Space Law, McGill University.

Sarah Estabrooks, Program Associate, Project Ploughshares.

Thomas Graham Jr., Morgan, Lewis & Bockius LLP/Lawyers Alliance for World Security.

Jesper Grolin, Executive Director, eParliament.

Theresa Hitchens, Vice President, Center for Defense Information.

Zhang Hui, Research Fellow, Belfer Center for Science and International Affairs, Harvard University.

Wade Huntley, Director, Simons Centre for Disarmament and Non-Proliferation Research.

Ram Jakhu, Associate Professor, Institute of Air and Space Law, McGill University.

Bhupendra Jasani, Visiting Professor, Department of War Studies, King's College London.

David Koplow, Director, Center for Applied Legal Studies, Georgetown University.

Robert Lawson, Manager, International Security Research and Outreach Programme, Foreign Affairs Canada.

Jeffrey Lewis, Cooperative Security and Arms Control Project, University of Maryland.

William Marshall, Post-doctoral fellow, Belfer Center for Science and International Affairs, Harvard University.

Deborah Paul, Deputy Director, Non-Proliferation, Arms Control, and Disarmament Division, Foreign Affairs Canada.

Christopher Petras, Chief, International Air Operations law, NORAD-USNORTHCOM/JA.

Pavel Podvig, Research Associate, Center for International Security and Cooperation, Stanford University.

Y.S. Rajan, Confederation of Indian Industry.

Ernie Regehr, Director, Project Ploughshares.

Steve Staples, Polaris Institute.

Lucy Stojak, Senior Researcher, Institute of Air and Space Law, McGill University.

Jean-Jacques Tortora, Space attaché and Centre National d'Études Spatiales (CNES) Representative, Embassy of France in the United States.

Peter van Fenema, Jonker c.s. Advocaten, Amsterdam.

Elizabeth Waldrop, Chief of Space Law and International Law, US Air Force Space Command.

Olga Zhdanovich, Consultant, Moscow.

## 2. Observers[2]

Tissa Abeyratne, International Civil Aviation Organization (ICAO).

Harold W. Bashor, Institute of Air and Space Law, McGill University.

Raja Bhatacharaya, Research Assistant, Institute of Air and Space Law, McGill University.

Maria Buzdugan, Research Assistant, Institute of Air and Space Law, McGill University.

Angela Galanopoulos, International Security Research and Outreach Programme, Foreign Affairs Canada.

Jonathan Galloway, International Institute of Space Law.

Pat Gleeson, Institute of Air and Space Law, McGill University.

Rita Grossman-Vermaas, International Security Research and Outreach Programme, Foreign Affairs Canada.

Anna Jaikaran, People Against Weapons in Space.

Ayesha Laldin, International Security Research and Outreach Programme, Foreign Affairs Canada.

Mark Lupisella, Secure World Foundation.

Nicolas M. Matte, Director Emeritus, Institute of Air and Space Law, McGill University.

Philip A. Meek, Associate General Counsel, US Department of the Air Force.

Darius Nikanpour, Canadian Space Agency.

Mark Peterson, Institute of Air and Space Law, McGill University.

Marc Philippe, Royal Military College.

Dean Reinhardt, Institute of Air and Space Law, McGill University.

Kristine St. Pierre, International Security Research and Outreach Programme, Foreign Affairs Canada.

Ivan A. Vlasic, Professor Emeritus, Institute of Air and Space Law, McGill University.

Bill Wechsler, Department of Political Science, McGill University.

Anusha Wickramasinghe, Institute of Air and Space Law, McGill University.

[1] Not all SSWG members participated in the assessment of every indicator.

[2] The observers to the SSWG did not complete the SSWG Survey but provided qualitative feedback on the *Space Security 2004* draft notes and during the meeting itself.

"I know of no similar yearly baseline of what is happening in space. The Index is a valuable tool for informing much-needed global discussions of how best to achieve space security."

**Professor John M. Logsdon**
**Director, Space Policy Institute, Elliott School of International Affair, George Washington University**

"Space Security 2004 is a salutary reminder of how dependent the world has become on space-based systems for both commercial and military use. The overcrowding of both orbits and frequencies needs international co-operation, but the book highlights some worrying security trends. We cannot leave control of space to any one nation, and international policy makers need to read this excellent survey to understand the dangers."

**Air Marshal Lord Garden**
**UK Liberal Democrat Defence Spokesman & Former UK Assistant Chief of the Defence Staff**

"Satellites are critical for national security. Space Security 2004 is a comprehensive analysis of the activities of space powers and how they are perceived to affect the security of these important assets and their environment. While all may not agree with these perceptions it is essential that space professionals and political leaders understand them. This is an important contribution towards that goal."

**Brigadier General Simon P. Worden, United States Air Force (Ret.)**
**Research Professor of Astronomy, Planetary Sciences and Optical Sciences, University of Arizona**

"In a single source, this publication provides a comprehensive view of the latest developments in space, and the trends that are influencing space security policies.

As an annual exercise, the review is likely to play a key role in the emerging and increasingly important debate on space security. It is a balanced account which should aid decision making and enlighten discussion by politicians, militaries, diplomats and journalists on important issues such as managing the space debris hazard or decisions on the deployment of space-based weapons."

**Mr. Philip E. Coyle**
**Senior Advisor, Center for Defense Information, Former Assistant Secretary of Defense and Director, Operational Test and Evaluation, US Department of Defense**