SPACE SECURITY

2003

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Published in Washington, DC

ISBN 0-920231-36-5

Printed in Toronto
by Northview Press Ltd.

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Space is the only global commons that borders every community, providing an unprecedented potential nexus of social, economic, and military power. Space helps us monitor our weather and natural resources, produce food, communicate with each other, trade, and travel. Space is home to unprecedented achievements of international scientific cooperation. It generates tens of billions of dollars in commercial revenues. Space is rapidly becoming part of our critical national and international infrastructure; it supports our medical systems, our public services, our police forces, our militaries.

Space is also a global commons that is uniquely fragile, and its growing strategic importance raises concerns about the security of our space systems. How does the unique nature of the space environment shape the security of our access to and use of space? How can we most effectively balance today's civil, commercial, and military space interests against our need for sustainable space use? Can space be secured for peaceful purposes, as defined by our collective obligations under the Outer Space Treaty?

This research project attempted to address these important issues by asking a fundamental question: is it possible to define space security? The early answer appeared to be more of a maybe than a solid yes. While the space community was seeking what could broadly be called space security, it was unclear what this would mean in practical terms. To address this challenge, we worked closely with a range of space experts, between December 2003 and June 2004, to develop a working definition of space security and a methodology for providing an annual comprehensive assessment of the status of space security. Our working definition of space security was designed with consistency with international law in mind and included two key elements:

- Secure and sustainable access to and use of space
- Freedom from space-based threats

This volume reports on our efforts to assess the status of space security in 2003 in order to pilot test this working definition and the expert consultation process which generated this assessment. A description of this pilot test and its participants is provided in the Annex.

While the focus of this report is upon space security in 2003, an early assessment of developments in 2004 underscores the growing complexity and importance of the space security debate. While the X-Prize broke new ground for space tourism, the US debate on military counter-space operations doctrine continued to attract international attention.

While much work remains to fully develop our research approach, we believe that this volume clearly demonstrates the value and viability of an evidence-based assessment of the status of space security. Much is at stake in space, and there is a clear need to broaden our knowledge of the dynamics of space security. Understanding these dynamics is the key to developing a clear vision of how civil, commercial, and military space actors can best achieve an objective they all seem to share: secure and sustainable access to and use of space, as well as assurances that space will not become a source of direct military attack.

We would like to express our gratitude to the many researchers and administrative assistants who supported this project. At the Eisenhower Institute: Dr. Roald Sagdeev; Mr. Ryan McFarland; Mr. Tyler Nottberg; Mr. Andrew Park; Ms. Olga Prygoda; and Ms. Suzanne Vogel. Through the International Security Research and Outreach Programme at Foreign Affairs Canada: Mr. Phillip Baines; Mr. Michel Bourbonnière; Mr. Simon Collard-Wexler; Ms. Jessy Cowan; Ms. Sarah Estabrooks; Dr. Nicole Evans; Mr. Maciek Hawrylak; Ms. Theresa Hitchens; Dr. Andrew Latham; Dr. William Marshall; Mr. Robert McDougall; Dr. David Mutimer; Mr. Robbie Schingler; Mr. Gabriel Stern; Dr. Lucy Stojak; and Mr. George Whitesides. More details on the experts consulted over the course of this project are included in the Annex.

Susan Eisenhower, Thomas Graham Jr., Robert J. Lawson

Executive Summary

The Space Environment

The utility of the satellites for civil, commercial, and military applications depends upon three space environment related factors: secure access to an orbital slot for each satellite; secure access to a radio-frequency allocation to allow communication with each satellite; and security against space debris with the capability to damage or destroy satellites. Space-craft are particularly vulnerable to space debris, and the accumulation of space debris grows each year. In highly valued geostationary orbits (GEO), space debris is essentially permanent due to the lack of atmosphere at 36,000km above the earth. Since space is considered, under the Outer Space Treaty, as open to everyone and belonging to no one, the allocation of the limited orbital slots and radio-frequency spectra have to be negotiated among space-faring nations.

Space Debris

There was little or no effect on space security in 2003 with respect to this indicator.

- Space debris remained a serious concern with regard to secure and sustainable access to space – particularly with respect to low earth and geostationary orbits. While the amount of space debris continued to increase in absolute terms during 2003, the rate of this increase declined.

- The UN Inter-Agency Space Debris Coordination Committee developed voluntary international guidelines for space debris mitigation, which were expected to be endorsed by the UN Committee on the Peaceful Uses of Outer Space in 2004. While a largely positive development, compliance with these guidelines remained problematic as most mitigation measures are relatively expensive, which presented a challenge for commercial and emerging space actors.

Space Resource Allocation

There was little or no effect on space security in 2003 with respect to this indicator.

- The dramatic growth in demand for radio-frequency allocations and orbital slots in GEO continued, largely related to competing commercial and military demands. However, significant steps were undertaken to address the growing pressures on these scarce resource by reforming procedures within the International Telecommunication Union for allocating radio-frequency and orbital slots.

- The US-EU dispute over Galileo radio-frequency allocation provided an example of the potential for future conflicts over space resource allocations.

The Intentions of Space Security Actors

Intentions of space security actors are relevant to space security because they provide important indicators of how they perceive the opportunities and challenges of the space environment, as well as possible threats to their secure access to and use of space. These intentions are often communicated through national space security policies and doctrines, and at the international level, through each actor's record of engagement with international law and international institutions relevant to space security issues.

National Space Security Doctrines and Military Doctrines

Space security had been somewhat reduced in 2003 with respect to this indicator.

- Despite a general trend of continuity in national space security policies and doctrines supportive of the peaceful and non-aggressive uses of outer space, 2003 provided indications of growing support for space weaponization on the part of some actors, raising concerns about the sustainability of space security over the long term.

- While official US military space doctrine emphasized reversible and non-destructive means of pursuing space control, longer-range US military planning documents recommended that the US seek offensive counter-space capabilities.

- The announcement of the US Missile Defence Agency's intention to place a 'test bed' for space-based ballistic missile interceptors in orbit no earlier than 2012 represented a delay from previous estimates, but still raised concerns, as did the announcement that the Indian Air Force has started conceptual work on anti-satellite weapons. Although the Indian announcement was later officially retracted, concerns remained about their intentions, as well as those of other actors. For example, US defence officials assessed that China was likely working on anti-satellite weapons.

Legal, Normative, and Institutional Developments

There was little or no effect on space security in 2003 with respect to this indicator.

- The institutions charged with issues relevant to space security such as debris, radio spectrum and orbit allocations were taking what appeared to be effective steps to deal with challenges related to these space environment issues.

- The adoption of the annual UN General Assembly resolution calling for progress within the Conference on Disarmament (CD) to prevent an arms race in space provided a good indication of the continued strength of the normative trend supportive of the peaceful uses of outer space.

- The CD remained deadlocked throughout the year on the issue of the prevention of an arms race in outer space. The Chinese move within the CD to accept a compromise formulation of the mandate for an ad hoc committee to address this issue raised hopes that work might begin on this issue within the CD in 2004.

The Capabilities of Space Security Actors

The capabilities of space actors affect space security dynamics since they provide the means by which they are able to access and use space for peaceful and non-aggressive purposes, as well as the means through which an actor can potentially negate the ability of other actors to access and use space.

Space Access

Space security was somewhat enhanced in 2003 with respect to this indicator

- China's first manned space mission and India's successful test of its GEO launch capability continued a general trend of growth in the number of nations with the capability to access space for a diverse range of applications.

- This increase in the number of countries with access to space can potentially enhance space security by providing healthy market competition, access to space for actors without a dedicated launch program and redundancy in the case of system failures. However, there is also a level of concern that more countries with access to space could increase the threat to space assets, undermining space security over the longer term.

- The Brazilian and US civil space tragedies in 2003 underscored the risks associated with space access, as well as the corresponding value of a growing diversity of space access capabilities.

Civil Space Programs and Global Utilities

There was little or no effect on space security in 2003 with respect to this indicator

- The ongoing importance of international cooperation across civil space programs was underscored by developments during 2003 – in particular Russia's agreement to continue servicing the International Space Station following the Columbia tragedy.

- China's entry into manned space flight was also an important civil space development which appeared to stimulate the civil space activities of others.

- The continued dispute between Europe and the US over Galileo spectrum allocation was a concern regarding global utilities.

Space Industry

There was little or no effect on space security in 2003 with respect to this indicator

- The general trend in recent years within the space industrial sector has been an ongoing economic downturn. Even though civil and military actors turned increasingly to the commercial sector to meet their needs for space services, the space industry sector itself remained burdened by overcapacity in 2003.

- While overcapacity within the space industry sector was assessed by some as having a negative impact on space access, it also tended to increase market competition within the sector and contributed to pressures for lower space access costs.

Surveillance of Space

Space security was somewhat enhanced in 2003 with respect to this indicator.

- Space actors continued to demonstrate a growing interest in developing enhanced capacities to support cooperative surveillance of space capabilities.

- Development of an experimental US space-based optical sensor suggested the potential for improvements in the capability of the US Space Surveillance Network to detect smaller objects. Space surveillance capabilities were also critical to collision avoidance and protection against orbital debris.

- Space surveillance capabilities are generally based on dual-use technologies that can be detrimental to space security. There was an indication of US interest in applying these technologies in support of space control and ballistic missile defence missions. However, on balance, it was assessed that there had been an increase in the transparency of space activities related to the management of space for peaceful purposes.

Space and Terrestrial Military Operations

Space security had been somewhat reduced in 2003 with respect to this indicator.

- The trend towards greater dependency on space assets to support terrestrial military operations continued in the 2003 as the US launched an attack on Iraq that relied heavily upon the use of space-based systems.

- While the dependency upon space assets to support precision-guided munitions had some positive dimensions, it also increased the incentives on the part of other nations or entities to develop capabilities to negate these systems. Consequently, there was a corresponding trend on the part of nations dependent upon space assets to seek greater protection for these assets against such negation capabilities.

- These trends and developments underscored the need for the careful management of the protection/negation dynamic in order to mitigate incentives to develop more destructive oriented negation capabilities such as anti-satellite weapons. Such a dynamic would have the potential to trigger an action-reaction cycle that could lead to the breaching of the normative barrier prohibiting the deployment of weapons in space, undermining the sustainability of space security.

Space Systems Protection

There was little or no effect on space security in 2003 with respect to this indicator.

- There continued to be a growing recognition on the part of key governmental space security players of the threats facing space systems, and the need to support greater efforts to put appropriate protective measures in place.

- In contrast to this move to protect government systems, there was inadequate effort devoted to protection measures for commercial space systems. Improved information assurance measures, electronic protection measures, increased encryption usage, and enhanced radiation hardening all add costs to space systems. Commercial providers in a competitive marketplace remained reticent to pay for such additional measures. Thus, there appeared to have been no significant changes in the level of protection for commercial space systems in 2003.

Space Systems Negation

Space security had been somewhat reduced in 2003 with respect to this indicator.

- Despite what appeared to be a long term trend on the part of some space-faring nations to develop more robust space negation capabilities based on the physical destruction of satellites, there was little evidence in 2003 that such capabilities were being actively developed via funded programs.

- Concerns were raised that the jamming of navigation satellite signals during the Iraq war and the intentional interference with US satellite television signals during times other than war had helped to establish a state practice that could have a negative impact upon the sustainability of space security.

- A measured step was taken in 2003 by the US to enhance its capabilities for space negation through the temporary and reversible effects of electronic warfare.

Space-Based Strike Weapons

Space security had been somewhat reduced in 2003 with respect to this indicator.

- Consistent with previous years, no space-based strike weapons (SBSW) were deployed in space during 2003, and few states possessed any of the key capabilities required for SBSW systems.

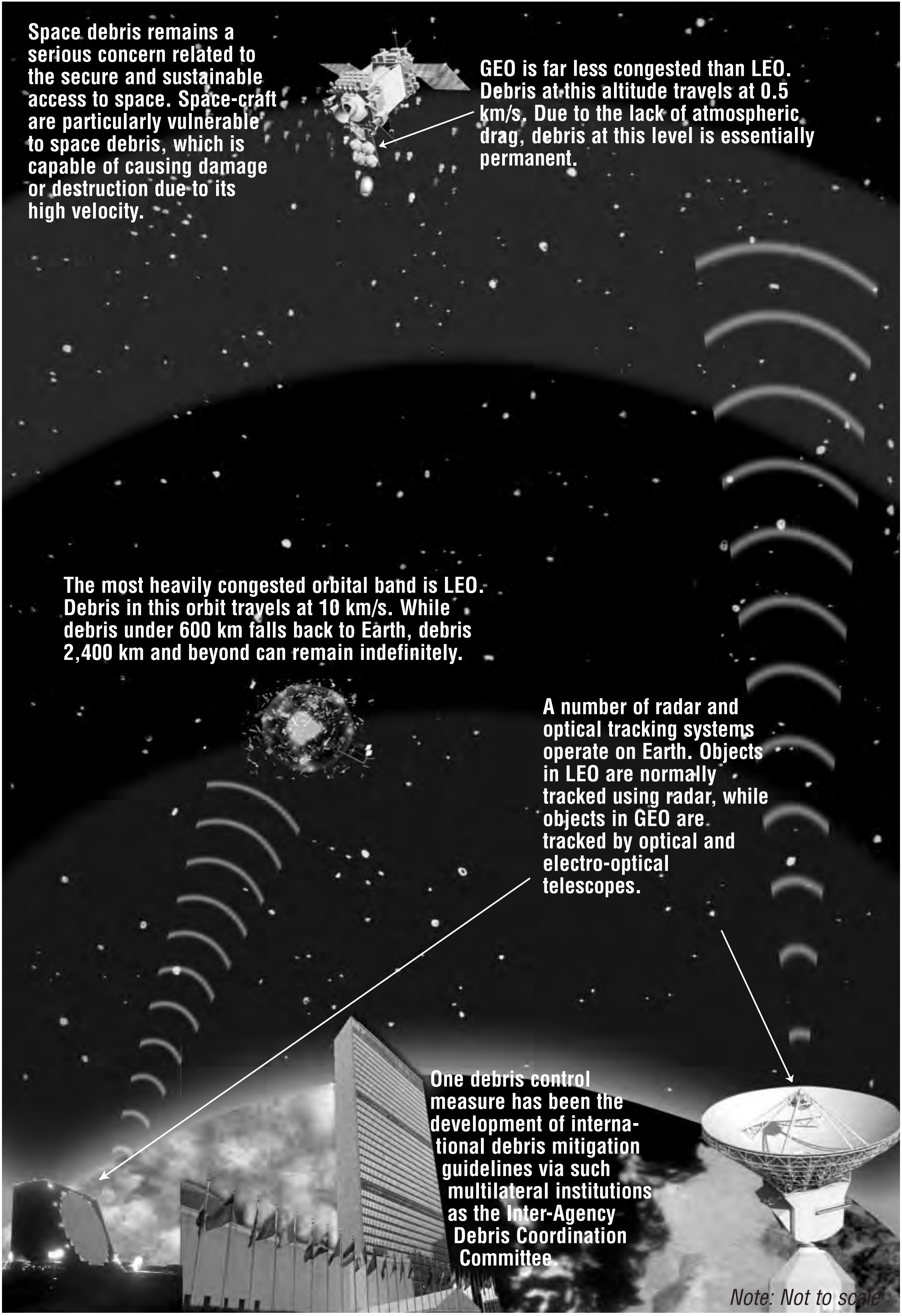
- The sustainability of space access and the degree to which states believed they will continue to enjoy freedom from space-based threats remained an issue of significant concern for many space actors. The US Missile Defence Agency plans to develop and deploy a space-based interceptor test bed by 2012, which, although a delay from previous estimates, was frequently cited in relationship to these concerns.

- The apparent reaction to these developments by Chinese and Indian officials underscored the risk that some space security actors were already beginning to plan for a time that space would become weaponized.

Space Security in 2003

Overall, it was assessed that space security had been somewhat reduced in 2003. There were clearly some positive developments in the areas of space access and space surveillance. However, developments in the areas of national space security policies and doctrines, space and terrestrial military operations, space systems negation, and space-based strike weapons were assessed to have had a negative impact on the sustainability of space security over the longer term.

Figure 1-1



Space debris remains a serious concern related to the secure and sustainable access to space. Space-craft are particularly vulnerable to space debris, which is capable of causing damage or destruction due to its high velocity.

GEO is far less congested than LEO. Debris at this altitude travels at 0.5 km/s. Due to the lack of atmospheric drag, debris at this level is essentially permanent.

The most heavily congested orbital band is LEO. Debris in this orbit travels at 10 km/s. While debris under 600 km falls back to Earth, debris 2,400 km and beyond can remain indefinitely.

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.

One debris control measure has been the development of international debris mitigation guidelines via such multilateral institutions as the Inter-Agency Debris Coordination Committee.

Note: Not to scale

I-01 Space Debris

1

This chapter assesses trends and developments related to the amounts of space debris at various near-earth orbits, both naturally generated and man-made, as well as efforts to reduce the production of new debris, reduce existing debris, and mitigate the hazards that debris presents for the uses of space.

All space missions inevitably create space debris - rocket booster stages are expended and exhaust products are created. Factors that affect debris production include the number of objects in orbit, the number of new satellites being launched, as well as measures taken to mitigate the debris created by these launch and satellite operation activities. The testing of anti-satellite weapons during the Cold War also created significant amounts of space debris.

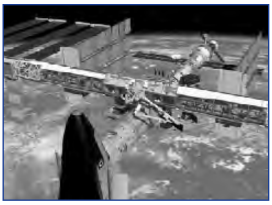


Figure 1-2
On 15 December 2001 the International Space Station was moved to avoid collision with a Russian SL-8 upper stage rocket that had been launched in 1971.

Since 1957 the US Air Force has registered more than 27,000 large - and medium-sized objects orbiting earth, of which approximately 13,000 are in orbit today and 6-7 percent of which are operational satellites.[1] However, the overwhelming majority of debris in LEO is smaller than 10 centimeters and is too small to be verifiably tracked and catalogued.[2] Space scientists estimate that there are tens of millions of objects between 1-10 centimeters in size (i.e., larger than a marble), and perhaps trillions of pieces measuring less than that.[3] Even tiny fragments of space debris can harm operational spacecraft due to the high relative velocities of in-orbit collision.

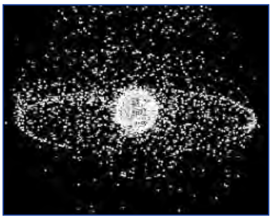


Figure 1-3
While the relative concentration of debris in GEO may be less than in LEO, debris at this altitude is essentially permanent.

Space debris tends to 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 time due to atmospheric drag, at altitudes greater than 600 kilometers debris can remain in orbit for “tens, hundreds, or even thousands of years.”[4]

Space debris has the potential to directly threaten space security since it increases risks associated with accessing and using space. For example, the Russian Kosmos 1275 is believed to have been destroyed by space debris, while in 1996 the French military satellite Cerise had its stabilization arm severed by a briefcase-sized portion of an Ariane rocket, and was temporarily put out of commission.[5] All actors appear to understand the inherent dangers of debris, and recognize the potential for its metamorphosis from nuisance to serious obstacle. Indeed, NASA believes that collisions between space assets and larger pieces of debris will remain rare only for the next decade.[6]

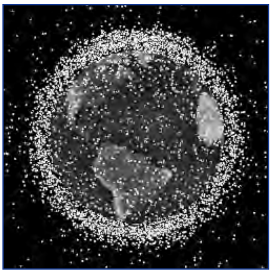


Figure 1-4
LEO currently has the highest concentrations of space debris.

BACKGROUND

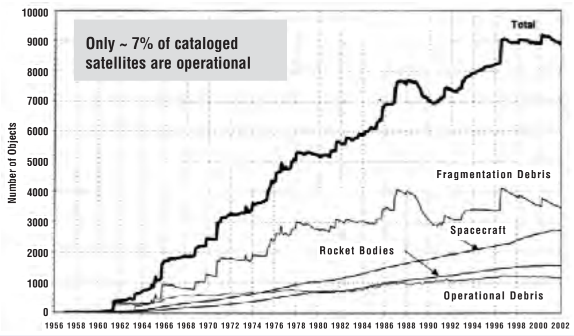
As early as the 1970s, space scientists began predicting via observations and modeling that the growth of orbital debris would increase the threat of damage to working satellites unless steps were taken to mitigate its creation.[7] The major factors which affect how quickly debris becomes a serious problem, if at all, include the rate of new debris production as well as debris mitigation measures designed to reduce the amount of new debris being created and reduce the impact of debris on space operations.

Debris Production

Two of the key factors affecting debris production include the number of objects in orbit and the number of new satellites being launched each year. As Box 1-1 illustrates, the growth of the catalogued satellite/debris population has been on a steady rate of increase since the dawn of the space age. The highest concentration of space debris is found in LEO. It is important to note that growth in the debris population also increased the probability of inter-debris collisions with the potential to create even more debris.

Box 1-1

Growth of the Catalogued Satellite/Debris Population



Regarding the potential for debris creation from launch activities, it is noteworthy that worldwide, launch figures over the period 1998-2002 held steady for non-commercial launches and declined for commercial launches. Major space actors with indigenous launch capabilities, including the United States, Russia, the ESA, China, Japan, India, and Israel, attempted 213 non-commercial launches for an average of forty-three launches per year.[8] However, the commercial launch sector has not yet recovered from the global economic downturn that took place during the middle of the same five-year period, and this is reflected in the progressive decline in the number of commercial launches during those years, with forty, thirty-nine, thirty-five, sixteen, and twenty-four launches from 1998-2002 respectively.[9] In fact, launch rates are at historic lows: while the average annual launch rate worldwide during the 1980s was 116, the rate for 2001 and 2002 was just over half that, at around sixty-five launches per year.[10]

In terms of actors accessing space, in addition to those with indigenous capabilities listed above, Pakistan, through its ballistic missile program, has the capability to launch into LEO, although this has never been demonstrated. North Korea and Iran are working on ballistic missile programs that could give them the same capabilities. Many other countries own satellites purchased and launched from foreign providers. All told, there are some fifty-five countries, groups of countries, and international commercial or civil consortia owning space assets.[11] Indeed, this number is only limited by certain national commercial controls and the desire of countries to commercially purchase and launch satellites.

Current Impact

Today, collisions between space assets like the International Space Station and minute debris are a daily but manageable problem, primarily in LEO, the area of space with the heaviest concentration of debris.[12] On average, objects in LEO move at relative velocities of about 10 kilometers per second (about 36,000 kilometers per hour). Thus, the impact from a 1 kilogram (10 centimeter diameter) object in LEO with this relative velocity would equal that of a 35,000 kilogram truck moving at 190 kilometers per hour on earth. A collision with a debris fragment of this size could result in the catastrophic break-up of a 1,000 kilogram spacecraft (a typical spacecraft bus weighs about 1,200 kilograms).[13]

In GEO, objects have lower relative velocities because they are orbiting at slower speeds than in LEO, and are traveling in the same direction in essentially similar orbits. The average collision velocity in GEO is thus only about 0.5 kilometers per second.[14] However, debris can still cause damage at this speed, with an impact about the same as a rifle bullet. A fragment 10 centimeters in diameter has the same potential to damage a spacecraft as a 1 centimeter fragment in LEO, and a 1 centimeter fragment is the equivalent of a 1 millimeter LEO fragment.[15]

As an aggregate, these characteristics are worrisome. Debris fragments between 1-10 centimeters “will penetrate and damage most spacecraft,” according to the Center for Orbital Re-entry and Debris Studies (CORDS) of The Aerospace Corporation. 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.”[16] Indeed, according to a 1995 study by the US National Research Council,

> In LEO, debris as small as a few millimetres in diameter can puncture unprotected fuel lines and damage other sensitive components, and debris smaller than 1 mm in diameter can erode thermal surfaces and optics.… Components that are difficult to protect from debris (including photovoltaic arrays, suites of communications antennas, and sensors) may…be at risk even in well-designed spacecraft.[17]

While major collisions so far have been rare, the Space Shuttle has been hit several times by particles bigger than 1 millimeter; and the ten-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.[18] In fact, a 1994 NASA risk analysis noted that the first thirty-three shuttle flights had sustained debris damage to some of the tiles on the shuttles' undersides.[19] The ESA satellite ERS-1 was moved twice, in June 1997 and March 1998, and the French SPOT-2 was moved in July 1997.[20] 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.[21]

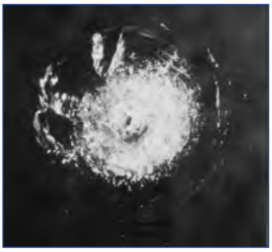


Figure 1-5
Window pit from orbital debris on STS-007.

Potential for Future Damage

Still, most space scientists, industrialists, and space agency officials agree that the current level of debris is not highly hazardous to space operations. All spacecraft are routinely hit by particles smaller than 1 millimeter in diameter, but with rare exceptions like the cases above, such impacts do not have highly deleterious effects.[22] Institutionally, this sentiment is expressed in a 1999 report by the UN Committee on the Peaceful Uses of Outer Space, which noted that "in most cases, man-made space debris today poses little risk to the successful operations of … active spacecraft now in Earth orbit."[23] In fact, the 1995 US NRC study found that within the orbital altitude 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, with even larger odds against impact for higher orbits.[24]

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."[25] Indeed, according to NASA models, without further implementation of orbital debris mitigation measures, the number of objects 10 centimeters and greater in orbit—which can cause fatal damage to an average-size satellite—"might begin" to grow rapidly in the second half of this century.[26]

Debris Mitigation

As concerns have grown about debris, space agencies and the space industry have increasingly focused on mitigation efforts. Experts note that debris mitigation efforts by the major space powers, particularly the United States and Russia, have helped stave off serious problems. Space actors have attempted to address the debris issue via national and international regulation, physical spacecraft protection, and detection, monitoring, and tracking systems. The result of these mitigation efforts has been positive: although there was a nearly steady annual growth of catalogued debris until the mid-1990s, the rate of this growth has since been observed to be leveling off.[27]

National and International Regulation

Discussions among space agencies regarding the burgeoning debris problem began in the 1980s, and since then many of the space-faring countries have developed debris mitigation guidelines. NASA has been a leader in this arena, and all US national space policies since 1988 have addressed the debris issue. NASA issued guidelines on limiting orbital debris in August 1995 in the form of the NASA Safety Standard (NSS) 1740.14. The current US National Space Policy (PDD-NSC-49/NSTC-8), which dates from September 1996, makes it the policy of the United States to "seek to minimize the creation of space debris."[28] In December 2000, the US government issued formal orbital debris mitigation standard practices for space operators developed by the Defense Department and NASA. These cover four key areas: control of debris from normal operations; minimization of debris created by explosions; safe flight and operational parameters; and, disposal of spacecraft.[29]

These initiatives were duplicated by the other space powers. ESA formed a Space Debris Working Group in 1986, and first introduced a space debris mitigation effort in 1998.[30] ESA published the "ESA Space Debris Mitigation Handbook" on 7 April 1999, and issued the European Space Debris Safety and Mitigation Standard (Issue 1, Revision 0) on 27 September 2002. ESA, like NASA, is a strong supporter of international efforts to build a universally accepted set of debris mitigation practices. Russia also has a formal debris mitigation policy, the Russian Federal Law on Space Activity of 1993, and issued a standard practices document in October 2002 entitled "Space Technology Items, General Requirements, Mitigation of Space Debris Population, Russian Aviation and Space Agency Standard OCT 134-1023-2000." A number of other major space powers, such as Japan, have similar guideline documents.[31]

On an international scale, the Scientific and Technical Subcommittee of the UN Committee on the Peaceful Uses of Outer Space (COPUOS) has discussed space debris since 1994, ultimately publishing the "Technical Report on Space Debris" in 1999. The primary debris-oriented body, however, is the UN-mandated Inter-Agency Space Debris Coordination Committee (IADC), which is charged with coordinating national guidelines and is composed of the space agencies from China, the ESA, France, Germany, India, Italy, Japan, Russia, Ukraine, the United Kingdom, and the United States. In 2001, COPUOS asked the IADC to develop and submit a set of voluntary international guidelines for submission to the United Nations. In 2002 the IADC released its guidelines, which cover limiting debris released during normal space operations, minimizing the potential for in-orbit break-ups, post-mission disposal, and prevention of collisions. In addition, the IADC recommended that a space debris mitigation plan be put together for each space project, and asked nations to voluntarily report on mitigation efforts.[32]

Figure 1-6
The members of the IADC establish international guidelines for debris mitigation.

Physical Spacecraft Protection

In addition to regulation, mitigation can include measures designed to reduce the impact of debris on space objects. Physical improvements are some of the ways in which spacecraft operators can protect their assets. Spacecraft can be effectively shielded against particles ranging from 1 millimeter to 1 centimeter by using Kevlar, which is five times stronger than steel and currently protects the International Space Station.[33] Still, debris larger than 1 centimeter in size cannot be effectively shielded against. Another measure of physical protection is redundancy, which could potentially allow a spacecraft to continue to function even after a collision with debris. Finally, spacecraft can also be equipped with the means to avoid collisions through maneuvering, but doing so has impacts on mission and life expectancy. Maneuvering consumes fuel, which means extra fuel must be carried—adding weight and thus cost. Maneuvering can also mean interrupting data collection or services as the spacecraft shifts orbits.[34]

Detection, Monitoring, and Tracking

Detecting, tracking, and cataloguing debris remains a major challenge, though it is still the major instrument in the fight against debris. Debris is detected, tracked, and catalogued through direct monitoring as well as complex models. In general, LEO is monitored using ground-based radar, while GEO is usually monitored using optical telescopes (see I-8 Surveillance of Space for more detail). In addition, space agencies examine returned spacecraft for debris damage, and models are used to characterize the debris environment. In LEO, monitoring systems "do not reliably track objects … with a radar cross-section of less than 10 cm in equivalent diameter."[35] Objects between 1 millimeter and 10 centimeters can be detected, but not always reliably tracked or precisely located. Objects smaller than 1 millimeter cannot be monitored.[36] In GEO, the much greater distance from earth means that only objects 1 meter and larger are monitored and catalogued, with objects as small as 10 centimeters detectable by the European Zeiss telescope in Tenerife.[37]

Figure 1-7
The 70 m Goldstone radar near Barstow, CA is capable of detecting 2 mm objects in LEO.

There are only two monitoring systems today that are capable of reliably registering space objects: the US Space Surveillance Network (SSN), and the Russian Space Surveillance System (SSS). The catalogues kept by both systems for objects in LEO are essentially the same for objects 50 centimeters in diameter and above, while the US version is more complete for objects between 10 and 15 centimeters.[38]

Obstacles to Mitigation

There are, however, several serious obstacles to the continued improvement of the debris situation, namely in the fields of national and international regulation and detection, monitoring, and tracking. Moreover, one of the more dangerous potential obstacles to debris mitigation is the weaponization of space, which can result in the destruction of satellites and the creation of new debris.

National and International Regulation Obstacles

First, in terms of national debris mitigation policies, all of the aforementioned national standards provide waivers that allow operators to avoid putting them in place if costs become prohibitive, or, in the case of the United States, if mission goals might be negatively impacted. There are also differences in technical parameters amongst the varying mitigation standards, such as in their requirements for post-mission disposal of spacecraft—which is critical to ensure against future debris growth.[39] Further, according to debris experts, it is highly unclear if nations with standards actually routinely impose them or follow up to enforce them—the Russian space program, for example, has suffered extensive budget cuts and has little capacity to maintain its current space assets, much less police launch providers.

In the international arena, some experts are concerned that the new IADC guidelines will be unable to prevent future growth in space debris. Given that most debris mitigation measures involve the use of valuable fuel for transfer to graveyard orbits, and thus an increase in launch costs associated with added weight, critics argue that the commercial sector will be unlikely to follow these profit-reducing guidelines if their competitors are not required to do the same. Efforts to establish standard mitigation practices by the international community are to be welcomed—but many debris experts are convinced that such voluntary standards eventually will have to be replaced with legal or regulatory regimes. Indeed, as competition in the space launch business heats up—which is inevitable in the short term as new launching states enter the already overcapacity market—incentives to ignore practices that will require even modest extra expenditures may actually increase. “It is unlikely that voluntary application of mitigation measures will solve the space debris problem,” notes Walter Flury, director of the space debris program at ESA. “Just think about the commercial sector of space with activities with its competitive character.”[40] Indeed, according to Flury, while all space operators have long been aware of the recommendations to boost dead spacecraft in GEO to a graveyard orbit at least 300 kilometer higher than GEO for disposal, only about one-third of operators now do so.[41] Over one hundred satellites have been left in GEO at their end-of-life rather than being transferred to a disposal

Figure 1-8
A NASA report in 1994 concluded that "The cessation of...anti-satellite tests [in the 1980s] by both the United States and Russia has helped to reduce the growth of orbital debris."[59]

orbit.[42] Moreover, emerging space powers may view these requirements as barriers to competing in the global launch market.

Detection, Monitoring, and Tracking Obstacles

There are shortcomings in the detection, monitoring, and tracking field as well. Although capabilities and technology have improved over the past several decades, the US SSN does not provide continuous tracking of objects and the uncertainty regarding the location of objects in LEO is generally on the order of tens of kilometers, although the uncertainty varies according to altitude and orbital inclination.[43] The US system has no sensors in the southern hemisphere.[44] The Russian system is limited by its lack of sensors outside the former Soviet Union—and it therefore cannot track all of GEO. Even the locations of the 9,000 objects catalogued by the SSN are not documented sufficiently to predict potential collisions with accuracy.[45] This is not simply due to the limits of technology—part of the issue is cost. For example, if a wider network of large optical telescopes was developed, tracking could be improved.

Weaponization

Finally, a future factor that could affect the population of space debris is the possibility that space may become weaponized. The testing and/or deployment of large constellations of space-based missile interceptors would add to the debris population—simply by the fact of launching them into space. In addition, testing of anti-satellite weapons (ASATs) using mass-to-target vehicles could result in "a significant amount of debris."[46] The effect of ASAT testing on the debris population has already been established. A NASA report in 1994 concluded that "The cessation of…anti-satellite tests [in the 1980s] by both the United States and Russia has helped to reduce the growth of orbital debris."[47]

The most worrisome variety of ASAT would be one equipped with a mass-to-target warhead, designed to kill a satellite by smashing into it. Indeed, a US Air Force study in 1991 found that a "large amount of debris will be produced when a [mass-to-target] weapon, traveling at hypervelocity, collides with a satellite in orbit," producing thousands of new satellite fragments.[48] In recent years, US Air Force officials have expressed concerns about the possibility that the Army's Kinetic Energy ASAT (KE-ASAT) program could result in the creation of significant debris, despite design elements aimed at mitigation. Air Force officials are understandably concerned about the possibility that new debris could harm the US's own military space assets.[49] Nonetheless, Pentagon plans project continued funding for research and development on mass-to-target or other destructive ASAT technologies, as well as mass-to-target missile defense systems.[50]

2003 DEVELOPMENTS

There were a number of key developments during 2003 with respect to debris, particularly in the cases of worldwide, US, Chinese, and European developments. Developments in 2003 were consistent with the contradictory trends of the last several years. As mentioned above, these include a continued slump in the commercial marketplace, continued efforts to put in place voluntary mitigation guidelines and improve tracking, and continued movement by nations to explore new activities in space.

Worldwide

Launch figures continued to drop, which was a positive development in terms of the amounts of debris production. Commercial launches were expected to drop from twenty-four in 2002 to seventeen this year, continuing the depressed trend of the last few years. Non-commercial launches, however, held steady, with forty-six launches taking place, versus forty-one in 2002.[51]

The IADC presented its new recommendations to the Scientific Subcommittee of COPUOS in February 2003. The Subcommittee asked the member states to review the report, and noted that the Subcommittee "could establish a working group to consider comments from member States on the IADC proposals and to consider further progress on the subject." Deliberations on the report are to begin at the forty-first session in 2004.[52]

United States

The United States in the last several years has made progress in detecting and tracking objects between 5-10 centimeters. From March 2002 through May 2003, nearly 2,000 new objects in that class were detected and tracked.[53] In addition, the SSN's catalogue grew from around 10,870 space objects tracked on 1 January to around 13,120 by 21 November.[54] The increase was due largely to the reactivation of the upgraded Cobra Dane radar in Alaska.

The other major debris-related development in the United States concerned the space shuttle Columbia, which was tragically lost during re-entry on 1 February. The cause of the disaster was a piece of foam insulation from the external tank which broke off and struck the wing of the Columbia some eighty seconds after launch.[55] While the piece of debris clearly did not originate in space, it does nonetheless illustrate the danger that debris can cause manned spacecraft.

Box 1-2

Orbital Objects Tracked By The SSN, December 2003

Actor	Payloads	Rocket Bodies/ Debris	Total
China	38	283	321
Russia	1354	2606	3957
ESA	34	305	339
India	27	113	140
Japan	82	48	130
US	986	2795	3781
Other	357	32	389
TOTAL	2875	6182	9057

China

One particularly interesting development was the entry of China into the exclusive club of countries with a manned space program, coupled with China's commitment to future space exploration, thus raising the question of how such a routine Chinese program might affect debris creation.

In August, Li Benzhen, an official with the Commission of Science, Technology and Industry for National Defence, said that "the research into space debris … is greatly significant to China, even though it did not start until 2000 and is very much behind that in the United States and other countries." The Commission was given $3.6 million in funding from 2000-2005 to research how to minimize the effects of space debris and develop protection against it. It is working to improve observation methods, enhance studies into space debris environments, and set up a data bank to help China's space exploration. Li noted China has put into operation an optical telescope with a diameter of 25 centimeters and will "soon" launch one with a diameter of 65 centimeters.[56]

On 24 December, China announced it planned to launch three programs to monitor, prevent, and curb the movements of debris in outer space. The programs are to be carried out between 2006 and 2020, and in the interim China would also establish data banks and national standards for the implementation of the programs.[57]

ESA

Up-to-date debris regulation was announced in Europe in 2003. An updated draft of the European Space Debris Safety and Mitigation Standard was issued on 7 February, and its implementation was being coordinated through the European Cooperation for Space Standards framework throughout 2003.

Just six of fifteen end-of-life GEO satellites were placed in graveyard orbits in 2003, according to the ESOC Space Operations Centre in Germany. One of the fifteen, Loral Space and Communications' Telstar 4, abruptly failed in orbit and could not be moved. The other eight failures were relocated to orbital positions that were insufficiently out of the way. The pedigree and scope of the satellite operators who failed to achieve graveyard orbits suggests that even mature space actors are not sufficiently capable or motivated to properly dispose of terminated satellites. The eight satellites which failed were Telesat Canada's Anik C1, the Intelsat 5A, the Eutelsat 2 F1, the PanAmSat Galaxy 6, the Hispasat 1A, the German DFS Kopernikus 3, Russia's Gals 2 and India's Insat 2C.[58]

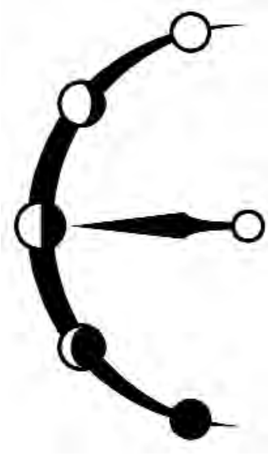
SPACE SECURITY SURVEY 2003: KEY ASSESSMENTS

Space Security 2003: Survey Results

Space Security Survey (20/10/2003-14/11/2003)		Space Security Working Group (24/11/2003-25/11/2003)	
Question: Taking into account your views on the effect of both production and mitigation of space debris in the past year, how have overall changes in this area affected space security?		*Question:* In your view, space security with respect to this indicator has been...?	
Enhanced:	0	Enhanced:	0
Somewhat enhanced:	24	Somewhat enhanced:	6
Little or no effect:	53	Little or no effect:	19
Somewhat reduced:	28	Somewhat reduced:	0
Reduced:	5	Reduced:	0

- Space debris remained a serious concern with regard to secure and sustainable access to space particularly with respect to low earth and geostationary orbits. While the amount of space debris continued to increase in absolute terms during 2003, the rate of this increase declined.
- The UN Inter-Agency Space Debris Coordination Committee developed voluntary international guidelines for space debris mitigation, which were expected to be endorsed by the UN Committee on the Peaceful Uses of Outer Space in 2004. While a largely positive development, compliance with these guidelines remained problematic as most mitigation measures are relatively expensive, which presented a challenge for commercial and emerging space actors.

There was little or no effect on space security in 2003 with respect to this indicator.



LITTLE OR NO EFFECT

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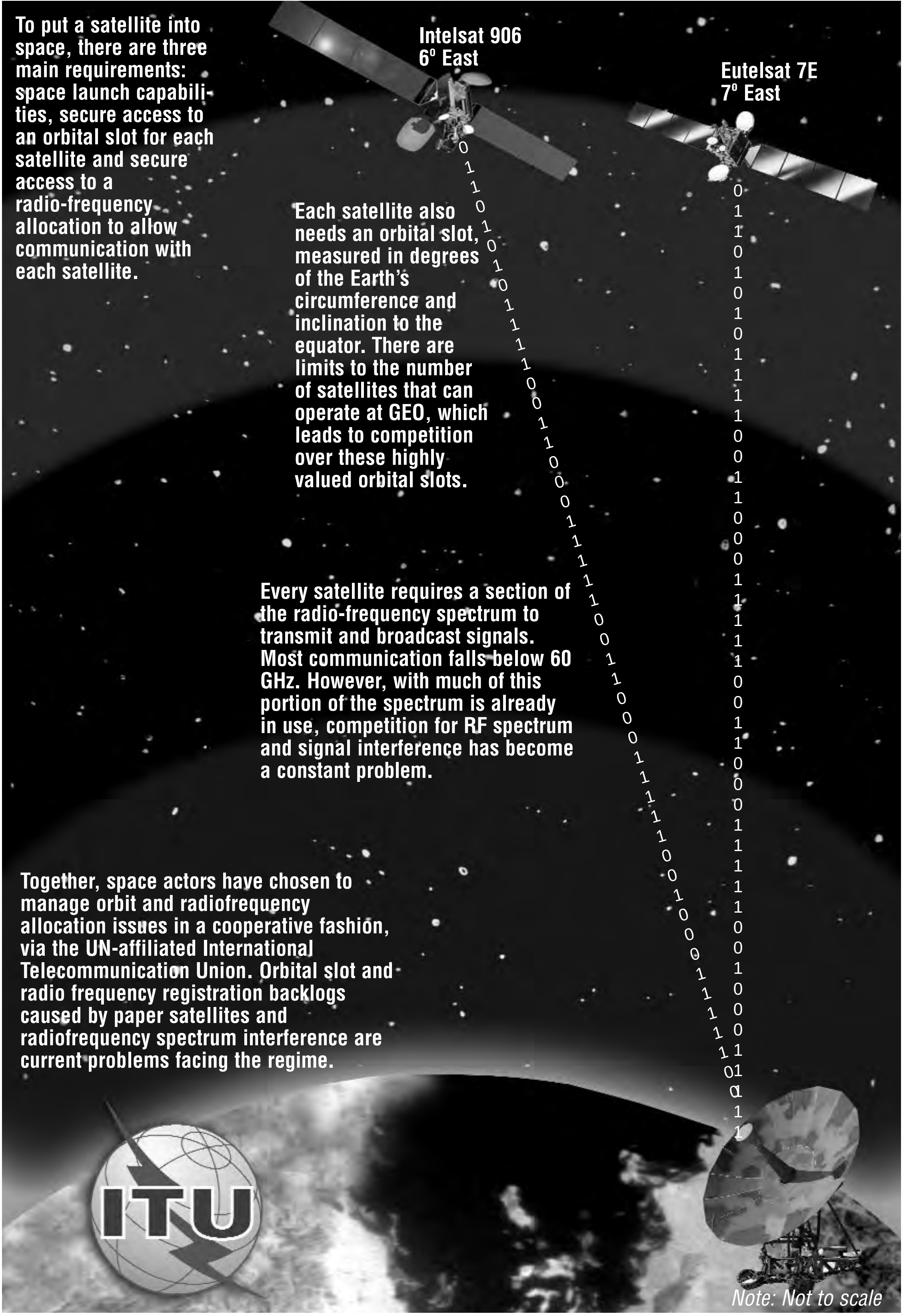
Figure 2-1



To put a satellite into space, there are three main requirements: space launch capabilities, secure access to an orbital slot for each satellite and secure access to a radio-frequency allocation to allow communication with each satellite.

Each satellite also needs 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.

Every satellite requires a section of the radio-frequency spectrum to transmit and broadcast signals. Most communication falls below 60 GHz. However, with much of this portion of the spectrum is already in use, competition for RF spectrum and signal interference has become a constant problem.

Together, space actors have chosen to manage orbit and radiofrequency allocation issues in a cooperative fashion, via the UN-affiliated International Telecommunication Union. Orbital slot and radio frequency registration backlogs caused by paper satellites and radiofrequency spectrum interference are current problems facing the regime.

Note: Not to scale

2

This chapter assesses trends and developments related to international cooperation and conflict in the allocation and use of orbital slots and radio frequency spectrum by space actors, including compliance with existing norms and procedures developed by the International Telecommunication Union (ITU).

The use of space to station a satellite for civil, commercial, or military applications requires the allocation of two key resources—an orbital slot within which to place the satellite, and a portion of the radio frequency spectrum to enable communications with the satellite to ensure its effective operation. Both radio spectrum and orbital slots are recognized by the international community through the ITU Convention as "limited natural resources" given their finite number and indivisible nature.[1] Because space is considered, under the Outer Space Treaty, as open to everyone and belonging to no one, the allocation usage of these two limited resources has to be negotiated among space-faring powers. Indeed, space actors have cooperatively managed orbital slot and spectrum allocation issues through the ITU since 1963.

Figure 2-2
Eutelsat's Eurobird 1 was involved in an orbital slot dispute in 1999. Countries such as Tonga, Indonesia, the US, China, Thailand, the UK, Russia, Mexico, and the Netherlands have all been involved in recent orbital slot disputes.

A satellite's orbit determines the types of services it can best provide. LEO is often used for remote sensing, and MEO is the home of critical navigation systems such as the US Global Positioning System and the anticipated European Galileo system. Most communications satellites are in GEO, as are most weather satellites. Satellites in GEO present the greatest resource allocation challenges, as there are only about 180 orbital slots along the prime equator orbital path and satellites are required to maintain at least 2 degrees of separation to avoid signal interference with other satellites.

The degree to which space resource allocation issues are addressed in a cooperative manner directly affects the ability of space actors to access and use space, and hence space security. Growing numbers of space actors, particularly in the communications sector, has led to more competition and friction over orbital slot allocations. However, there are strong incentives for space users to cooperate in spectrum usage and slot allocation—if only to protect the functionality of their own assets. Further, there are positive signs that the international telecommunications community is increasingly focused on potential long-term problems and working to develop technical, operational, and process-oriented methods of avoiding them.

BACKGROUND

The RF Spectrum

The RF 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 (the wider the band, the more information can be transmitted). Satellites carry transponders to receive (uplink) and then amplify and retransmit (downlink) signals in certain frequency bands, which can carry unofficial letter designations. In terms of strictly communication satellites, at the low end of the spectrum the L-band (1-2 gigahertz) and S-band (2-4 gigahertz) transponders are used for mobile phones, ship communications, and messaging. The C-band (4-8 gigahertz) is widely used by commercial operators to provide services such as telephony across wide areas, and the Ku-band (12-18 gigahertz) is used to provide connections between users. The Ka-band (27-40 gigahertz) is now being used for broadband communications. The Ultra-High Frequency (UHF), X-, and K-bands (240-340 megahertz, 8-12 gigahertz, and 18-27 gigahertz, respectively) are reserved for the United States military.[2]

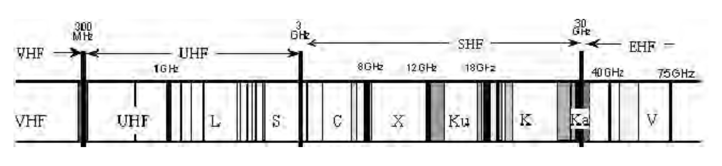


Figure 2-3
Popular bands in the RF spectrum.

While the RF spectrum runs from about 3 kilohertz to 300 gigahertz, most communication falls below 60 gigahertz because of the power requirements, costs, and technology limitations for communications at higher frequencies. Therefore, users are competing for a relatively small portion of the spectrum—with demand greatest for spectrum under 3 gigahertz. However, much of this portion of the spectrum is already in use.[3] Additionally, the number of satellites operating in the 7-8 gigahertz band commonly used by GEO satellites has been growing rapidly over the past two decades.[4] These GEO satellites pose the greatest problem in terms of potential spectrum interference, as they occupy almost the same location in space.

Stationing satellites too close to one another can result in signal interference. While interference is not currently at epidemic proportions, is it a daily fact of life for satellite operators. In fact, in a recent article, AsiaSat's general manager of engineering noted that "frequency coordination is a full-time occupation for about 5% of our staff, and that's about right for most other satellite companies."[5]

Still, an official at another satellite operator, New Skies, noted that while "interference is a daily occurrence…satellite operators monitor their systems around the clock and can pinpoint interference and its source fairly easily in most cases."[6] Indeed, there are a number of measures available to mitigate the potential for signal interference. The simplest of these measures is to ensure that all actors have access to reasonable and sufficient amounts of spectrum. For example, in the US an agreement was reached in July 2002 to release military-reserved spectrum from 1,710-1,755 megahertz to the commercial sector. This space had been requested by the commercial arena for third-generation (3G) wireless communications, and is to be vacated by 2008.[7]

Other measures are technological, such as frequency hopping, lower power output, and laser technology. Modern receivers can be made to tolerate higher levels of interference—meaning more users can share frequencies, thus greatly improving the situation according to experts. For example, the FCC is currently looking at creating receiver standards for TVs, wireless Internet devices, etc.[8] In addition, there is widespread research on using lasers for communications—particularly by the US military. The use of lasers for communication purposes, as opposed to less focused radio waves, would allow tighter placement of satellites, alleviating some of the current congestion.

Figure 2-4
A better satellite TV receiver standard is just one of the ways in which technological advances may help mitigate signal interference.

Orbital Slots and RF Complications

The other half of the limited resources equation is the orbital slot of a satellite and its effect on RF transmissions. Today's satellites operate in three basic orbital bands: Low Earth Orbit (LEO), Medium Earth Orbit (MEO), and Geostationary Orbit (GEO) (see I-05 Space Access for a more detailed explanation). There are about 620-plus operational satellites in these orbits: about 270 in LEO, up to fifty in MEO, and slightly more than 300 in GEO.[9] However, exact numbers are impossible to quantify due to the classified nature of many military satellites and the non-existence of any centralized tracking system for commercial and civil satellites, meaning that the actual figure could be significantly higher.[10]

A satellite's orbit determines the types of services it can best provide. As noted above, LEO is usually used for remote sensing, and MEO is the home of the US Global Positioning System (GPS) and its future double, the European Galileo. According to Boeing, 239 of the approximately 300 satellites in GEO are used for communications purposes (see Figure 2-5).[11] Satellites in all three bands must register for an orbital slot, or the orbital positions in space they will occupy along their trajectories. Slots for satellites in LEO and MEO, which orbit the earth every ninety minutes or more and pass over multiple regions, have a wide range of orbital trajectories available to them.

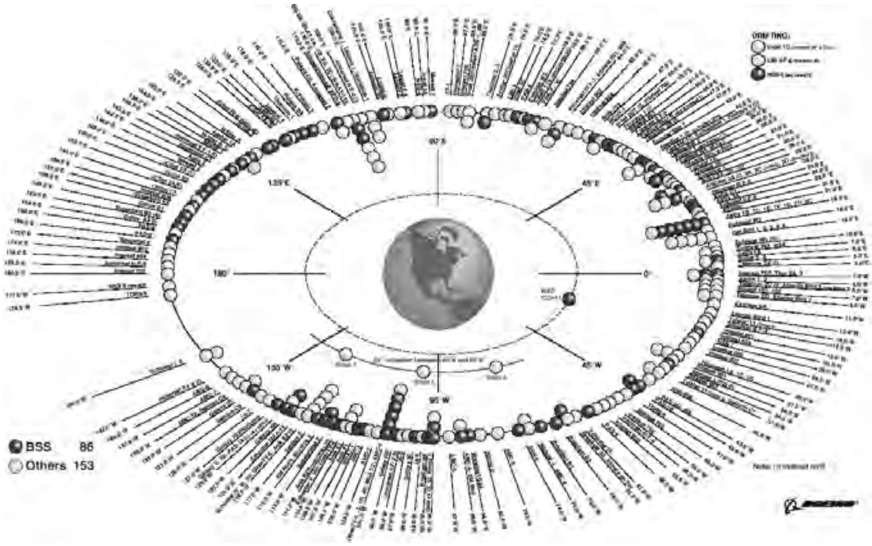


Figure 2-5
Current orbital slots of GEO communications satellites.

As noted above, however, GEO is unique in that the orbital movement of the satellite is synchronized with the earth's twenty-four-hour rotation so that the satellite appears to remain stationary over a single area on earth, eliminating the need for expensive tracking receivers.[12] This feature of GEO is the root of a number of complications. First, not all orbital slots are created equal. The best GEO slots are those located above or close to the equator, as this allows for a greater communications footprint. Satellites in an orbit with an inclination, for example, too far north of the equator may not be able, in the case of a North American-positioned satellite, to communicate with Argentina or Brazil.

Second, orbital slots are distributed according to available spaces along two halves of the earth's 360-degree circumference, resulting, for example, in Eutelsat's Atlantic Bird 1 at 12.5 degrees West, and Intelsat's IS-906 at 64 degrees East. However, around three-quarters of the earth's surface is water, with little demand for satellite communication in those regions. As a result, "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." Similar limitations are true for all geographic regions, and in the case of the US, this range of desirable slots is optimal for Canada, Mexico, and parts of Latin America as well, resulting in competition amongst these actors.[13]

Third, in order to avoid RF interference, GEO satellites are required to maintain at least 2 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.[14] This means that a maximum of 180 satellites could occupy the prime equator (0∞ degree inclination) orbital path. In terms of the most desired equatorial arc around the continental US, there is room for only thirty-eight satellites. In fact, according to the AsiaSat official, true spacing to avoid interference should be 5 degrees, as the 2 degree stipulation is based on restrictions on the size of the satellite's antenna and the power of the transmission. As the official noted "the FCC does this in the US [… but] the US is only one country."[15] GEO satellites must generate high power transmissions to deliver a strong signal to earth given their distance, in addition to the fact that many of them are transmitting high bandwidth signals such as television or broadband.[16] To make matters worse, current FCC practice stipulates that US direct broadcast satellites (DBS) must be spaced 9 degrees apart.[17]

However, as with the RF spectrum, there are mitigation measures for orbital slots which can help reduce the problem of competition and signal interference. First, the 2 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 for collision avoidance purposes, according to the FCC.[18]

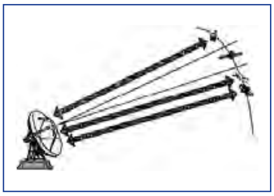


Figure 2-6
If satellites are stationed too closely together in orbit, a ground station may be unable to transmit or receive signals from the proper satellite.

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.[19] For example, the 91-92 degrees West slot in GEO has a Brazilsat, two Galaxy satellites and a Canadian Nimiq located there.[20]

Third, some experts note that it may be that satellite designs can in the future be further tweaked to allow frequency reuse and spectrum sharing. Finally, reducing satellite use may be an option for communications: for example, whereas in the 1980s satellite share of overseas telephony stood at 70 percent, today over 80 percent of this traffic is handled by undersea cables.[21]

Orbital Slot and RF Spectrum Regulation—The ITU

Space actors have chosen to manage the allocation of orbital slots and radio spectrum in a cooperative fashion within the ITU since 1963. While every nation has the right to manage the use of spectrum within its borders, when signals cross borders (almost always the case for space-based communications) international coordination becomes necessary—if only to avoid interference that would make one's own system useless. The ITU is open to governments, who join as member states by signing the ITU Convention, as well as private industry and groups, who join as sector members and may participate in ITU activities but do not have voting rights.[22] There are currently 193 member states and about 400 sector members.[23] The ITU, however, has no enforcement powers—

member states choose voluntarily to abide by ITU rules and regulations. Indeed, member states may decline to abide by the rules for national defense reasons, and, notably, nations may exempt systems used for military applications from the satellite registration process.[24] However, by signing the convention, members agree to resolve any conflicts about spectrum usage in good faith.

Figure 2-7
The ITU's first-come, first-served registration basis facilitated Greece and Cyprus's first accession to space in 2003, with the launch of the Hellas-Sat.

Under the ITU rules, a national government must apply to the ITU for registration to use certain frequency bands and specific orbital slots before launching a new satellite. Governments must apply for the registration even when the satellite owner or operator is a private company. Registrations are granted on a first-come, first-served basis if the usage will be consistent with the existing Table of Frequency Allocations, and if no other nation in view of the proposed satellite objects. A nation can object if the satellite's operations will interfere with other users of the same frequency bands within its borders.[25] The registration lasts for the life-time of the particular satellite in theory, but in practice nations often hang on to frequency allocations and orbital slots by replacing older satellites with new ones. As an illustration, Russia's ownership of the 40 degrees East GEO slot is now considered traditional.[26] The registration process is quite complicated: the multipart ITU filing can take three years to complete, bilateral national bureaucratic agreements another two, and the actual building of the satellite a final two or three years. As a result, applicants are given seven years before their registration lapses.[27]

Such a complicated and voluntary process naturally leads to disputes. The resolution of disputes about spectrum and slot allocations, rules, regulations, and technical standards is achieved in two fora: the quadrennial ITU Plenipotentiary Conference and the biennial ITU World Radiocommunications (WRC) Conference.[28] Conflicts over spectrum allocation and/or slot usage are resolved by detailed technical analyses of potential signals interference and through negotiations between the parties.[29] More specifically, two major problems perennially afflict the ITU process: slot competition and paper satellites.

Slot Competition

While most countries continue to play by ITU rules, there are some signs of discontent—especially among developing countries and in the hot Asian market. For example, Colombia continues to use most ITU and WRC meetings to reassert the so-called Bogota Declaration of 1976, wherein a number of equatorial countries try to lay claim to all geostationary slots because they are determined by reference to the equator. This claim has essentially been dismissed, but Colombia's continued politicking has prompted others (the United States, European countries, and Mexico) to make proclamations refusing to accept any such claims.[30]

There have also been numerous disputes over slot ownership, involving a wide variety of countries:

- Tonga-Indonesia-US-China. In 1992 the Indonesian Pasifik Satellite Nusantara (PSN) company placed a satellite into a vacant but registered Tongan GEO slot. Indonesia refused to abide by the ITU rule 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.[31] The two sides met in late 1993 and agreed to share the slot.[32] In 1996, Tonga leased the same slot to a Chinese company, which prompted PSN to jam the satellite.[33] Talks ensued, and ultimately the 1998 Asian financial crisis forced PSN to abandon its project. Perhaps most worrisome, however, 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.
- Thailand-China. In 1992 two companies were registered within a half-degree of one another, but through negotiations it was agreed that the Thai satellite would move to a new position. In 2002, the same two companies were again involved in a dispute, with the Chinese satellite now in orbit and the Thai one slated for launch in 2004.[34] The likely problem of interference has not yet been resolved.[35]
- UK-China-Thailand-Russia. Companies in these countries had several disputes in the mid-1990s in the 99-101 degrees East range.[36]
- Mexico-Netherlands. A dispute occurred between companies in these two countries in 2001.[37]

Figure 2-8
Numerous nations, both big and small, have been involved in recent slot disputes.

Paper Satellites

Another endemic problem to the ITU process is the subject of paper satellites, or satellites that do not exist but whose registration papers are submitted to the ITU in order for an applicant to either hold open a slot/frequency allocation for future use or for leasing to others.[38] For example, in 1988 Tonga registered with the ITU for sixteen slots in GEO over the Pacific—a move that led to cries of outrage from other nations interested in Pacific Rim slots. At the time, the sixteen slots were the last unoccupied slots in that region.[39] Tonga was awarded seven of the slots despite not having any satellites of its own until 2001.[40]

Paper satellite applications have caused an enormous backlog in the ITU system. As of late 2002, 1,200 applications were pending and 400-500 registration requests were being lodged per year.[41] Some developing countries have applauded Tonga's action, noting that the first-come, first-served policy levels the playing field with developed and mature space-faring powers.[42] Others, including the former director of the ITU's Radiocommunication Bureau, believe that this is a purely speculative abuse of the process which blocks legitimate users from access.[43] Indeed, in 2001 there were at least thirty slots in GEO that had more than one hundred filings from multiple countries.[44]

To combat this problem, the ITU has imposed larger cost recovery fees, which resulted in a “marked reduction” in filings in 2002 when the fees went into effect, with the time lag for applications consequently falling from 154 weeks to 129 weeks.[45] Furthermore, at the 2002 ITU Plenipotentiary Conference, its members adopted more stringent requirements for information on a system’s plan for operations including when it will be launched; and penalties for not meeting ITU deadlines, such as cancelling the filing if the registration fee is not paid in six months.[46]

2003 DEVELOPMENTS

Given the international nature of this indicator, most of the key 2003 developments adopted an international character. Still, key developments can be attributed to actions in the United States, the European Union, and other international bodies.

United States

New technologies continue to be developed to allow users to better share spectrum. In 2003 DARPA issued over $13 million worth of tenders for Phase II of its NeXt Generation Communications Program, known as XG. XG will allow a number of users to share wireless spectrum across a wide band of frequencies. In simple terms, this would allow a device to hop through the frequency to find unused bits and pick out where to broadcast from at any one time. DARPA expects to have prototypes by 2006, but the technology is in its earliest stages.[47]

On the demand front, the US military indicated that its demand for spectrum would only continue to grow. “We’ve got no clear view of when it might slow down,” said Admiral James Ellis, commander of US Strategic Command, in an August interview with *Space News*. “I believe that it will almost certainly never stop—the only question is the pace at which it continues to grow.”[48] In terms of what this will produce, Colonel John E. Hyten, now US Air Force chief of space control, warned that “Conflicts in this area are beginning to grow as crowding increases due to the finite number of unoccupied geostationary slots and the limited amount of unallocated spectrum.”[49]

Also in 2003, the potential for future conflict among users, coupled with the bureaucratic tangle, led to the initiation in June of an interagency task force led by the Commerce Department to formalize a road map for managing spectrum by June 2004. This task force will need to examine the increasing number of disagreements between the US military and commercial industry as new technologies emerge with new spectrum demands, such as wireless fidelity (Wi-Fi) that allows laptop computers and other devices to transmit data wirelessly.[50]

In terms of RF spectrum, another Department of Defense-industry agreement was reached in January 2003 allowing Wi-Fi providers to use a range of spectrum around the 5 gigahertz band used by military radar. The US Department of Defense feared interference from the popular new technology, but an agreement was made based on technical requirements for frequency hopping by the wireless devices when military radars are operating in their range, and limits on power output.[51] Further concessions were made in November, with 45 megahertz of frequency surrendered. The newly commercialized frequency is to be auctioned off to commercial bidders in early 2004 to compensate the Pentagon for the cost of moving to new spectrum—although high transition costs may delay the auction.[52]

Figure 2-9
A DoD-industry agreement in January will allow Wi-Fi providers to use the 5 GHz band, while a further 45 MHz of frequency was surrendered in November.

SES-Americom and DirecTV both applied to the FCC to have the 9 degree DBS spacing rule reviewed and changed. SES-Americom applied to place a DBS at the 105.5 degrees West location. The FCC agreed to hold consultations on the matter and may revisit this policy, creating more room in the American orbital slot market.[53]

In international application, the US attempted to take this agreement to the ITU in hopes of persuading other nations to follow the same course—obviously, the US military operates all over the world and can be just as affected by other nation's decisions on spectrum usage. The United States successfully raised its plan for allowing Wi-Fi use of the 5 gigahertz band at the June 2003 WRC meeting.[54]

European Union

Other nations are also concerned about protecting spectrum usage from interference. During the 9 June - 4 July 2003 World Radiocommunication Conference (WRC-2003), the European Union was seeking to protect frequencies assigned for 3G communications from interference from Asian satellites. Additionally, there has been an ongoing dispute at recent WRC meetings between the European Union and its Arab neighbours regarding the rules for television broadcast signals.[55]

This year was also notable for developments in the resolution of one of the key current spectrum allocation disputes: the US-EU conflict over the Galileo navigation system. While some of this dispute is purely at the political and industrial level, the US military has expressed concerns over the planned frequency band for Galileo's secure, encrypted service (ostensibly for EU law enforcement services, but also exploitable by European militaries), which is the same as that being planned for an

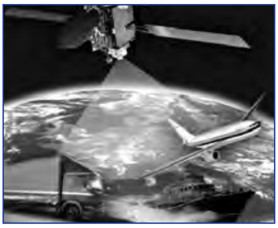


Figure 2-10
In July the US and the EU reached an accord on how to allow Galileo to use the same 1,164-1,215 MHz band as GPS.

upgrade to the US GPS's military signal, called M-Code.[56] The use of the same frequency band could make it difficult for the US military to jam Galileo service to an enemy nation during a military conflict, because of the possibility of interfering with GPS's own signals.[57] On 4 July the two sides reached an accord on the outlines of a technical agreement on how to allow Galileo to use the same 1,164-1,215 megahertz band as GPS.[58] However, the US and EU failed to completely resolve the M-code issue, despite technical expert meetings throughout 2003.[59] While European officials have been insisting jamming would be possible even with some overlay, US officials continue to reject this idea.[60] As of the end of 2003, this spectrum problem remained unresolved.

Other International Bodies

The US, EU, and Russia were able to agree to a new technical standard for how to manage interference with each other during the WRC-2003 meeting, along with new regulatory provisions for coordination.[61] Also at the WRC-2003 meeting, there was a contentious debate around a proposal by Iran to block a country from continuing to use an orbital slot/frequency allocation after the end of the lifetime of the first satellite so registered. "This turned out to be one of the most serious issues to reach the plenary with no resolution," noted a report on the meeting by the European Radiocommunications Office.[62] Iran wanted a time limit on slots of twenty to thirty years, but many other actors wanted no time limits, including the Europeans and the United States. The WRC essentially went along with no time limit policy, although it accepted wording proposed by Australia that specified that slot allocations are not "perpetual."[63]

In terms of the ITU, the aforementioned recent improvements in the satellite filing process were beginning to show dividends in 2003. From January to March 2003, some ninety-eight applications for spectrum allocation were withdrawn, reducing the registration backlog.[64]

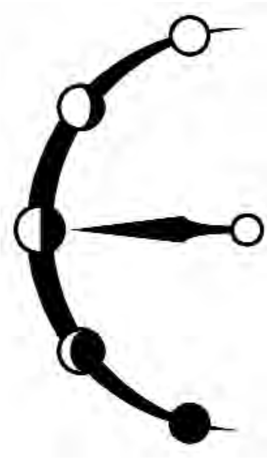
SPACE SECURITY SURVEY 2003: KEY ASSESSMENTS

Space Security 2003: Survey Results

Space Security Survey (20/10/2003-14/11/2003)		Space Security Working Group (24/11/2003-25/11/2003)	
Question: Taking into account your views on developments on both the allocation of orbital positions and radio frequencies in the past year, how have overall changes in this area affected space security?		*Question:* In your view, space security with respect to this indicator has been...?	
Enhanced:	2	Enhanced:	0
Somewhat enhanced:	16	Somewhat enhanced:	1
Little or no effect:	**56**	**Little or no effect:**	**16**
Somewhat reduced:	17	Somewhat reduced:	6
Reduced:	6	Reduced:	0

- The dramatic growth in demand for radio-frequency allocations and orbital slots in GEO continued, largely related to competing commercial and military demands. However, significant steps were undertaken to address the growing pressures on these scarce resource by reforming procedures within the International Telecommunication Union for allocating radio-frequency and orbital slots.
- The US-EU dispute over Galileo radio-frequency allocation provided an example of the potential for future conflicts over space resource allocations.

There was little or no effect on space security in 2003 with respect to this indicator.



LITTLE OR NO EFFECT

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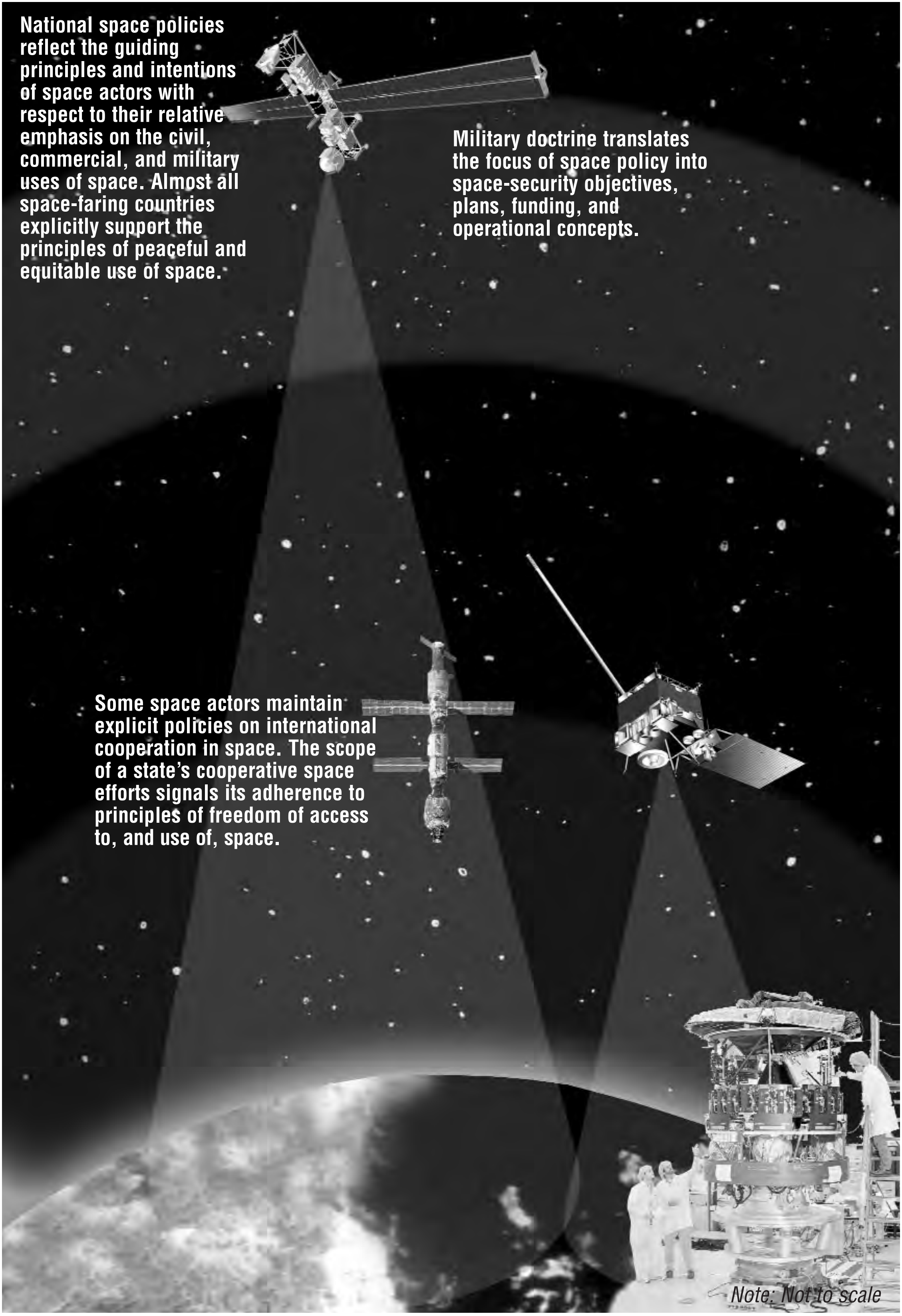
[63] “Report on WRC-03 (Geneva, 9 June-4 July 2003), European Radiocommunications Office, 29 July 2003, p.15. Available at http://www.ero.dk/wrc-03.

[64] Gerry Oberst, “Regulatory Review: ITU Satellite Filing Fees – The Bill Is In The Mail,” *Via Satellite*, 1 June 2003.

Figure 3-1



National space policies reflect the guiding principles and intentions of space actors with respect to their relative emphasis on the civil, commercial, and military uses of space. Almost all space-faring countries explicitly support the principles of peaceful and equitable use of space.

Military doctrine translates the focus of space policy into space-security objectives, plans, funding, and operational concepts.

Some space actors maintain explicit policies on international cooperation in space. The scope of a state's cooperative space efforts signals its adherence to principles of freedom of access to, and use of, space.

Note: Not to scale

3

This chapter assesses trends and developments in national space security relevant policies and doctrines. This includes 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. This chapter also assesses national military space policies and doctrines through which national space policies are translated into military space capabilities. National civil and commercial space developments are examined in chapters I-06 and I-07 respectively.

The national space policies of major space-faring states (China, Europe, Russia, and the US) are generally consistent in terms of their principles and objectives. Almost all space-faring countries 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 economic, social, scientific, and technological development.[1] Thus, such policies can be said to enhance space security to the extent that they support forms of access to and uses of space by an actor which do not have a negative impact upon the abilities of others to enjoy similar types of access and use.

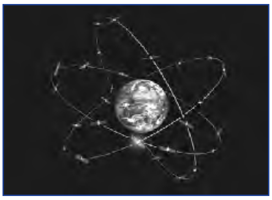


Figure 3-2
National space policies outline how actors view access to and the use of space, both for themselves and for others.

Some space actors also have national military space doctrines that support the development of specific military space applications such as navigation, communications, intelligence, surveillance, reconnaissance, or meteorological capabilities. It is noteworthy in this regard that almost all states support the annual UN General Assembly resolution that calls for the prevention of an arms race in outer space. However, it is also the case that US military space doctrine has begun to emphasize the development of capabilities to deny the freedom of action in space of a potential adversary, suggesting a potential negative impact upon space security.

Some space actors also maintain explicit policies on international cooperation in space with the potential to exert a 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 an interest in maintaining peaceful and equitable uses of space.

BACKGROUND

United States

National Space Policy

The US's 1996 *National Space Policy* recognizes the US as leading the world in the exploration and use of space, and declares itself "committed to the exploration and use of outer space by all nations for peaceful purposes and for the benefit of humanity."[2] It views access to and the use of space as central for preserving peace and advancing American civil, commercial, and national security interests.[3]

US national space policy has five major goals which provide an illustration of its relative focus on civil, commercial, and military space objectives (see Box 3-1).[4] While the US maintains a commitment to space access for all for peaceful purposes, it defines peaceful purposes as allowing "defense and intelligence-related activities in pursuit of national security and other goals."[5] Thus, US policy argues that national security space activities contribute to US national security by providing the means to counter space systems and services used for hostile purposes.[6]

Box 3-1

US National Space Policy: Major Goals

- Enhance knowledge of the earth, the solar system, and the universe through human and robotic exploration;
- Strengthen and maintain the national security of the United States;
- Enhance the economic competitiveness, and scientific and technical capabilities of the United States;
- Encourage state, local, and private sector investment in, and use of, space technologies; and
- Promote international cooperation to further US domestic, national security, and foreign policies.

Military Doctrine

US military space doctrine reflects a growing interest in space control, the ability to ensure "freedom of action in space for friendly forces while, when directed, denying it to an adversary."[7] This interest can be traced to perceptions of the vulnerability of US space assets. For example, the 2001 US Space Commission warned that if the US is "to avoid a 'Space Pearl Harbour' it needs to take seriously the possibility of an attack on US space systems."[8] US military space doctrine also reflects concerns about US vulnerability to ballistic missile attacks.

This sense of vulnerability has fuelled an active debate regarding the best way to assure the security of US space assets. Some advocate the development of robust space control capabilities, including enhanced protection, active defence systems, and space-based counter-space weapons. Others advocate enhanced protection and similar measures, but oppose the deployment of weapons in space.[9] There is also an ongoing debate regarding how best to defend the US against ballistic missile attack, with some supporting a limited system of ground- and sea-based interceptors, and others a more ambitious system including ground-, sea-, air-, and space-based interceptors.

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),[10] official US military space doctrine has remained focused primarily on force enhancement as reflected in the 1999 Department of Defense *Space Policy.*[11] The authoritative statement of joint doctrine, Joint Publication 3-14, also reflects a continuing emphasis on traditional force enhancement or combat support operations. With respect to space control, Joint Publication 3-14 emphasizes reversible and non-destructive approaches.[12]

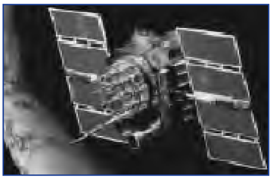


Figure 3-3
One side of the military space doctrine debate in the US can be found in documents such as *US Space Command Vision for 2020* that advocate the development of capabilities to control the access to and use of space by others.

International Cooperation

The US has the most to offer to international cooperative space efforts, and 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."[13] 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.[14] It also seeks to enhance relations with US allies and Russia, while supporting initiatives with emerging space-faring nations.[15] 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.[16] Within these parameters it is clear that the US has significantly increased the diffusion of capabilities to access and use space, increasing the number of actors with an interest in maintaining peaceful and equitable uses of space.

Russia

National Space Policy

Russian national space policy is outlined in *The Foundations of Russian Policy in Space Research for up to 2010*. A key part of this plan is the development of Russian space launching centers for various orbits.[17] The development of this launch potential also carries commercial opportunities, as it would allow Russia to increase the number of annual foreign and commercial satellite launches. Russian national space policy also prioritizes the development of modern telecommunications technologies as an integral part of securing Russia's national interests.[18] Russia's space program and launching capabilities are one of the few areas of the military-industrial complex that provide reliable sources of income. Thus, increased importance is being placed upon the development of capabilities for launching civilian assets into space.

Military Doctrine

Figure 3-4
One of the main thrusts of Russian national space policy is the development of launch capabilities to ensure domestic access to space and the generation of commercial revenues.

Russian military space doctrine echoes the national space policy claim that space is critical to technological advancement and commercial opportunity. In all of its military doctrine documents since 1992, Russia has expressed concerns that attacks on its early warning and space surveillance systems would represent a direct threat to its security.[19] Therefore, a basic Russian national military space policy security objective is the protection of Russian space systems including ground stations and assets in orbit.[20] These concerns derive from Russia's understanding of the nature of modern war, which it assesses is increasingly becoming dependent upon space-based force enhancement capabilities.[21]

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 the development of cheaper and more efficient information technology systems.[22] The second priority is to upgrade the Russian nuclear missile attack warning system. It is expected that the first of the anticipated new space systems would be brought on line by 2007. Together, these new developments are seen as having a critical role in guaranteeing Russia's free access to space.[23] Russia has clearly expressed grave concerns 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.[24] Russia has actively argued for the conclusion of a multilateral treaty prohibiting the deployment of weapons in space.

International Cooperation

Russia is deeply engaged in cooperative international space activities, arguing that international cooperation is more rational and expedient in the field of space exploration than breakthroughs by separate states.[25] The International Space Station is seen by Russian officials as a good example of this strategy. The Russian-American Observation Satellite

Program (RAMOS), designed to detect the launch of ballistic missiles, is another example of a Russian cooperative space effort, although work on this initiative has been stalled since 2002. Under the most recent restructuring of the program, Russia would be responsible for building, launching, and operating two satellites which would carry American-built infrared sensors.[26] Russia has also undertaken cooperative space ventures with France, Germany, Canada, China, India, Bulgaria, Hungary, Pakistan, Portugal, Israel, and the ESA on various occasions.[27] Thus, like the US, Russian space cooperation activities have tended to support the diffusion of capabilities to access and use space, thereby increasing the number of space actors with an interest in maintaining peaceful and equitable uses of space.

China

National Space Policy

China's national space policy argues that space applications are directly related to the tasks of development and modernization and exert a profound influence on any modern society.[28] The stated goals of China's space activities are to explore outer space, and learn more about the cosmos and the earth; to utilize outer space for peaceful purposes, promote mankind's civilization and social progress, and benefit the whole of mankind; and to meet the growing demands of economic construction, national security, science and technology, development and social progress, protect China's national interests, and build up its comprehensive national strength.[29] China is reportedly quite satisfied with the six telecommunications, earth resources, and meteorological satellites it has developed and launched in recent years, which it sees as having generated remarkable social and economic returns.[30]

Figure 3-5
Development and modernization are two key objectives of the Chinese national space policy.

Military Doctrine

China maintains a public commitment to the peaceful use of outer space in the interests of all mankind.[31] However, China's military space doctrine appears to be influenced by their assessments of US space-based force enhancement capabilities, including space-based missile defenses and what China perceives to be America's increasingly aggressive pursuit of space dominance and space control.[32] The official Chinese position is that space security will be undermined rather than enhanced by the weaponization of space, and that weaponization will lead to a costly and destabilizing arms race in space. They also believe that such an arms race 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 their case for such a multilateral treaty within the Prevention of an Arms Race in Outer Space (PAROS) talks at the UN Conference on Disarmament.[33]

Unlike Russia, however, China does not seem to be entertaining the possibility of Sino-American space cooperation as a way to mitigate the effects of US space dominance. Some observers suggest that space is becoming a central focus of Chinese strategic thinking and that it is working to develop robust space-control capabilities, including anti-satellite systems.[34] Official US documents have expressed concerns at what appear to be Chinese intentions to "concentrate on intensifying research of the key technologies in anti-satellite weapons that attack ground and space bases, and as quickly as possible develop one or two anti-satellite weapons that are useful as a deterrent against enemy space systems, in order to gain the initiative in future wars."[35] Others have assessed that while basic research on anti-satellite technologies has been underway in China since the 1980s, evidence of China's commitment to developing an operational anti-satellite capability remains ambiguous and "serious questions remain about their technical capability and political will to undertake such a costly program."[36] 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.

Figure 3-6
Artist's conception of the Chinese-Brazilian CBERS-2 in orbit.

International Cooperation

While China concedes that it will actively promote international exchanges and cooperation, it has clearly stated that they must be carried out according to the principles of independence, self-reliance, and self-renovation: "China shall rely on its own strength to tackle any key problems and make breakthroughs in space technology."[37] 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, it shall be combined organically with technology import on the principles of mutual benefit and reciprocity.[38]

China has emphasized Asia-Pacific regional space cooperation. In 1998, regional space cooperation led to the signing of the Memorandum of Understanding on Cooperation in Small Multi-Mission Satellite and Related Activities.[39] China has also pursued space cooperation with large and small space-faring states, such as the US, Italy, Germany, Britain, France, Japan, Sweden, Argentina, Brazil, Russia, Ukraine, and Chile. China is also collaborating with Brazil on a series of earth resources satellites, with the first satellite (CBERS-1) being successfully launched by China in 1999.[40]

Europe

National Space Policy

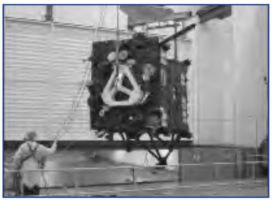


Figure 3-7
Space science features prominently in the national space policies of European states.

While it difficult to argue that there is a "national" European space policy, there is a broad consistency in the views on such issues among the five major European space actors—France, Germany, the UK, the European Space Agency, and the European Union itself. French space policy emphasizes the role space can play in strengthening a country's sovereignty and independence, with space serving as a motor for economic progress in telecommunications, navigation, earth observation, and general scientific research. National and collective defense are also prioritized by French space policy.[41] Germany has tended to devote its space attentions to industrial and technological development and competitiveness, focusing its efforts on promoting excellence in scientific research and the development of commercial applications.[42]

From the 1970s onwards, UK space efforts have largely focused on developing a cutting edge telecommunications satellite industry.[43] Current UK space policy is outlined in the 1999 *United Kingdom Space Strategy, 1999-2002: New Frontiers*. Five objectives formed the basis of UK space strategy: to help industry maximize profitable business opportunities in the development and exploitation of space systems which improve the quality of life and enhance choice for consumers; to foster the development of innovative technology, its commercial exploitation, and its application in research; to pursue the highest quality astronomy and space science; to improve our understanding of the earth's environment and natural resources; and to communicate the results and their significance to a broad audience.[44]

ESA's priorities are earth scientific research, space exploration, the development of satellite-based technologies and services, and the promotion of European industries.[45] The EU considers the provision of satellite telecommunications as an important unifying device through the strengthening of economic growth, job creation, and competitiveness.[46] The EU also sees space technologies as being useful to combat poverty and foster growth in the developing world through monitoring, increased access to information, and resource and environmental management.[47]

Military Doctrine

French military space doctrine recognizes that space plays a primordial role in military informatics and support. UK military space doctrine calls for greater satellite use for communications, intelligence, target acquisition, and reconnaissance, with emphasis on small satellites for both civil and military service requirements. ESA has traditionally focused on civil uses of space, a role mandated by the reference in its statute to "exclusively peaceful purposes."[48] Still, ESA considers itself to be free to launch and implement space programs for defense and security purposes, should its members so desire.

The EU's declarations regarding its desire to assume a larger role in international affairs can only be achieved through space assets such as global communications, positioning, and observation systems.[49] While most EU space capabilities have been focused on civilian use, there is an increasing awareness of the need to strengthen dual-use capabilities. According to the EU, "[c]reating 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."[50] The EU *Green Paper* on European Space Policy suggests that it will work to strengthen and enforce international space law, and will work to develop an effective treaty prohibiting the deployment of space weapons.[51]

International Cooperation

Figure 3-8
The Mars Express spacecraft was built with parts from all fifteen ESA members.

International cooperation is a key focus of the national space policies of European actors. Germany and the UK both have extensive cooperative ventures with the US. The ESA facilitates European space cooperation by providing a platform for discussion and policy making for the European scientific and industrial community.[52] 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."[53] The EU clearly believes that the long-term independent access to space is important to attaining various policy goals. 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.

Other Actors

India's national space policies have focused largely on telecommunications and developmental capabilities, although military applications of space assets have also featured prominently.[54] Like most space-faring states, India remains committed to the peaceful and equitable use of space. It also seems to have expressed little concern about the protection of its space assets.

Brazil's national space policy has concentrated on enabling Brazilian society to benefit from new developments in space science and technology. Brazil has enunciated four main foci for its space program: increasing Brazil's autonomy in a number of strategic areas; providing the means for Brazilian industry to participate and become competitive in the space area; encouraging the development and dissemination of space technology; and contributing to the expansion of scientific knowledge.[55] Brazil has been involved in cooperative space efforts and the International Space Station.

Canada's national space objectives include efforts "to promote the peaceful use and development of space, to advance the knowledge of space through science and to ensure that space science and technology provide social and economic benefits for Canadians."[56] Canadian military space policy recognizes the need to ensure the security of space assets while opposing the weaponization of space. Canada participates actively in the ESA decision-making process, as well as many ESA programs, especially in the spheres of satellite communications, earth observation, and generic space technology development.[57]

2003 DEVELOPMENTS

Key developments in national space policies, military space doctrines, and cooperative space ventures took place in the United States, Russia, Europe, and India in 2003.

United States

In November 2003 the US Air Force released its *Transformation Flight Plan*, a document which provides timelines for the development of specific military space capabilities.[58] This document is significant in that it calls for the development of both "active, on-board" protection capabilities and "full spectrum, sea, air, land and space-based offensive counterspace systems capable of prevention of unauthorized use of friendly space services and negating adversarial space capabilities from low earth up to geosynchronous orbits."[59] The document also states that "the focus, when practical, will be on denying adversary access to space on a temporary basis," suggesting that while reversible/non-destructive approaches are to be preferred, should military requirements dictate, destructive approaches will be developed. *Tranformation Flight Plan* envisages that most of the ASAT and space weapon projects will not be ready for deployment until 2015 at the earliest.[60] It should be noted, however, that *Transformation Flight Plan* reflects the views of the US Air Force and does not represent official US government policy.

Figure 3-9
The USAF *Transformation Flight Plan*, while not official US policy, speculates about increasing American capability to deny space access to others.

Russia

The October 2003 *White Paper* on Russian military doctrine acknowledged the increased importance of space-based assets in modern warfare. It argued that in taking advantage of space applications, “special attention must be devoted to the employment of electronic topographical maps” because the use of such systems could increase the effectiveness of the employment of troops and weapon systems by 50-70 percent.[61]

Europe

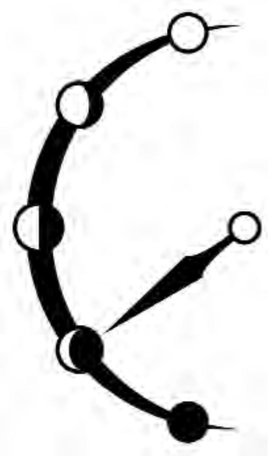
Following the release of its *Green Paper* on European Space Policy earlier in 2003 the EU published a *White Paper* articulating its vision of how the Union should use space to achieve its economic, political, security, and defense objectives as well as to provide increased capacities to use space to support terrestrial military operations.[62] Among its recommendations, the paper calls for the development of independent EU capabilities in the following key areas: surveillance/global monitoring (to support treaty verification, monitoring of borders, and the anticipation and management of humanitarian crises), signals intelligence, early warning, and space surveillance. Concerns about this strategy have been raised by the ESA and the European scientific community, who believe that the ESA’s integration of military space applications would compromise what they see as the primary objective of the ESA—scientific space research.[63]

SPACE SECURITY SURVEY 2003: KEY ASSESSMENTS

Space Security 2003: Survey Results

Space Security Survey (20/10/2003-14/11/2003)		Space Security Working Group (24/11/2003-25/11/2003)	
Question: Taking into account your views on developments in both policies/doctrine and budgets in the past year, how have overall changes in this area affected space security?		*Question:* In your view, space security with respect to this indicator has been...?	
Enhanced:	2	Enhanced:	0
Somewhat enhanced:	13	Somewhat enhanced:	1
Little or no effect:	14	Little or no effect:	4
Somewhat reduced:	**42**	**Somewhat reduced:**	**20**
Reduced:	31	Reduced:	1

- Despite a general trend of continuity in national space security policies and doctrines supportive of the peaceful and non-aggressive uses of outer space, 2003 provided indications of growing support for space weaponization on the part of some actors, raising concerns about the sustainability of space security over the long term.
- While official US military space doctrine emphasized reversible and non-destructive means of pursuing space control, longer-range US military planning documents recommended that the US seek offensive counter-space capabilities.
- The announcement of the US Missile Defence Agency’s intention to place a test bed for space-based ballistic missile interceptors in orbit no earlier than 2012 represented a delay from previous estimates, but still raised concerns, as did the announcement that the Indian Air Force has started conceptual work on anti-satellite weapons. Although the Indian announcement was later officially retracted, concerns remained about their intentions, as well as those of other actors. For example, US defence officials assessed that China was likely working on anti-satellite weapons.



SOMEWHAT REDUCED

Space security had been somewhat reduced in 2003 with respect to this indicator.

ENDNOTES

[1] For a representative sample of policy statements see Brazil (http://www.inpe.br/english/about_inpe/mission.htm), the United Kingdom (http://www.bnsc.gov.uk), or India (http://www.isro.org).

[2] "National Space Policy," US National Science and Technology Council, US White House Fact Sheet, 19 September 1996. Available at http://www.ostp.gov/NSTC/html/fs/fs-5.html.

[3] "National Space Policy," US National Science and Technology Council, US White House Fact Sheet, 19 September 1996. Available at http://www.ostp.gov/NSTC/html/fs/fs-5.html.

[4] "National Space Policy," US National Science and Technology Council, US White House Fact Sheet, 19 September 1996. Available at http://www.ostp.gov/NSTC/html/fs/fs-5.html.

[5] "National Space Policy," US National Science and Technology Council, US White House Fact Sheet, 19 September 1996. Available at http://www.ostp.gov/NSTC/html/fs/fs-5.html.

[6] "National Space Policy," US National Science and Technology Council, US White House Fact Sheet, 19 September 1996. Available at http://www.ostp.gov/NSTC/html/fs/fs-5.html.

[7] Joint Publication 3-14 is all but silent on the space strike mission, stating only that "currently there are no space force application assets operating in space," p.x.

[8] "Report of the Commission to Assess United States National Security Space Management and Organization," 11 January 2001. Available at http://www.space.gov/docs/fullreport.pdf.

[9] For a discussion of the spectrum of views regarding space weapons see Peter L. Hays, "Current and Future Military Uses of Space." Available at http://www.unidir.org/bdd/fiche-article.php?ref_article=1989.

[10] *US Space Command Vision for 2020* and the *Long Range Plan* are available at http://www.fas.org/spp/military/docops/usspac. It is important to recognise that both documents represent the views of the US Space Command, and not of the US military or government as a whole.

[11] "Space Policy," US Department of Defense, Directive 3100.10, (Updated 9 July 1999), available at http://www.dtic.mil/whs/directives/corres/pdf/d310010_070999/d310010p.pdf, and "Joint Doctrine; Tactics, Techniques, and Procedures for Space Operations," US Department of Defense, Joint Publication 3-14, available at http://www.fas.org/spp/military/docops/defense/JP3-14Excerpt.htm.

[12] Joint Publication 3-14 is all but silent on the space strike mission, stating only that "currently there are no space force application assets operating in space," p.x.

[13] "National Space Policy," US National Science and Technology Council, US White House Fact Sheet, 19 September 1996. Available at http://www.ostp.gov/NSTC/html/fs/fs-5.html.

[14] "National Space Policy," US National Science and Technology Council, US White House Fact Sheet, 19 September 1996. Available at http://www.ostp.gov/NSTC/html/fs/fs-5.html.

[15] "National Space Policy," US National Science and Technology Council, US White House Fact Sheet, 19 September 1996. Available at http://www.ostp.gov/NSTC/html/fs/fs-5.html.

[16] "National Space Policy," US National Science and Technology Council, US White House Fact Sheet, 19 September 1996. Available at http://www.ostp.gov/NSTC/html/fs/fs-5.html.

[17] "Russian Space Forces Commander Inspecting Svobodny Space Center," Interfax-AVN, 25 March 2003. See also, "Svobodny Cosmodrome Has Special Role in Russia's Space Programs - Space Troops Chief," Interfax-AVN, 14 April 2003.

[18] Government of the Russian Federation, "Russian Federation National Security Blueprint," Rossiiskaya gazeta, 26 December 1997, Section II, Defense.

[19] See Government of the Russian Federation, "The Basic Provisions of the Military Doctrine of the Russian Federation," FBIS-SOV 19, no. 222, 1993, Section 3.1. First Published: Rossiiskie vesti, 18

November 1992, p.1-2; Government of the Russian Federation, “Draft Russian Military Doctrine,” BBC Worldwide Monitoring, 1999, Section 1.5. First Published: Krasnaya zvezda, 9 October 1999, p.3-4; Government of the Russian Federation, “Russian Federation Military Doctrine,” Nezavisimaya gazeta, 22 April 2000, Section I.5; Russian Federation Ministry of Defence, “Russian Federation Ministry of Defence Brochure: Urgent Tasks of the Development of the Russian Federation Armed Forces,” Moscow, 2003, Section II, p.13.

[20] Government of the Russian Federation, “Draft Russian Military Doctrine,” BBC Worldwide Monitoring, 1999, Section 1.10.a. First Published: Krasnaya zvezda, 9 October 1999.

[21] Government of the Russian Federation, “Russian Federation Military Doctrine,” Nezavisimaya gazeta, 22 April 2000, Section II.3; Russian Federation Ministry of Defence, “Russian Federation Ministry of Defence Brochure: Urgent Tasks of the Development of the Russian Federation Armed Forces,” Moscow, 2003, Section IV, p.18-19.

[22] “Putin Reiterates Priorities in Developing Space Forces,” Interfax-AVN, 7 April 2003.

[23] “Svobodny Cosmodrome Has Special Role in Russia’s Space Programs - Space Troops Chief,” Interfax-AVN, 14 April 2003.

[24] Vladimir Putin, Andrew Gowers, Robert Cottrell, and Andrew Jack, “Transcript: Interview with Vladimir Putin, 13 December,” FT.com, 15 December 2001, p.2.

[25] “Russia May Cooperate with US in Space Programs,” *Itar-Tass*, 21 January 2004.

[26] “Status Report Requested of RAMOS Program,” *CDI Missile Defence Update*, no. 16, 2003.

[27] Russian Federation, Rosaviakosmos, “International Cooperation.” Available at http://www.rosaviakosmos.ru/english/ecoop.html.

[28] PRC Information Office of the State Council, “China’s Space Activities,” 2000. Available at http://english.peopledaily.com.cn/features/spacepaper/spacepaper.html.

[29] PRC Information Office of the State Council, “China’s Space Activities,” 2000. Available at http://english.peopledaily.com.cn/features/spacepaper/spacepaper.html.

[30] PRC Information Office of the State Council, “China’s Space Activities,” 2000. Available at http://english.peopledaily.com.cn/features/spacepaper/spacepaper.html.

[31] PRC Information Office of the State Council, “China’s Space Activities,” 2000. Available at http://english.peopledaily.com.cn/features/spacepaper/spacepaper.html.

[32] For a discussion, see William C. Martel and Toshi Yoshihara, “Averting a Sino-US Space Race,” *Washington Quarterly*, Autumn 2003, p.19-35.

[33] See the Chinese working paper “Possible Elements of the Future International Legal instrument on the Prevention of the Weaponization of Outer Space,” CD document CD/1645, 6 June 2001; and “Russia-China CD Working Paper on New Space Treaty,” CD document CD/1679, 28 June 2002.

[34] For an extended statement of this case see Larry M. Wortzel, “China and the Battlefield in Space.” Available at http://www.heritage.org/Research/AsiaandthePacific/wm346.cfm.

[35] “Annual Report on the Military Power of the Peoples’ Republic of China,” United States, Department of Defense, Washington D.C., 28 July 2003. Available at http://www.fas.org/nuke/guide/china/dod-2003.pdf.

[36] Phillip Saunders, Jing-dong Yuan, S. Lieggi, and A. Deters, “China’s Space Capabilities and the Strategic Logic of Anti-Satellite Weapons,” Monterey Institute of International Studies, 22 July 2002. Available at http://cns.miis.edu/pubs/week/020722.htm.

[37] PRC Information Office of the State Council, “China’s Space Activities,” 2000. Available at http://english.peopledaily.com.cn/features/spacepaper/spacepaper.html.

[38] PRC Information Office of the State Council, “China’s Space Activities,” 2000. Available at http://english.peopledaily.com.cn/features/spacepaper/spacepaper.html.

[39] PRC Information Office of the State Council, “China’s Space Activities,” 2000. Available at http://english.peopledaily.com.cn/features/spacepaper/spacepaper.html. Signatories include China, Iran, Republic of Korea, Mongolia, Pakistan, and Thailand.

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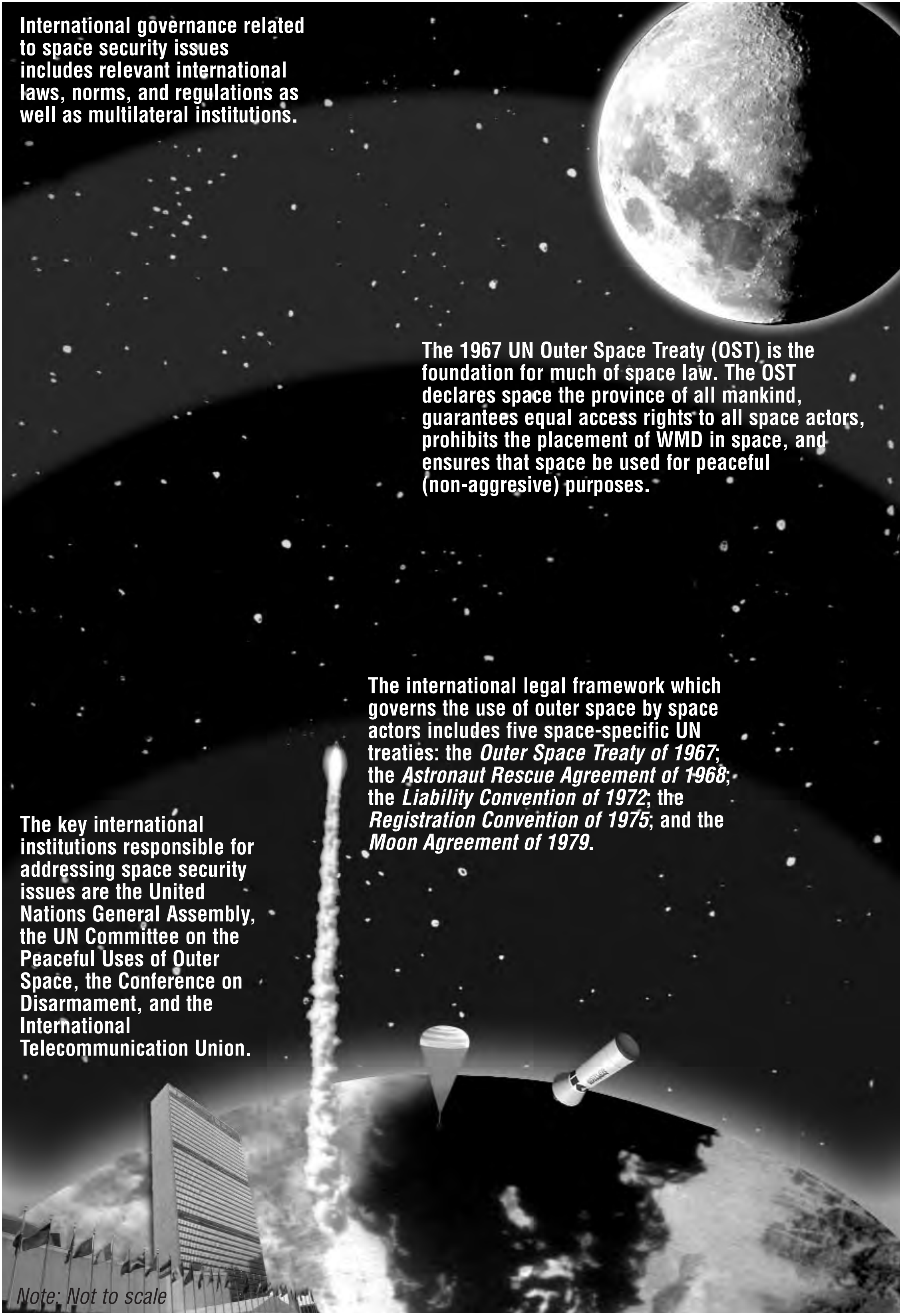
Figure 4-1



International governance related to space security issues includes relevant international laws, norms, and regulations as well as multilateral institutions.

The 1967 UN Outer Space Treaty (OST) is the foundation for much of space law. The OST declares space the province of all mankind, guarantees equal access rights to all space actors, prohibits the placement of WMD in space, and ensures that space be used for peaceful (non-aggresive) purposes.

The international legal framework which governs the use of outer space by space actors includes five space-specific UN treaties: the *Outer Space Treaty of 1967*; the *Astronaut Rescue Agreement of 1968*; the *Liability Convention of 1972*; the *Registration Convention of 1975*; and the *Moon Agreement of 1979*.

The key international institutions responsible for addressing space security issues are the United Nations General Assembly, the UN Committee on the Peaceful Uses of Outer Space, the Conference on Disarmament, and the International Telecommunication Union.

Note: Not to scale

4

This chapter assesses trends and developments with respect to space security relevant international norms and legal obligations, as well as trends and developments with respect to space security relevant international institutions.

There are two key space security relevant dimensions to the issues addressed by this chapter. The first is the international legal and regulatory framework that seeks to shape the uses of space. The foundation of this international legal framework is based on a series of UN initiatives, including the UN Charter itself, five UN treaties, four UN principles, and the UN-based International Telecommunication Union's (ITU) Convention. The key five UN treaties include: the Outer Space Treaty of 1967; the Astronaut Rescue Agreement of 1968; the Liability Convention of 1972; the Registration Convention of 1975; and, the Moon Agreement of 1979.[1]

Figure 4-2
Article IV of the OST prohibits any future moon bases of a military nature.

This legal framework establishes parameters including, but not limited to, the common ownership of space, the weaponization of space, and resource allocation. For example, the widely ratified Outer Space Treaty establishes that the uses of outer space "shall be carried out for the benefit and in the interests of all countries." This foundation is supported by additional multilateral and bilateral arms control and outer space agreements, such as the Comprehensive Test Ban Treaty or the Launch Notification Agreement, designed in part to address fears that space would become a zone of conflict.

The second key dimension of this indicator is the multilateral institutional context, which includes the various international organizations involved in managing and regulating the uses of space. Developments within institutions such as the UN International Telecommunication Union and the Conference on Disarmament (CD) are relevant to space security considerations as they provide the mechanisms through which space actors identify space security challenges, voice concerns over developments and trends, and attempt to resolve challenges to space security. Here, bodies including but not limited to the UN General Assembly (UNGA), the UN Committee on the Peaceful Uses of Outer Space (COPUOS), and the Conference on Disarmament attempt to resolve differences and discuss and draft new legislation.

BACKGROUND

The International Legal Framework

The United Nations

The most general UN document which pertains to space is the UN Charter.[2] The Charter establishes the 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).

Figure 4-3
The Outer Space Treaty is the Magna Carta of outer space, and emphasizes the peaceful and non-appropriative use of space.

More specifically, the five UN treaties noted above expound upon space issues in greater detail.[3] These treaties establish the fundamental rights of access to space as well as state responsibility regarding space activities. They also remove space from national appropriation and prohibit certain space military activities, such as the placing in orbit of objects carrying weapons of mass destruction. Four further UN principles discussed below also impact space conduct, while the ITU Convention regulates the allocation of limited space resources.

Box 4-1

Military Uses vs. Weaponization

The position maintained from the very beginning of the space age by the US is that the Outer Space Treaty's references to "peaceful purposes" should be interpreted as meaning non-aggressive.[4] The interpretation favored by Soviet officials equated "peaceful purposes" with wholly non-military ones.[5] State practice over the past forty years has generally endorsed the non-aggressive interpretation of the term. Thus, space assets have been used to guide munitions, identify and track troop movements, and allow lost soldiers to navigate their way to safety. These military uses of space have stopped short, however, of weaponization, which would involve the direct striking of targets from space, using conventional, nuclear, or exotic means.

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, it is important to note that the OST contains no verification or enforcement provisions. Article I declares that 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 and in accordance with international law."

Pursuant to Article II, outer space, including the moon and other celestial bodies, is not "subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means." Unlike terrestrial practice, then, space cannot be nationally appropriated and does not belong to a single entity.

Article III, however, confirms that general principles of terrestrial international law—including rules of customary law—and the UN Charter are applicable to outer space.[6] Therefore, the prevalent view is that Article 2(4) of the UN Charter applies to outer space and as a result it is unlawful for a state to interfere in a hostile manner with the space-borne assets of another state.[7] Nevertheless, should such hostile actions occur, a state can legally use force to defend itself pursuant to Article 51.[8]

Article IV contains the only provision of the OST dealing directly with military activities. Under paragraph 1 of this article, the contracting parties "undertake not to place in orbit around the Earth any objects carrying nuclear weapons or any other kinds of weapons of mass destruction, install such weapons on celestial bodies, or station such weapons in outer space in any other manner." While all areas of space are therefore protected from WMDs, paragraph 2 also stipulates that the "Moon and other celestial bodies" are to be used "exclusively for peaceful purposes," with even conventional military installations, weapons testing, and maneuvers expressly prohibited.

However, the OST does not expressly prohibit the development, testing, and deployment of conventional weapons in the expanses of outer space, nor does it prohibit the development, testing, and deployment of ground-based systems that can reach targets in space using conventional, nuclear, or directed-energy kill mechanisms. As a result, Article IV has often been cited to support the claim that all military activities in outer space are permissible, unless specifically prohibited by another treaty or customary international law. For example, the Soviet Fractional Orbital Bombardment System (FOBS) was not covered by the OST, but any new incarnations of a FOBS-type system are prohibited under the current SALT II Agreement. Finally, there has been some debate regarding the expression "peaceful purposes," with two different interpretations being advanced, namely, non-aggressive and non-military uses of space (see Box 4-1).

Article VI of the OST provides that states are internationally responsible for "national activities in outer space," including cases where activities are "carried on […] by non-governmental entities." The activities of non-governmental entities—such as the private sector—in outer space shall require "authorization and continuing supervision by the appropriate State Party to the Treaty." The importance of the common interest of all nations permeates the Treaty text. In particular, Article IX stresses that parties to the Treaty shall be guided by the principles of cooperation and mutual assistance in the exploration and use of outer space, and shall conduct their activities with due regard to the corresponding interest of all state parties to the Treaty. Article IX further requires state parties to undertake international consultations before proceeding with any activity that would cause potentially "harmful interference" with the "peaceful exploration and use" of outer space by other states. Since the term "harmful interference" is not defined in the Treaty, the question could be raised whether the words "harmful interference with activities in the peaceful exploration and use of outer space" also cover military activities in outer space. As of today, and as far as is publicly known, no state party has ever undertaken consultations pursuant to this provision.

Figure 4-4
Astronaut Alan B. Shepard is seen on the deck of the U.S.S. Champlain after the recovery of his Mercury capsule.

Rescue Agreement—This Agreement designates astronauts as "envoys of mankind," and as such accords them a kind of diplomatic immunity. Astronauts in distress are to be tendered assistance and rescued whether on sovereign or foreign territory. The Agreement stipulates that astronauts and their spacecraft are to be returned promptly to the launching authority should they land within the jurisdiction of another state party.

Liability Convention—This Convention establishes a two-tier liability system. In the first tier of cases, Article II specifies that any damages to a state's surface or air assets as a result of another state's space activities are to be compensated by the state that launched the offending object. In the second tier, Article III stipulates that damages to assets in space are to be compensated by the state at fault. In both these cases, the Convention reiterates that state parties remain responsible for the activities of their nationals and non-governmental entities. This obligation is most often fulfilled via regulations, national legislation, and licensing provisions, primarily via insurance requirements. However, the evolution in the use of outer space, which has become a more commercial and military-based environment, is challenging the liability structure of this convention. For example, in dealing with concerns regarding the commercial use of GPS signals, legal publicists do not agree on the applicability of the Liability Convention to aviation accidents caused by erroneous satellite navigation signals.[9] Another issue of growing concern related to the growing number of private and international actors undertaking space launches is the definition of the term "launching state."

Registration Convention—The Convention establishes a mandatory system of registration of space objects launched into orbit and beyond, with registries maintained at the national (Article II) and international (Article IV) level. Mandatory reporting is required to the Secretary-General of the United Nations on a number of data, 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 effective management of traffic, enforcement of safety standards, and imputation of liability for damage.

However, the Convention remains an incomplete tool. First, information is to be provided "as soon as practicable," which in practice can take weeks or months. Second, states are not obliged to disclose the true function of the satellite, but only the "general function of the space objects."[10] To date, not one of the launchings registered has ever been described as having a military function. Third, the Convention does not require a launching state to provide appropriate identification markings for its spacecraft and its component parts. Though a step in the right direction, the Convention does not currently ensure timely and full reporting of space missions.

Various proposals have been advanced to resolve its enumerated shortcomings.[11] These proposals reflect the Convention as an instrument via which some outer space activities of military value may be governed. This view, however, is not shared unanimously. Some delegations are of the opinion that the Registration Convention is neither an arms control nor a confidence-building instrument, but a legal instrument establishing an international registry of space objects for the purpose of giving practical effect to the Liability Convention.[12]

Moon Agreement—This Agreement generally echoes the language and spirit of the OST in terms of the prohibitions on aggressive behavior on and around the moon, the installation of weapons, WMDs, and bases, and other non-peaceful activities.[13] Of the five multilateral treaties devoted entirely to outer space, the Moon Agreement is the most recent and enjoys the least support.[14] Objections to the provisions regarding the establishment of an international regime to govern the exploitation of the moon's natural resources when such exploitation becomes feasible, 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 have kept space-faring nations and others from ratifying this Agreement. Only a handful of states are party to it, and France is the only major space power to have signed it.

Figure 4-5
The Moon Agreement has been the most controversial UN space treaty.

UN Space Principles—In addition to treaties, four sets of UN principles have been adopted by the General Assembly for the regulation of special categories of space activities. They are: the Principles on Direct Broadcasting by Satellite (DBS); the Principles on Remote Sensing; the Principles on Nuclear Power Sources; and the Declaration on Outer Space Benefits.[15] Though these Principles are not legally binding instruments, they retain a certain legal significance by establishing a code of conduct recommended by the UN General Assembly, and reflecting a legal conviction of the international community on these issues.

Figure 4-6
The ITU Convention establishes that all satellite communication must not interfere with the communications of others.

ITU Convention—The presently applicable ITU Convention was adopted in 1992.[16] The Convention was drafted to govern the international use of the finite radio spectrum and orbital slots used by satellites for communications purposes (see chapter I-02 Space Resource Allocation). The two most important articles of the Convention are Articles 35 and 38. Article 35 stipulates that "all stations, whatever their purpose, must be established and operated in such a manner as not to cause harmful interference to the radio services or communications of other members…." Endangering, obstructing, or degrading the signal of another space asset using one's own signal would fall under the category of "harmful interference," as defined in the Convention under Annex 2. Article 38 exempts military telecommunications from the Convention, though they must nonetheless observe measures to prevent harmful interference as much as possible.[17] Additionally, parties are allowed to stop the transmission of any private telegram or telecommunication that is threatening to state security or which appears to pose such a threat.[18] Finally, the Convention states that radio frequencies and the geostationary orbit "must be used efficiently and economically so that countries or group of countries may have *equitable access* to both."[19] In the case of the GEO orbits allocated by the ITU, the principle has been interpreted as meaning such positions should be made available on a first-come first-served basis.

Multilateral and Bilateral Arms Control and Outer Space Agreements

As the weaponization of space has always been a topic of particular concern, another group of legal instruments relevant to space security 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. Key examples include the ABM Treaty of 1972 and the SALT I Agreement of 1972, which derived from the first round of the Strategic Arms Limitation Talks (SALT) between the US and the USSR in 1972.[20] The SALT Agreement froze the number of ICBM launchers both sides could have, which is important because ICBMs could potentially be used to interfere with space assets in LEO. The ABM Treaty, annulled in 2002,[21] was particularly important because it prohibited the development, testing, or deployment of space-based ABM systems, as well as limiting the development of other types of ABMs. One of the primary national technical means (NTMs) of treaty compliance verification is space-based imaging, and so one of the key provisions of the Treaty prohibited interference with NTMs of verification. This provision therefore recognized the legality and legitimacy of space-based reconnaissance as a means of verification of treaty compliance, and prohibited any interference with their function.

Figure 4-7
The CFE Treaty of 1990 is one of a number of treaties which explicitly accepts the use of space assets for monitoring treaty compliance.

The principle of non-interference with NTMs of verification can also be found in other US-Soviet arms control agreements, such as the SALT II Treaty of 1979, the INF Treaty of 1987, and the START I Treaty of 1991.[22] Furthermore, the Treaty on Conventional Armed Forces in Europe of 1990 (CFE) contains a prohibition on interference with "national or…multinational technical means of verification of another state party."[23] Upon entering into force in 1992, the CFE Treaty therefore extended application of the once bilateral principle of non-interference with NTMs to all state parties to the Treaty (currently thirty). 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 designed and operated "in the interest of maintaining peace and international security."[24] In addition to these initiatives, pacts such as the Hotline Modernization Agreement of 1973 and the Environmental Modification Convention of 1977 touched upon space law or space security as a secondary concern.[25]

Other US-USSR bilateral agreements provide information and notification of certain activities. The Launch Notification Agreement of 1988 provides for notification, no less than twenty-four hours in advance, of the planned date, launch area, and area of impact for any launch of a strategic ballistic missile.[26] This notification protocol was expanded to include all space launches with the signing of a Memorandum of Understanding (MOU) establishing the Joint Data Exchange Center (JDEC) in Moscow on 4 June 2000.[27] Once JDEC is completed, the two countries are to exchange information obtained from their respective ground- and space-based early warning systems on US and Russian space launches. Eventually this exchange of data will also include data sharing on detected space launches of third parties. On 16 December 2000 a second MOU was signed establishing a Pre- and Post-Missile Launch Notification System (PLNS) for launches of ballistic missiles and space launches. JDEC and PLNS provide space-related confidence-building measures designed to enhance stability and transparency of actions.

Other Initiatives

Coordination among participating states in the Missile Technology Control Regime (MTCR) in terms of national missile technology export licensing efforts adds another layer to the building of an international legal framework.[28] The MTCR is not a treaty but rather a voluntary arrangement between thirty-three states to apply a common export control policy (MTCR Guidelines) on an agreed upon list (MTCR Annex) of technologies.[29]

Figure 4-8
Export controls aim to limit the proliferation of missile technology.

Another recent effort in this field includes The International Code of Conduct against Ballistic Missile Proliferation (ICOC)—also referred to as the Hague Code of Conduct—which aims to supplement the MTCR.[30] It calls for greater restraint in developing, testing, using, and proliferating ballistic missiles. It does not prohibit states from owning ballistic missiles nor from benefiting from the peaceful uses of outer space. 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 corpus of international humanitarian law composed primarily of the Hague and Geneva Conventions—also known as the laws of armed conflict. These treaties regulate the means and methods of warfare. 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.

International Institutional Framework

The international legal framework was naturally not created in a vacuum. A host of international institutions are required to debate and draft international treaties, and identify and address new problems as they emerge. Institutions including UNGA, COPUOS, the CD, the ITU, and other institutions—and the mechanisms and processes they use and follow—are critical to the stability of the space environment.

UNGA

The UNGA has long recognized the contribution that the prevention of an arms race in outer space could make to disarmament and peace. Every year since 1981 the First Committee (Disarmament and International Security) has deliberated and voted on a resolution pertaining to the Prevention of an Arms Race in Outer Space. Resolutions adopted by the First Committee are then voted on by simple majority within UNGA. Most of these resolutions have been unanimous and without opposition, with only the United States and a few other members abstaining in the recent past, clearly demonstrating widespread desire to expand existing multilateral agreements to include prohibitions against weapons in space.

COPUOS

The UNGA created COPUOS in 1958 to review the scope of international cooperation in peaceful uses of outer space, devise programs in this field to be undertaken under United Nations auspices, encourage continued research and the dissemination of information on outer space matters, and study legal problems arising from the exploration of outer space.[31] In terms of organizational structure and processes, COPUOS has two standing subcommittees (the Scientific and Technical Subcommittee and the Legal Subcommittee), as well as the stand-alone Inter-Agency Space Debris Coordination Committee (IADC). COPUOS and its two Subcommittees meet annually to consider questions put before them by UNGA, reports submitted to them, and issues raised by the Member States. The Committee and the Subcommittees, working on the basis of consensus, make recommendations to the General Assembly. There are currently sixty-five Member States. The IADC is composed of space agencies of major space actors and was established in 1993.

In terms of work plans and achievements, the Vienna Declaration on Space and Human Development recognized the significant changes in the structure and content of world space activities and the growing contribution of the private sector in the promotion and implementation of space activities. As such, COPUOS has recently taken measures to involve industries and organizations engaged in private commercial space activities, with the purpose of reviewing and analyzing the way in which the present regulatory regime affects their present and future operations. The IADC has also played a role in developing space security, in the form of space debris mitigation guidelines. The group submitted recommendations for limiting debris released during normal space operations, minimizing the potential for in-orbit break-ups, and post-mission disposal and prevention of collision to the Scientific and Technical Subcommittee in 2002.[32]

CD

The CD was established in 1979 as the single multilateral disarmament negotiating forum of the international community, and conducts all its work by consensus. Its sixty-six members have repeatedly attempted to address the issue of the non-weaponization of space.

In 1982, the year after the first UNGA Prevention of an Arms Race in Outer Space resolution, The People’s Republic of Mongolia put forward a proposal to create a committee to negotiate a treaty to that effect.[33] After three years of deliberation within the CD, the Committee on the Prevention of an Arms Race in Outer Space (PAROS) was created and given a mandate not to negotiate but “to examine, as a first step at this stage, through substantive and general consideration, issues relevant to the prevention of an arms race in outer space…taking into account all existing agreements, existing proposals and future initiatives."[34] From 1985 to 1998, PAROS made several recommendations for CBMs, including:

- improved registration and notification of information by the strengthening of the Registration Convention;
- the elaboration of a code of conduct or of rules of the road as a way to reduce the threat of possible incidents in space and lower the risk of misinterpretation of space object activities;
- the establishment of "keep-out zones" around spacecraft;
- the elaboration of an agreement dealing with the international transfer of missile technology and other sensitive technology to better promote civilian cooperation in space while removing the dangers of the diversion of technology for developing a ballistic missile capability; and
- "multilateralizing" the protection offered to certain satellite systems under US-USSR/Russian Federation arms control agreements.

A disagreement within the CD, however, has kept PAROS from meeting since 1998. The US has prioritized the Fissile Material Cut-off Treaty (FMCT) over PAROS, while China has prioritized the reverse, with the result being an impasse in both. In 2000 the Brazilian Ambassador attempted to break the deadlock by proposing that PAROS should meet to "deal with" the space issue and another committee should "negotiate" the FMCT.[35] 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 was upgraded from discussions to negotiations to reach an international legally binding instrument. Despite persistent objection by the US, on 28 June 2002 China and the Russian Federation, 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, the Threat or Use of Force Against Outer Space Objects."[36] The proposal, which builds on an earlier Chinese version, contains possible elements of an international legal agreement on the prohibition of deployment of any weapons in outer space. It would also prohibit the threat or use of force against space objects, a concept which would apply to anti-satellite weapons, either mounted on aircraft or ground-based.

ITU

As noted above, the ITU governs the international use of radio spectrum and orbital slots. Organizationally, through the Radio Regulations Board (RRB), the ITU applies two types of procedures for the regulation of the use of radio frequencies for space services and geostationary orbital slots: (a) the rule of first-come, first-served, and (b) *a priori* planning. In practice, however, this approach has resulted in a large increase in ITU filings (500-600 per year, even though fewer than one hundred satellites are typically launched each year) causing a huge backlog of satellite applications. This problem of paper satellites—where countries apply for spectrum and slots without actually preparing to launch a satellite—has combined with the non-enforcement of ITU regulations against states to lead to wasteful and inequitable use of resources.[37]

Other Institutions

As a result of the growing diversity of space-related activities, legal issues pertaining to outer space increasingly emerge in different international fora. International trade and market access issues are increasingly being addressed by the World Trade Organization (WTO). In addition, the WTO has an annex concerning telecommunication services. The International Institute for the Unification of Private Law (UNIDROIT) is playing a role in developing an international instrument that will facilitate the private financing of space assets, potentially improving access to space. Large-scale cooperative space ventures such as the International Space Station (ISS) also contribute to the legal and organizational framework of space activities. All of these developments are of relevance to space security in that they highlight the ever growing number of space actors and the increasing requirement to ensure that space be used in the common interest of all and that space actors abide by the same norms and regulations.

2003 DEVELOPMENTS

International law and institutions evolve slowly. Promising developments occurred in 2003 on several fronts, however, notably in UNGA, COPUOS, the CD, and the ITU.

UNGA

On the institutional level, the UNGA adopted Resolution A/RES/58/36, dealing with the Prevention of an Arms Race in Outer Space, on 8 December 2003. The resolution received the support of 174 states, with none against and four abstentions, a manner consistent with previous resolutions on the issue.[38] The resolution requests that all states refrain from actions contrary to the peaceful use of outer space and calls for negotiation in the Conference on Disarmament on a multilateral agreement to prevent an arms race in outer space.

COPUOS

The IADC presented its voluntary guidelines for space debris mitigation to the Scientific and Technical Subcommittee (STS) of COPUOS during its meeting in February. Several delegations (notably Russia and India) submitted comments asking for changes that require renewed IADC discussions. As a result, the STS requested that the IADC revise its proposal and provide the STS with a new draft of proposals for space debris mitigation for consideration at its next session.

CD

One of the most important developments of 2003 was the attempt to break a six-year-old impasse within the CD through the "Five Ambassadors Initiative."[39] The proposal contained a compromise concerning the ad hoc PAROS mandate, which would "identify and examine without limitation and without prejudice, any specific topics or proposals which would include confidence-building measures or transparency measures, general principles, treaty commitments and the elaboration of a regime capable of preventing an arms race in outer space." In August, China announced that it would accept the mandate for an ad hoc PAROS as formulated by the Five Ambassadors proposal.[40] It remains to be seen how the US will respond to this new display of flexibility on China's part, but acceptance could likely lead to adoption of the first program of work on the issue of PAROS in seven years.

On 31 July 2003 China and the Russian Federation introduced a working paper on PAROS titled "Compilation of Comments and Suggestions to the CD."[41] Further, Russia's ambassador to the CD called for a moratorium during the negotiation of any treaty and underlined Russia's commitment to preventing the weaponization of outer space.

The ITU

At the ITU's WRC-2003, concerns continued to be raised regarding the issue of orbital slot overcrowding and paper satellites. With respect to the issue of frequency bandwidth to be granted to the EU Galileo satellite navigation system, no accord was reached between the US and the EU, but progress was made.

Figure 4-9
The US-EU Galileo frequency dispute remained unresolved in 2003.

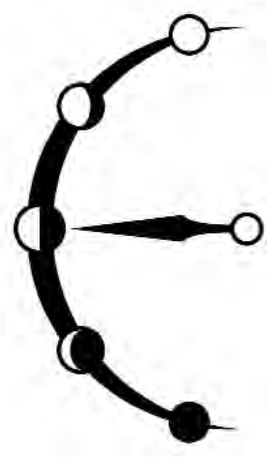
SPACE SECURITY SURVEY 2003: KEY ASSESSMENTS

Space Security 2003: Survey Results

Space Security Survey (20/10/2003-14/11/2003)		Space Security Working Group (24/11/2003-25/11/2003)	
Question: Taking into account your views on developments on both international legal and multilateral institutional developments in the past year, how have overall changes in this area affected space security?		*Question:* In your view, space security with respect to this indicator has been...?	
Enhanced:	2	Enhanced:	0
Somewhat enhanced:	16	Somewhat enhanced:	1
Little or no effect:	**47**	**Little or no effect:**	**15**
Somewhat reduced:	22	Somewhat reduced:	6
Reduced:	10	Reduced:	0

- The institutions charged with issues relevant to space security such as debris, radio spectrum and orbit allocations were taking what appeared to be effective steps to deal with challenges related to these space environment issues.
- The adoption of the annual UN General Assembly resolution calling for progress within the Conference on Disarmament (CD) to prevent an arms race in space provided a good indication of the continued strength of the normative trend supportive of the peaceful uses of outer space.
- The CD remained deadlocked throughout the year on the issue of the prevention of an arms race in outer space. The Chinese move within the CD to accept a compromise formulation of the mandate for an ad hoc committee to address this issue raised hopes that work might begin on this issue within the CD in 2004.

There was little or no effect on space security in 2003 with respect to this indicator.



LITTLE OR NO EFFECT

ENDNOTES

[1] “Treaty on the Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies,” 610 U.N.T.S. 205, 18 U.S.T. 2410. Opened for signature 27 January 1967; entered into force 10 October 1967. As of 1 January 2003, the Treaty had 98 State Parties and had been signed by an additional 27 States. See also, “Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space,” 19 U.S.T. 7570, 1968. Opened for signature on 22 April 1968; entered into force on 3 December 1968. As of 1 January 2003, the Rescue Agreement had 88 State Parties and had been signed by 25 additional States. See also, “Convention on International Liability for Damage,” 24 U.S.T. 2389, T.I.A.S. no. 7762. Opened for signature on 29 March 1972; entered into force on 1 September 1972. As of 1 January 2003, the Liability Convention had 82 State Parties and had been signed by 25 additional States. See also, “Convention on the Registration of Objects Launched into Outer Space,” 1023 U.N.T.S. 15, 28 U.S.T. no. 8480. Opened for signature on 14 January 1975; entered into force on 15 September 1976. As of 1 January 2003, the Registration Convention had 44 State Parties and had been signed by an additional 4 States. See also, “Agreement on the Activities of States on the Moon and Other Celestial Bodies,” (1979) I.L.M. 1434. Opened for signature on 5 December 1979; entered into force 11 July 1984. As of 1 January 2003, the Moon Agreement had 10 State Parties and had been signed by 5 additional States. France is the only major space power to have signed this Agreement.

[2] Can. T.S. no. 7. Opened for signature on 26 June 1945; entered into force on 24 October 1945.

[3] “Treaty on the Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies,” 610 U.N.T.S. 205, 18 U.S.T. 2410. Opened for signature 27 January 1967; entered into force 10 October 1967. As of 1 January 2003, the Treaty had 98 State Parties and had been signed by an additional 27 States. See also, “Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space,” 19 U.S.T. 7570, 1968. Opened for signature on 22 April 1968; entered into force on 3 December 1968. As of 1 January 2003, the Rescue Agreement had 88 State Parties and had been signed by 25 additional States. See also, “Convention on International Liability for Damage,” 24 U.S.T. 2389, T.I.A.S. no. 7762. Opened for signature on 29 March 1972; entered into force on 1 September 1972. As of 1 January 2003, the Liability Convention had 82 State Parties and had been signed by 25 additional States. See also, “Convention on the Registration of Objects Launched into Outer Space,” 1023 U.N.T.S. 15, 28 U.S.T. no. 8480. Opened for signature on 14 January 1975; entered into force on 15 September 1976. As of 1 January 2003, the Registration Convention had 44 State Parties and had been signed by an additional 4 States. See also, “Agreement on the Activities of States on the Moon and Other Celestial Bodies,” (1979) I.L.M. 1434. Opened for signature on 5 December 1979; entered into force 11 July 1984. As of 1 January 2003, the Moon Agreement had 10 State Parties and had been signed by 5 additional States. France is the only major space power to have signed this Agreement.

[4] The US interpretation of “peaceful” as synonymous with “non-aggressive” was a logical extension of the US effort to gain international recognition of the permissibility of reconnaissance satellites while simultaneously discouraging military space activities that threatened these assets—two major goals of US policy during the period predating the Outer Space Treaty (1957-67). See P.B. Stares, *The Militarization of Space: US Policy, 1945-84*, 1988, p.59-71.

[5] I.A.Vlasic, “The Legal Aspects of Peaceful and Non-Peaceful Uses of Outer Space,” in B. Jasani, ed., *Peaceful and Non-Peaceful Uses of Space: Problems of Definition for the Prevention of an Arms race in Outer Space*, 1991. Vlasic notes that at the time negotiations on the Outer Space Treaty began, the United States and the Soviet Union were both “already using outer space for a variety of military purposes” (e.g., surveillance, communications, navigation, etc.) which the United States openly regarded

as "peaceful." While the Soviet Union publicly opposed these activities, it secretly engaged in them as well, and thus acquiesced to the US interpretation.

[6] See I.A. Vlasic, "Space Law and the Military Applications of Space Technology," in N. Jasentuliyana, ed., *Perspectives on International Law*, (Boston: Kluwer Law International, 1995), p.394.

[7] See I.A. Vlasic, "Space Law and the Military Applications of Space Technology," in N. Jasentuliyana, ed., *Perspectives on International Law*, (Boston: Kluwer Law International, 1995), p.394. See also, M. Lachs, "Preserving the Space Environment," Opening Address to the Symposium on the Conditions Essential for Maintaining Outer Space for Peaceful Uses, 12 March 1984, in N. Jasentuliyana, ed., *Maintaining Outer Space for Peaceful Purposes*, 1984, p.5, 7.

[8] "Under present treaty rules and/or customary international law, as demonstrated in practice, national statements, and the United Nations Resolutions…(i)nternational law, including the United Nations Charter where appropriate, applies to acts in outer space. This expressly included the right of self-defense." S.H. Lay and H.J Taubenfeld, *Study on the Law Relating to Activities of Man in Space*, (Chicago: University of Chicago Press, 1970), p.73.

[9] See Stephen Gorove, "Some Comments on the Convention on International Liability for Damage Caused by Space Objects," Proceedings of the Sixteenth Colloquium on the Law of Outer Space, 1973. Indirect damages were intentionally omitted from the recovery scheme and are therefore not covered. Jiefang Huang, "Development of the Long-term Legal Framework for the Global Navigation Satellite System," *Annals of Air and Space Law*, Vol. 22, no. 1, 1997, p.586. For the opposing view, see Paul B. Larsen, "Legal Liability for Global Navigation Satellite Systems," Proceedings of the Thirty-Sixth Colloquium on the Law of Outer Space, 1993.

[10] Article IV 1 (e).

[11] See infra, Confidence-Building Measures (CBMs) discussed at the Conference on Disarmament.

[12] Statement submitted by Japan to the Conference on Disarmament, CD/PV 419, 7 July 1987, p.12. Statement submitted by the United States, CD/905.

[13] Article 3(4).

[14] "Agreement on the Activities of States on the Moon and Other Celestial Bodies," (1979) I.L.M. 1434. Opened for signature on 5 December 1979; entered into force 11 July 1984 (The Moon Agreement). According to the Report of the Legal Subcommittee on the Work of its Forty-Second Session, 10 April 2003, available at http://www.oosa.unvienna.org/Reports/AC105_805E.pdf. As of 1 January 2003 the Moon Agreement had 10 State Parties and had been signed by 5 additional States.

[15] "The Principles Governing the Use of States of Artificial Earth Satellites for International Direct Television Broadcasting," adopted 10 December 1982 (U.N.G.A. Res 41/65). See also, "The Principles Relating to Remote Sensing of the Earth from Outer Space," adopted on 14 December 1986 (U.N.G.A. Res. 47/68). See also, "The Principles Relevant to the Use of Nuclear Power Sources in Outer Space," adopted 14 December 1992 (U.N.G.A. Res. 47/68). See also, "Declaration on International Cooperation in the Exploration and Use of Outer Space for the Benefit and in the Interest of All States Taking into Particular Account the Needs of Developing Countries," adopted on 12 December 1996 (U.N.G.A. Res. 51/122).

[16] "Constitution and Convention of the International Telecommunication Union: Final Acts of the Additional Plenipotentiary Conference," (Geneva: ITU, 1993). For an excellent description of the role of ITU see F. Lyall, "Communications Regulations: The Role of the International Telecommunication Union," *Journal of Law and Technology*, vol. 3, 1997. Available at http://elj.warwick.ac.uk/jilt/commsreg/97_3lyal/lyall.DOC.

[17] Article 38 para. 164.

[18] Article 19 para. 132, 133. See also Thomas C. Wingfield, "The Law of Information Conflict, National Security Law in Cyberspace," Aegis Research Corporation, p.322-337.

[19] Article 33 (2) (emphasis added).

[20] “Treaty Between the United States and the Union of Soviet Socialist Republics on the Limitation of Anti-Ballistic Missile Systems.” Treaties and other International Acts, Series 7503, (Washington: US Department of State, 1973). Signed on 26 May 1972; entered into force on 3 October 1972.

[21] The decision to withdraw from the ABM Treaty was based on a perceived change to the international security environment. It was argued that the new security environment required a “different approach to deterrence and new tools for defense.” The strategic logic of the cold war was deemed not applicable to the new threats.

[22] “Treaty Between the United States of America and the Union of Soviet Socialist Republics on the Limitation of Strategic Offensive Arms,” Article XV, (1979) 18 I.L.M. 1112. Signed in 18 June 1979; not in force. See also, “Treaty Between the United States and the Union of Soviet Socialist Republics on the Elimination of Their Intermediate-Range and Shorter-Range Missiles,” (INF Treaty), 8 December 1987, Article XII , 27 I.L.M. 90. See also, “Treaty on the Reduction and Limitation of Strategic Offensive Arms,” 31 July 1991, Article IX, S. Treaty Doc. no. 102-20 (START I).

[23] “Treaty on Conventional Armed Forces in Europe,” 30 I.L.M. 1. Entered into force on 9 November 1992. Article XV(2) (emphasis added).

[24] Article III of the Outer Space Treaty.

[25] “Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and Under Water,” 14 U.S.T. 1363. Opened for signature on 7 October 1963; entered into force on 10 October 1963 (hereinafter referred to as the Limited-Test Ban Treaty). See also, “The Comprehensive Test Ban Treaty.” Opened for signature on 24 September 1996; not entered into force yet. See also, The “Convention on the Prohibition of Military or any other Hostile Use of the Environmental Modification Techniques,” 31 U.S.T. 333. Opened for signature 18 May 1977; entered into force on 5 October 1978. See also, “Agreement on Measures to Improve the US-USSR Direct Communications Link,” (1972) 806 U.N.T.S. 402. Signed on 30 September 1971; entered into force on 30 September 1971. See also, 807 U.N.T.S. 57.

[26] “Agreement Between the Government of the United States of America and the Government of the Union of Soviet Socialist Republics on Notification of Launches of Intercontinental Ballistic Missiles and Sub-marine Launched Ballistic Missiles.” Opened for signature on 31 May 1988; entered into force on 31 May 1988.

[27] “Memorandum of Agreement Between the Government of the United States and Government of the Russian Federation on the Establishment of a Joint Center for the Exchange of Data from Early Warning Systems and Notifications of Missile Launches.” Entered into force on 4 June 2000.

[28] MTCR countries exercise vigilance over the transfer of missile equipment, materiel, and related technologies through a system of national export controls. These controls are not intended to impede peaceful aerospace programs. However, given the usefulness of some space technologies in the development of missiles, MTCR export controls can have this effect. Therefore, the MTCR is perceived by some countries, notably those outside the regime, as a restrictive cartel impeding access to space. See, for example, a paper presented by the Pakistan Mission to the UN on this issue. Available at http://www.un.int/pakistan/13970723.html. According to the Carnegie Endowment for International Peace the MTCR has a history of mixed failures and success. The failures are “missile developments in North Korea, India, and Pakistan” but the successes are “the suppression of the Argentine, Egypt and Iraqi Condor II ballistic missile program and South African and Central European missile activities.” Available at http://www.ceip.org/files/publications/ProliferationBrief407.asp?p=.

[29] US Department of State Fact Sheet. Available at http://www.state.gov/t/np/rls/fs/27514pf.htm.

[30] Brought into effect on 25 November 2002.

[31] UNGA Res. 1348 (XIII), 15 December 1958. COPUOS was made permanent by UNGA Res. 1472 (XIV), 12 December 1959.

[32] IADC Guidelines, p.8 section 5.2.

[33] See "Working Paper on the Prevention of an Arms Race in Outer Space," submitted by the Mongolian People's Republic to the Committee on Disarmament, CD/272, 5 April 1982.

[34] "Prevention of an Arms Race in Outer Space." Official Records of the General Assembly, A/RES/40/87, 12 December 1985. See also, "Mandate for the Ad Hoc Committee under item 5 of the agenda of the Conference on Disarmament entitled Prevention of an Arms Race in Outer Space," Conference on Disarmament, CD/1059, 14 February 1991, and previous documents under the same title.

[35] Hereinafter referred to as the "Amorim proposal."

[36] CD/1679. Available at http://disarmament2.un.org/cd/cd-docs2002.html.

[37] See discussion under chapter I-02 Space Resource Allocation: Radio Spectrum and Orbital Slot Allocation.

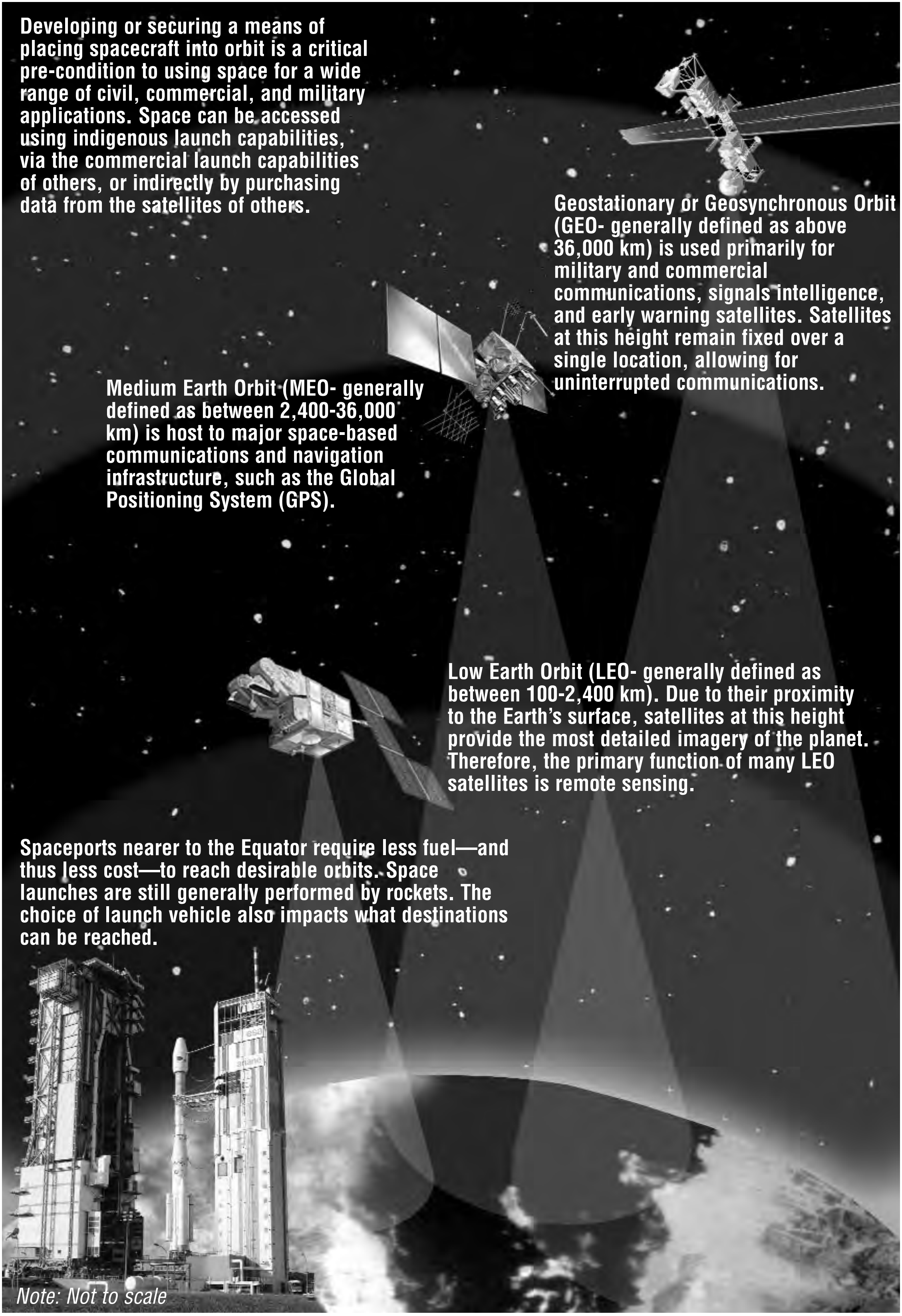
[38] These four abstentions included: the United States, Israel, Micronesia, and Marshall Islands.

[39] By the Ambassadors of Algeria, Belgium, Chile, Columbia, and Sweden. Available at http://www.reachingcriticalwill.org/political/cd/A5.pdf. See UN Press Release, "Five Ambassadors."

[40] China, Statement by Mr. Hu Xiaodi, Ambassador for Disarmament Affairs of China at the Plenary of the 2003 Session of the Conference on Disarmament, 7 August 2003. For different reasons France and the USA remain as holdouts to this compromise. For an excellent report on these developments see http://www.ploughshares.ca/content/MONITOR/mons03b.html.

[41] Final Record Of The Nine Hundred And Thirty-Third Plenary Meeting, UN, Conference on Disarmament, CD/PV.933, 31 July 2003. Available at http://disarmament2.un.org/cd/cd-mtngs2003.html. The revised working paper can be found at http://www.reachingcriticalwill.org/political/cd/speeches03/PAROSwp.htm.

Figure 5-1



Developing or securing a means of placing spacecraft into orbit is a critical pre-condition to using space for a wide range of civil, commercial, and military applications. Space can be accessed using indigenous launch capabilities, via the commercial launch capabilities of others, or indirectly by purchasing data from the satellites of others.

Geostationary or Geosynchronous Orbit (GEO- generally defined as above 36,000 km) is used primarily for military and commercial communications, signals intelligence, and early warning satellites. Satellites at this height remain fixed over a single location, allowing for uninterrupted communications.

Medium Earth Orbit (MEO- generally defined as between 2,400-36,000 km) is host to major space-based communications and navigation infrastructure, such as the Global Positioning System (GPS).

Low Earth Orbit (LEO- generally defined as between 100-2,400 km). Due to their proximity to the Earth's surface, satellites at this height provide the most detailed imagery of the planet. Therefore, the primary function of many LEO satellites is remote sensing.

Spaceports nearer to the Equator require less fuel—and thus less cost—to reach desirable orbits. Space launches are still generally performed by rockets. The choice of launch vehicle also impacts what destinations can be reached.

Note: Not to scale

5

This chapter assesses trends and developments with respect to the capabilities of actors to access space through an indigenous launch capability or through the launch capabilities of others. Such capabilities have a direct impact upon space security because developing or securing a means of placing spacecraft into orbit is a critical pre-condition to using space for a wide range of civil, commercial, and military applications.

There are different levels of space access associated with the three major orbits—LEO, MEO, and GEO— the characteristics of which determine the types of applications spacecraft at these orbits can best provide. With the exception of the US Space Shuttle, space access is currently provided by single-use rockets.

Figure 5-2
The launch of Sputnik started the space age in 1957.

The space age began with the Soviet launch of Sputnik in 1957 aboard an R-7A ICBM.[1] The first US satellite was launched into space on a modified Atlas ICBM in 1958.[2] The first human was launched into space by the USSR in 1962, followed about a year later by the first American in space. Over the past fifty years, indigenous launch capabilities have spread beyond the USSR/Russia and US to include the ESA (its fifteen member states), Japan, China, India, and Israel. All of these actors except the last can now access LEO, MEO, and GEO.

By 2003, over fifty-five countries and organizations had demonstrated the capability to place satellites in orbit either through an indigenous launch capability or through access to the launch capabilities of others.[3] On the one hand this growth in the number of actors who can access space implies a positive impact on space security because such growth tends to increase (1) the certainty and sustainability of space access; (2) the number of actors with an interest in maintaining secure access to space; and, (3) the possibility of using space for early warning, and other security enhancing activities such as the verification of compliance with weapons control and security regimes.

On the other hand, more actors with space access also holds risks for space security, such as those associated with (1) environmental factors (debris, scarcity of radio spectrum, and orbital slots); and, (2) space negation considerations such as the ability to use space access capabilities in anti-satellite roles through kinetic energy attacks on satellites and wide area attacks through the detonation of nuclear weapons in LEO (See chapter I-11 Space Systems Negation).

Box 5-1

Date of Selected Countries' First Space Launches[5]

USSR/Russia	**1957**
USA	**1958**
France	**1965**
Japan	**1970**
China	**1970**
UK	**1971**
ESA	**1979**
India	**1980**
Israel	**1988**

BACKGROUND

Indigenous Space Access

As noted above, Russia, the US, the ESA, Japan, China, India, and Israel have all developed indigenous space access capabilities. All except the ESA can unilaterally place military satellites into space. In the case of ESA, its status as a civil space program prohibits the launching of military assets, though both France and the UK have demonstrated launch capability prior to the formation of ESA (see Box 5-1). Collectively, these actors averaged forty-three launches per year over the five-year period 1998-2002—the vast majority of them successful. Russia and the US were responsible for 178 of these launches (84 percent). In addition to these countries, Brazil attempted to gain indigenous launch capability in 1999, but its attempt was unsuccessful.[4] Only the USSR/Russia, the US, and China have achieved manned spaceflight.

Commercial Space Access

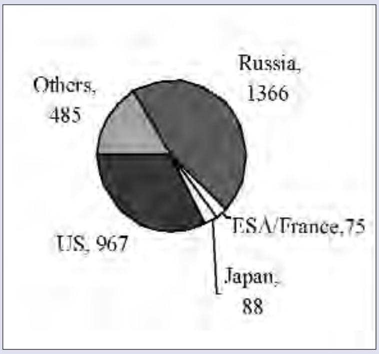
An important trend over the past quarter century has been the birth of the commercial launch industry (see also chapter I-07 Space Industry). The existence of this commercial market now means that space actors do not require indigenous launch capabilities to access space, although commercial launches do require the authority of the launching state. Today, launch companies exist in the US, Europe, and Russia with major companies including Boeing, Lockheed's International Launch Services, and Arianespace.[6] In addition to these, smaller outfits include an international consortium of US, Russian, Ukrainian, and Norwegian companies called Sea Launch, which offers commercial launches from a sea-based platform and is in the process of setting up ground-based launch services from Kazakhstan.[7] Another example is Eurockot Launch Services GmbH, a joint venture of Europe's EADS Space Transportation and Russia's Khrunichev Space Centre.[8]

This growth in space access capabilities has contributed to greater competition and to a steady decline in launch costs. Indeed, the average costs to place a payload into GEO went from $40,000/kilogram in 1990 to $26,000/kilogram in 2000, with prices still falling.[9] There is some question, however, whether this trend can continue given the theoretical limitations of vertical take-off chemical rockets, should the industry continue to use these exclusively.[10] Payloads can now be placed into LEO for as little as $5,000/kilogram, which makes it by far the easiest orbit to attain.[11] The ability of Europe and Russia to undercut the US in terms of launch costs has helped make ESA and the Russian space program the world's most active space launch providers, though the figures vary year-by-year.[12]

This growth in commercial launch services has allowed countries like Thailand and Indonesia to place their communications satellites into orbit.[13] As noted above, the number of countries and organizations that have demonstrated the capability to place and maintain satellites in orbit either through an indigenous launch capability or through access to the launch capabilities of others has reached over fifty-five.[14] Commercial actors attempted forty, thirty-nine, thirty-five, sixteen, and twenty-four launches from 1998-2002 respectively.[15] Together with non-commercial launches a total of 2,981 satellites have gained space access and are currently in orbit (see Box 5-2). Today there are over fifty expendable launch-vehicle variants built by twenty different manufacturers worldwide (see Box 5-3).

Box 5-2

Payloads in Orbit, Late 2003[16]



Indirect Access

A noteworthy indirect way in which an actor can access space is by purchasing data from another actor's satellite. In this way, those who wish to benefit from space-generated information forego the need for indigenous launch capabilities, a satellite, or even a space program. In 1997 Hitachi Ltd. and Mitsubishi Corp., both of Tokyo, spearheaded moves to sell and distribute high resolution satellite data in Japan from US satellites supplied by EarthWatch Inc. and Space Imaging Corp. According to Hitachi, agreements were signed with the Japanese Ministry of Agriculture, Forestry, and Fisheries, while the Ministry of Foreign Affairs and the Japanese Defence Agency were said to be interested.[18]

Box 5-3

Selected Commercially Available Launch Vehicles, 2002[17]

USA	**Delta 2**
USA	**Atlas 3**
USA	**Atlas 5**
Russia	**Proton M**
Russia	**Soyuz**
China	**Long March**
Ukraine	**Zenit 2**
Sea Launch	**Zenit 3SL**
ESA	**Ariane 5**
India	**GSLV**
Japan	**H-2A**

However, this type of access can be problematic from the perspective of some space actors. A 2003 report stating that the Chinese military had purchased images of Taiwan with a resolution of 1 meter from the South Korean affiliate of Space Imaging Corp. sparked a series of difficult exchanges between China and the US.[19]

Spaceports

Another element which impacts space access is the number and location of spaceports available for space launches. Even though access to space has increased over the years, the number of spaceports worldwide remains quite low. In addition to established space ports, some countries possess a latent launch capacity that is not currently being used. For example, Canada and Sweden have both launched sounding rockets—rockets that stay in the earth's atmosphere for up to fifteen minutes at a

Figure 5-3
Innovative ocean-based platforms like that operated by Sea Launch supplement the current ground-based launch facilities.

time—from spaceports in Fort Churchill and Esrange,[20] and Italy has the offshore San Marco launch facility, unused since 1988.[21] These facilities could be used to launch rockets such as the American Delta or the Chinese Long March.[22] Moreover, a dedicated launch facility is not a prerequisite for having a space launch capability: the US, for example, launches the Pegasus rocket from a B-52 aircraft and Sea Launch delivers from an ocean-based platform.[23] As of 2003, the US Federal Aviation Agency counted twenty-three active or potential spaceports worldwide.[24] The location of these spaceports affects the cost of launch, because launching near the equator reduces the energy required to achieve the popular equatorial orbits. The ESA's main launching point, therefore, is not in Europe but in Kourou, French Guiana, located close to the equator.

Cooperation

The civil, commercial, and military space launch sectors retain a tremendous degree of interpenetration. The result is a good deal of cooperation between actors in terms of designing new launch vehicles and in maintaining launch facilities. For example, China received assistance from Russia in the development of its Shenzhou series of spacecraft; plans have been underway since 2001 for Australia to build a launch site on Christmas Island that would be used to launch satellites into LEO using Russian launch vehicles;[25] the X-Prize competition (see **2003 Developments**) includes teams from the US, Russia, the UK, Canada, Argentina, and Israel;[26] and, finally, Sea Launch is a cooperation between companies in the US, Ukraine, Russia, and Norway.

Restraints on Access and Ballistic Missiles

An important factor that has expanded the scope of space actors is the proliferation of ballistic missile technology, because ICBMs are very similar to launch vehicles and many have the ability to reach LEO with little modification.[27] As such, ballistic missile systems and space launch systems have been historically interrelated. On the one hand, the proliferation of such technologies increases the number of actors with indigenous space access. On the other hand, restrictions on ballistic missiles and related technologies can impede the development of new space actors. For example, several advanced nations established the Missile Technology Control Regime (MTCR) in 1987. The regime, which currently boasts thirty-three members, exists to restrict the export of technologies that could be used in the development of delivery systems for weapons of mass destruction.[28] For example, in 1993 the US put pressure on Russia to cancel the transfer of cryogenic engine technology to India because of proliferation concerns. As a consequence, however, India has gone on to develop its own cryogenic engine technology, which is needed for the delivery of payloads into GEO.[29]

Because ICBMs pass through space, it is noteworthy that ballistic missiles can directly affect space security if they are used as anti-satellite weapons (see also chapter I-11 Space Systems Negation) or used to deliver and detonate a nuclear device in LEO which would threaten the secure use of space by others. Thus the proliferation of ballistic missiles capabilities can have a direct impact on space security.

Politically motivated trade agreements can also shackle the launch market. Up until 2000, for example, the US had bilateral deals with Russia and Ukraine limiting the number of American satellites launch parties in those countries could launch each year.[30] Moreover, those actors who forego developing indigenous access are also subject to restrictions concerning commercial launches. While numerous private launch services exist today, they are all subject to some degree of government control. In the US, for example, the federal government must license all commercial launches. Licenses are only granted if the Federal Aviation Administration's Associate Administration for Commercial Space Transportation (FAA AST)

> determines that an applicant's launch or re-entry proposal or proposal to operate a launch site will not jeopardize public health and safety, safety of property, US national security or foreign policy interests, or international obligations of the United States.[31]

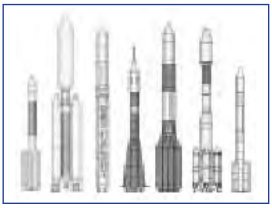


Figure 5-4
Rockets are the primary space access medium. From left to right, the US's Delta 2, Titan 4, Sea Launch's Zenit 3SL, Russia's Soyuz and Proton K, Europe's Ariane 4, and India's PSLV.

Even nominally international companies like Sea Launch are registered in national jurisdictions. For example, US law dictates that the FAA AST must license any international space launch initiative in which an American company has a controlling interest. Because the lead partner in Sea Launch is Boeing with a 40 percent stake, it comes under US jurisdiction.[32] This is not to say that countries will not launch others' military and intelligence satellites. In August 2003, for example, Russia announced that between 2005 and 2007 it will launch a series of unidentified foreign military satellites.[33] However, the only sure way to ensure free access to space is to develop an autonomous launch capability. This is the path China and India have decided to follow.

Non-chemical Rockets

The majority of current launch vehicles are large and small single-use vertical take off chemical rockets. However, alternative means of space access are currently under development and are summarized in Box 5-4. The rationale for these alternative methods of space access is that they would be able to provide a means of payload delivery much more cheaply and regularly than current options allow. However, they each require massive infrastructure investment.

Box 5-4

Alternative Space Access Technologies

- Air-breathing hypersonic engines could cut costs and facilitate space access. A hypersonic engine collects oxygen in flight thus reducing the weight of the vehicle.[34] However, this technology is in the experimental stage: the first generation NASA hypersonic demonstrator vehicle, the X-43A, is still undergoing testing.[35]
- Thermal nuclear propulsion has been under consideration sporadically since the 1950s both in the US and USSR including several successful high thrust demonstration vehicles. Nuclear propulsion is considerably more efficient than chemical rocket engines, but has serious downsides such as the generation of large quantities of radioactive waste.[36]
- A beamed energy launch in which a powerful microwave or laser source on the ground is used to push up a space craft.
- More futuristic ideas include:
  - ❑ the space elevator, which would lay a cable from the equator to GEO by which spacecraft would raise and lower themselves;[37]
  - ❑ a rail gun which would accelerate a craft along a rail and up a mountainside, releasing at the top at great speed.

2003 DEVELOPMENTS

Perhaps the key lesson from 2003 is the interdependency of space activities, highlighted by the Columbia disaster and the consequent reliance on the Russian Soyuz for servicing the International Space Station. Secure access to space requires multiple pathways into space for all types of space activities. Overcapacity in access capabilities has been more the trend within the commercial sector, with overall space access figures remaining depressed and financial hardships continuing to threaten space industry. This could lead to a reduction in the ability to access space if actors leave the commercial launch market, thus reducing competition and raising prices. Higher costs could prevent new actors from establishing a presence in space. Key developments occurred in China, the US, Russia, Brazil, India, and in the development of privately owned launch vehicles.

Commercial launches were expected to drop from 2002's total of twenty-four to only seventeen over the course of 2003, continuing the depressed trend of the past few years. Non-commercial launches, however, held steady, with forty-six launches taking place, versus forty in 1998 and forty-one in 2002.[38]

China

Arguably the most significant event in terms of space access to occur in 2003 was China's launching of its first taikonaut into LEO, on 15 October. In doing this China became but the third country to independently place a person into orbit in over fifty years of manned space flight. Moreover, at the time of launch it doubled the world's current ability to put people into space as the US program remained grounded in light of the Columbia disaster. This is important because it shows significant technological development in the launch capabilities of China.

Figure 5-5
A Chinese Long March 2F rocket launches the Shenzhou 5 space capsule into space.

United States

On 1 February 2003 the US Space Shuttle Columbia broke up upon re-entry, killing all seven astronauts on board. The NASA Board that investigated the tragedy concluded that the physical cause of the shuttle's break-up was a piece of foam insulation that broke off of Columbia's external tank upon launch and damaged part of the carbon covering on the left wing that protects the shuttle from the great heat it is subjected to upon re-entry[39] The Board also found that the shuttle's budget and the workforce sustaining it had decreased by 40 percent over the past ten years, which had made it increasingly difficult to maintain the shuttle as well as to identify and solve problems. In fact, given these operating conditions, the NASA Board believed it to be fortunate that no similar tragedy occurred sooner.[40] While initially there was talk of restarting shuttle missions in early 2004, the most recent target date for returning to flight is September 2004.[41] This accident highlights the rapidity with which space access can diminish, and illustrates the complexity and difficulty of maintaining access, even for the most experienced actors.

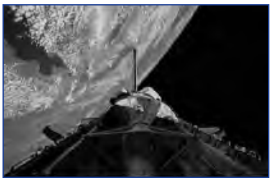


Figure 5-6
The loss of Columbia, seen here in 1994, was a tragic blow to manned US space access.

In US commercial developments, Boeing announced that it would withdraw its new Delta 4 booster from the commercial launching business. Its Integrated Defense Systems Chief was quoted as saying that Boeing would "eliminate all commercial launches over the next five years." Though Boeing plans to continue non-commercial launches, and the Delta 4 would be available via Boeing's participation in Sea Launch, this announcement was a shock to the launch industry.[42]

For future launch technologies the US has been focusing on developing an Orbital Space Plane as part of its Space Launch Initiative. The purpose of the Orbital Space Plane would be to complement the Space Shuttle in the short term as an additional means of reaching the International Space Station.[43] Moreover, NASA plans this vehicle to be an "interim" solution until a "next generation launch technology" is developed fully.[44]

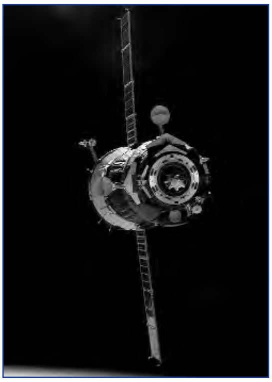


Figure 5-7
A Russian Soyuz TMA-3 approaches the International Space Station.

Russia

The grounding of all US Shuttle flights following the Columbia disaster demonstrated the importance of multiple means of access for space security, as Russia became the only country equipped to supply the International Space Station.[45] This put added pressure on the already financially struggling Russian Space Program. Russia has two main ways of reaching the International Space Station: by the manned Soyuz craft or by the unmanned Progress cargo ship. The Russian approach to space access has been different from the US approach to date: unlike the Space Shuttle, both of the Russian spacecraft can be used for one flight only and have smaller cargo capacities.[46] However, they can be launched for a fraction of the cost of the shuttle: the Progress and Soyuz cost between $20-30 million to launch, while the Shuttle costs $300 million. Their smaller cost allows for redundancy, which has placed Russia in a better position vis-à-vis space access. In a new cooperative venture, Russia and the ESA have recently signed an agreement to launch the Soyuz rocket from the spaceport in French Guiana.[47]

Brazil

On 22 August a Brazilian VLS-1 rocket exploded during a launch test, killing twenty-one people. Brazil has steadily been developing the ability to access space since its Alcantra launch site became operational in 1990 and the Brazilian Space Agency was established in 1994.[48] More recently Brazil has been working towards developing an “indigenous domestic and commercial satellite infrastructure,” part of which is an independent launch infrastructure. When the VLS-1 rocket exploded it was the third of three attempts to test the vehicle. As of now, the ignition system is believed to be the cause of the explosion.[49]

India

India’s ability to access space also continued to expand throughout 2003 as it made significant progress towards being able to place payloads into GEO.[50] On 8 May, India conducted a second successful test of its Geosynchronous Satellite Launch Vehicle (GSLV).[51] The launch successfully achieved the placement of an experimental satellite in an orbit with an apogee of 36,000 kilometers, with much of the equipment and technology employed being Indian in origin.[52] Following from this launch, India commissioned the GSLV “into service” for delivering 2,000 kilogram payloads into GEO.[53] Expanded GEO launch availability could help to decrease commercial launch costs further. India continued to develop indigenous components for the GSLV even after this launch, successfully testing an Indian-designed cryogenic engine for the GSLV in December.[54] India also announced plans for a satellite mission to the moon in 2007.[55]

South Korea

South Korea may become the next actor with indigenous launch capability. A ground-breaking ceremony was performed at the Yenae-ri Kohung-gun Space Centre in South Jeolla Province in preparation for the launch of the country's first satellite using an indigenous booster.[56]

Nigeria

Nigeria accessed space in 2003 with the commercial launch of a remote sensing satellite in September. The Nigerian National Space Research and Development Agency's (NASRDA) NigeriaSat-1 is another example of commercial-institutional cooperation, as Nigeria contracted Surrey Satellite Technology Ltd., a UK leader in small satellite technology, to build the satellite.[57] Nigeria thus became the third African nation, after South Africa and Algeria, to have a satellite in space.

Figure 5-8
SpaceShipOne is the early leader in the X-Prize competition to achieve private space flight.

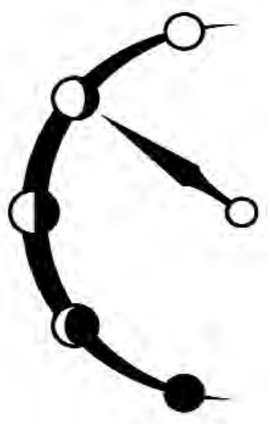
Privately Owned Launch Vehicles

Encouraged by the X-Prize, small private companies have been developing small launch vehicles. The X-Prize offers a $10 million prize to anyone who builds a manned launch vehicle that can fly to the suborbital height of 100 kilometers, return to earth, and then perform a second such flight within two weeks to "demonstrate reusability."[58] The Prize has stimulated efforts by a dozen teams in several countries including the US, Russia, Canada, the UK, Israel, and Argentina. Many of these efforts and the several others outside the X-Prize, including the Falcon vehicle of the Space Exploration Technologies Corporation, have attracted investment from very wealthy individuals. In late December 2003, SpaceShipOne, the entry of one of the American teams to X-Prize, completed a test flight.[59]

SPACE SECURITY SURVEY 2003: KEY ASSESSMENTS

Space Security 2003: Survey Results

Space Security Survey (20/10/2003-14/11/2003)		Space Security Working Group (24/11/2003-25/11/2003)	
Question: Taking into account your views on developments in the previous three areas (the capability to reach LEO, MEO and GEO as well as market access to space) in the past year, how have overall changes in this area affected space security?		*Question:* In your view, space security with respect to this indicator has been...?	
Enhanced:	3	Enhanced:	1
Somewhat enhanced:	**35**	**Somewhat enhanced**:	**15**
Little or no effect:	18	Little or no effect:	6
Somewhat reduced:	31	Somewhat reduced:	4
Reduced:	4	Reduced:	1



SOMEWHAT ENHANCED

- China's first manned space mission and India's successful test of its GEO launch capability continued a general trend of growth in the number of nations with the capability to access space for a diverse range of applications.
- This increase in the number of countries with access to space can potentially enhance space security by providing healthy market competition, access to space for actors without a dedicated launch program and redundancy in the case of system failures. However, there is also a level of concern that more countries with access to space could increase the threat to space assets, undermining space security over the longer term.
- The Brazilian and US civil space tragedies in 2003 underscored the risks associated with space access, as well as the corresponding value of a growing diversity of space access capabilities.

Space security was somewhat enhanced in 2003 with respect to this indicator.

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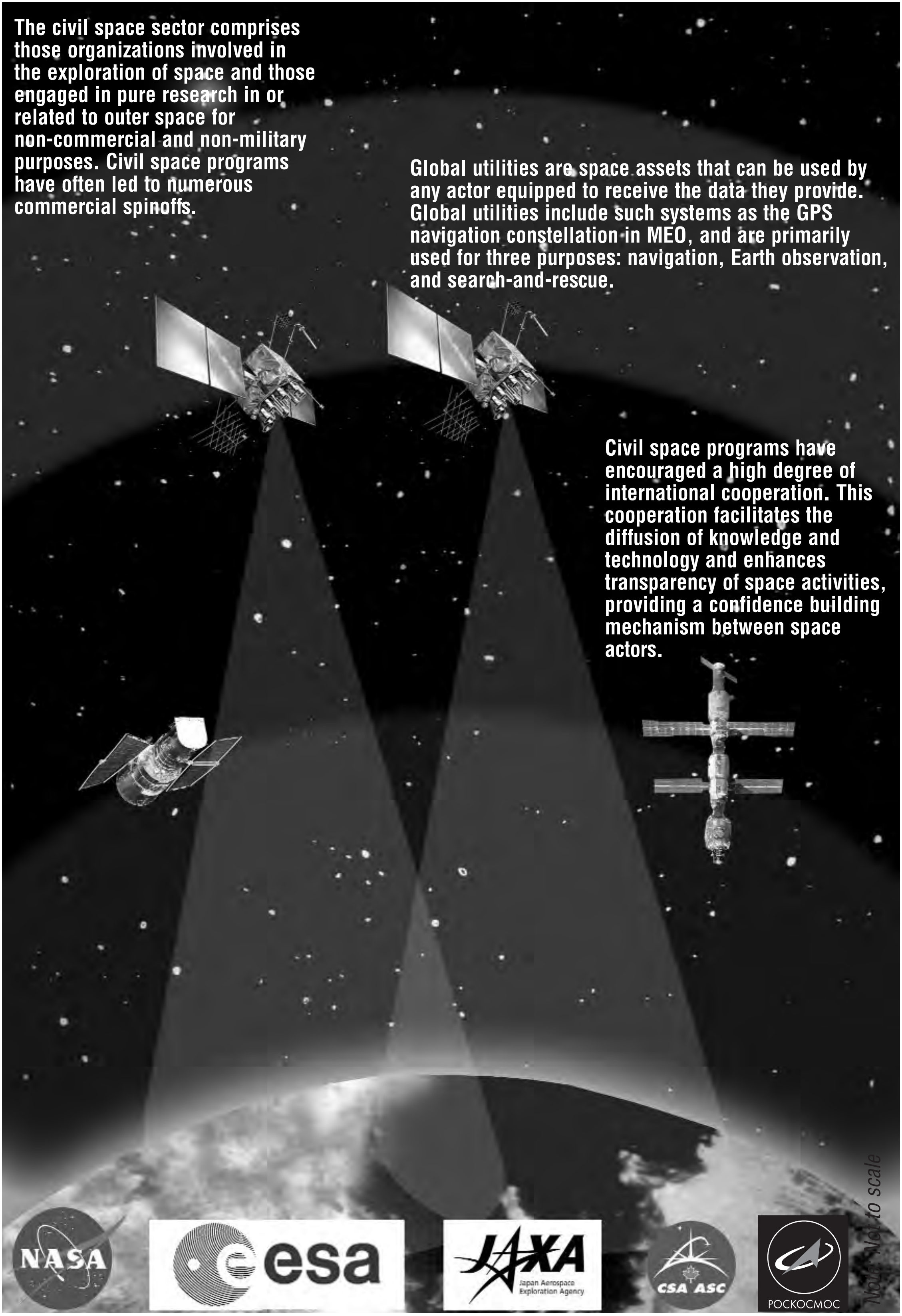
Figure 6-1



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 often led to numerous commercial spinoffs.

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.

I-06 Civil Space Programs and Global Utilities

6

This chapter assesses trends and developments in civil space programs and global space-based utilities. 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. Examples include the European Space Agency, the Indian Space Research Organisation, and the US National Oceanic and Atmospheric Administration (NOAA). Global utilities are space assets that can be used by any actor equipped to receive the data they provide. This most commonly includes earth observation, search and rescue, and navigation systems, the best known being the US Global Positioning System (GPS).

Civil space programs are relevant to space security because they underscore and enable the vast social and scientific benefits of secure and sustainable access to space. Indeed, civil space programs often closely mirror the ideal conception of the benefits of space, exemplified in the mandates of the civil space agencies. For example, NASA's mandate is to explore space, to understand space, and to use space, as well as to develop technologies both for its own use and that can also benefit other space sectors.[1] While the most celebrated achievements of national space programs were carried out by the two superpowers during the Cold War, since then a growing number of actors have joined the US and Russia in civil space endeavours including, but not limited to, Europe, China, India, Canada, and Japan as well as relative newcomers like Brazil and Nigeria.

Figure 6-2
The USSR's Sputnik was the world's first artificial satellite.

Global utilities are important for space security because they offer equitable access to and use of space to actors who do not possess space programs. Global utilities also broaden the community of actors with an investment in space security to include thousands of civil, commercial, and military actors who rely upon space-based services for navigation, earth observation, and search and rescue functions.

Civil space programs and global utilities further benefit space security by developing cooperative relationships among different space actors. Such cooperation enhances transparency, reinforces collective commitments to the maintenance of secure access to and use of space, and helps transfer of skills and technology necessary for the acquisition of space access capabilities by emerging actors.

BACKGROUND

Civil Space Programs

Through most of the Cold War, the US and USSR engaged in significant space competition driven by political considerations as well as the practical benefits of space research for civil, commercial, and military applications. Most of this research was oriented towards using rockets and satellites for military purposes and was conducted by the armed forces, such as the work done on unguided rockets by the US Navy in the 1950s.[2] As this research progressed, it increasingly was oriented to pure scientific research and other civil applications. As an example, while the USSR's Sputnik—the world's first artificial satellite—was launched into space in 1957 using a converted military rocket, it served as the genesis for the Soviet civil space program.[3] The world's most recognizable national space agency, the US's National Aeronautics and Space Administration (NASA) was founded in 1958, while the latest incarnation of the Russian Space Agency (Rosaviakosmos, RSA) came into being in 1992.[4] Together, these two countries were responsible for the vast majority of the greatest achievements in civil space during the Cold War period (see Box 6-1).

Box 6-1

Select Cold War Era Civil Program Landmarks

- **1957**: Sputnik first artificial satellite.
- **1959**: Luna-2 the first man-made object to impact the moon.
- **1961**: Yuri Gagarin completes world's first manned spaceflight onboard Vostok spacecraft.
- **1963**: Valentina Tereshkova, the world's first woman in space, completed orbital flight onboard Vostok-6 spacecraft.
- **1965**: Mariner-4 completes flyby of mars.
- **1969**: The Apollo-11 astronauts land and walk on the surface of the moon.
- **1973**: The last Saturn-5 rocket launches Skylab orbital lab.
- **1981**: The US Shuttle Columbia blasts off into the first test flight.
- **1986**: The core module of the Mir space station is launched.
- **1989**: The Voyager-2 becomes the first spacecraft to flyby and study neptune.

Other nations were active during this period as well. The precursor to the China National Space Administration (CNSA) was founded in 1956, and China launched its first artificial satellite into space in 1970.[5] Canada was the third country to put a satellite in space in 1962, and its various space-related departmental offices were merged to form the Canadian Space Agency (CSA) in 1989.[6] Yet the activities of these and other actors were minimal compared to those of the superpowers. China, for example, launched only five scientific satellites between 1970 and 1994, and Canada did not send an astronaut into space until

1984, at the invitation of the United States.[7] Finally, while collaborative European space programs date back to the 1950s, the ESA was formally founded in 1973. While not formally the space agency of the European Union, the two organizations do share "a joint space strategy."[8] In 1987, the ESA approved an "ambitious space programme" that coordinated the expertise and resources of its fifteen member states.[9]

United States

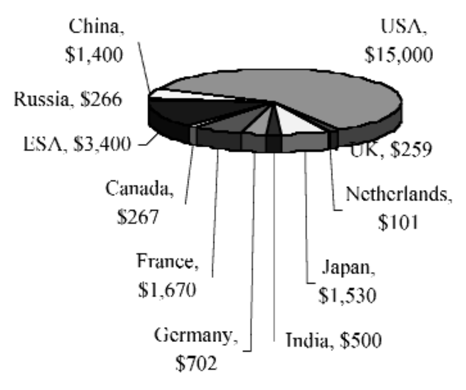
Since the end of the Cold War, American and Russian civil space funding has declined significantly. In 2000, for example, NASA's budget was $13.8 billion. Compared with the $94 billion (in 1990 dollars) that was budgeted for the Apollo program alone in 1961, the halcyon days of civil space programs have since passed.[10] NASA, for example, has been pursuing a strategy of "faster, better, cheaper" since the early 1990s. Despite these funding cuts, NASA has continued to achieve successes (and some failures) with the Galileo scientific spacecraft, the International Space Station, and shuttle rendezvous with the Russian Mir, among others.[11] Indeed, funding for NASA continues to dwarf that for all other competitors (see Box 6-2).

Russia

Russian civil space funding declined precipitously after the 1970s, and by 2000 was a mere $160 million, though the Russian Space Agency (RSA) was able to raise an additional $800 million through sales to foreign customers, mostly in the form of launching foreign satellites. In fact, "[f]unds from the Russian government account for no more than 20% of the more than $1bn which Rosaviakosmos needs annually to keep going."[12] In 2002 the financial situation improved somewhat, with the government contributing $265 million to the RSA.[13] During this time, the Russian program stationed a cosmonaut on Mir for a year-and-a-half—a record time for a human being in space—launched several additions to Mir, joined the ISS, and placed a cosmonaut aboard a space shuttle flight.[14]

Box 6-2

Selected National Civil Space Budgets[64]



Europe

An actor growing in importance within the civil space sector has been the ESA. The majority of the funding for ESA comes from a small group of countries with active national space programs and industries. Between 1991 and 2000, for example, Germany and France regularly accounted for between 40 percent and 50 percent of ESA's annual budget.[15] ESA's total budget is divided between Mandatory Activities, Optional Programs, and programs for, and financed by, third parties. Over 70 percent of the budget currently goes towards optional programs.[16] As with the American and Russian programs, European civil space funding has declined over time: between 1994 and 1997, ESA funding decreased by 18 percent.[17] Still, ESA has since become both a dominant player in the commercial launch market as well as a key research actor, and has become the third most active space organization, after NASA and the RSA.[18]

Select ESA achievements in the civil program include Spacelab, the reusable laboratory mounted inside the cargo bay of the Space Shuttle, and the Giotto and Ulysses scientific spacecraft, the former of which showed the shape of a comet's nucleus and discovered organic matter on a comet for the first time, and the latter of which was the first to show three-dimensional pictures of the Sun's heliosphere.[19]

China

One country that has also been increasing its civil space program significantly is China. While China had only launched five satellites by 1994, by October 2000, China had developed and launched forty-seven satellites of various types, with a flight success rate of over 90 percent. According to the CNSA, China has become the third country in the world to master satellite recovery, and the fifth to independently launch GEO satellites. In other accomplishments, over thirty million Chinese have received college or technical secondary school education and training through satellite education TV broadcasting programs established in the early 1990s.[20]

Other Actors

Dozens of other nations maintain civil space programs, including, but not limited to, Argentina, Brazil, Australia, Canada, India, Indonesia, Iraq, Israel, Japan, Nigeria, Pakistan, and South Korea.[21] Brazil is working on expanding its satellite communications and remote sensing capabilities, and developing an independent launch capability.[22] Similarly, India launched its first satellite in 1975, placed an astronaut in orbit in 1984 aboard a Soviet spacecraft, operates the advanced Indian National Satellite (INSAT) network for telecommunication, television broadcasting, meteorology, and disaster warning, and has been pursuing an autonomous GEO launch capability for some time.[23]

Global Utilities

In contrast to national civil space programs, global utilities offer space-based applications that even nations without space programs can access. Global utilities primarily serve three functions: navigation, earth observation, and search and rescue. Global utilities are precisely that: global. While they may be owned by a single entity (e.g., GPS is owned by the US), the majority of them are cooperative ventures whose operation and information are shared by partnering actors, and sometimes are even accessible to the public.

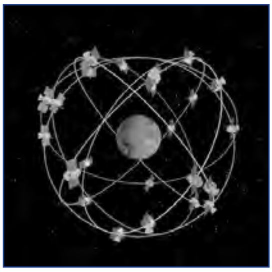


Figure 6-3
The GPS constellation.

Navigation

The GPS system, operated by the US Air Force, provides free navigation information to anyone who owns an inexpensive GPS receiver. This information is thus available for personal use, such as for hikers to orient themselves, and for commercial use, such as for helping ships at sea navigate their way to port. Similar navigation services are also provided by Russia’s Glonass constellation. China also has a small constellation of navigation satellites (Beidou) in GEO which provide limited navigation assistance. By 2008, GPS should be complemented by the European Galileo navigation system. It will be owned and operated by the civilian authorities from the twenty-five EU member states that are financing the project.[24]

Earth Observation

Earth observation global utilities primarily provide remote sensing services which monitor and measure such things as weather, temperature, water levels, rates of deforestation, etc. One of the most well-known earth observation utilities is NASA’s Earth Observing System (EOS). The components of the multinational EOS program are “1) a series of satellites specially designed to study the complexities of global change; 2) an advanced computer network for processing, storing, and distributing data (called EOSDIS); and 3) teams of scientists all over the world who will study the data.”[25] The flagship of the EOS is the Terra satellite, a joint US-Japanese-Canadian venture, which carries five measurement devices to report on pollutants in the atmosphere and other atmospheric and oceanic phenomena. Data from all five devices aboard Terra are freely available from the project website.[26]

Figure 6-4
Illustration of Terra’s MOPITT device scanning the earth for methane.

The US, EU, Russia, China, India, Japan, and France also collaborate under the rubric of the UN World Meteorological Organization to use satellites to monitor climate change over periods of time, as well as real-time early warning of developing natural disasters. Images taken by the satellites are provided by the respective partners.[27]

Search and Rescue

Figure 6-5
The COSPAS network.

Another key global utility is the COSPAS-SARSAT satellite network, a joint Canadian-American-French-Russian system used by thirty-seven parties to support search and rescue missions. The US and Russia provide five and two LEO satellites respectively (with Canadian and French instrumentation), while the GEO satellites are provided by the US (GOES series), India (INSAT series), and EUMETSAT (MSG series).[28] Since its inception in 1982, the COSPAS-SARSAT system has been involved in the rescue of over 15,700 people in almost 4,500 incidents. Moreover, the system was the only source of alert to search and rescue teams in 1,800 of these cases.[29]

International Cooperation

The most important aspect of civil space programs and global utilities is that they strongly advocate the peaceful use of space, and tend to be cooperative. The Indian Space Research Organisation (ISRO), the Indian space agency, holds as a guiding principle that India is not in space to compete against richer countries, but to "play a meaningful role nationally, and in the community of nations."[30] The ESA itself is representative of the international cooperation that thrives in the civil space sector today. The data generated by civil space programs is of use to diverse individuals and organizations. For example, ESA programs have helped to generate more accurate maps, useful for "improved town planning," and to generate more accurate weather forecasts, a boon to agriculture.[31] Moreover, unlike the data offered commercially, civil space data tends to be freely and publicly available, which helps to increase transparency and assuage any fears that civil assets are being used for military objectives. For example, the NOAA offers a host of weather and environmental imagery and information free on the internet at its website.[32]

Civil space cooperation is beneficial for space security because it facilitates the diffusion of ideas and technology, acts as a confidence-building mechanism, and encourages actors to share common space assets. Cooperation has also been responsible for increasing the number of actors directly involved with space activities. For example, a total of twenty-three states have placed astronauts into space via US and Soviet/Russian civil space programs. Another good example of inter-agency cooperation is the agreement between the ESA and Russia to send European astronauts to the ISS via the Russian Soyuz spacecraft between 2001 and 2006 and the continued sharing of metrological data between the US and Europe.[33]

The willingness of the US and Russia to cooperate with other countries and allow foreign astronauts access on their spacecraft has helped to expand the number of countries with active space programs. Indeed, whereas twenty years ago cooperation normally occurred between older and smaller established space actors (e.g., US-Canada), today many agreements are being forged between aspiring or burgeoning parties without the aid of an established space power (e.g., Brazil-China, see below). Military and civil actors also often coordinate common assets. The US government, for example, has merged its civil and military meteorological satellites into a single system.[34]

Besides the international cooperation between civil space programs, there is significant interaction between the civil and commercial sectors. Research is often performed using commercial facilities, equipment, and assets. Space research generated by universities is also often used as the basis for commercial consumer products. As such, civil space programs can be seen as generators of commercial spin-offs that take research done on one type of project and apply it to an altogether different project. It has been estimated that for every dollar spent on space research in the US, $7 will be returned to the government "in the form of corporate and personal income taxes from increased jobs and economic growth."[35]

Spin-offs therefore underscore how important space assets are to the broader economy, which makes secure and sustainable access to and use of space all the more important. As an illustration, GPS today is a $16 billion-a-year industry. Spin-offs can also be on a smaller scale, beneficial to all types of applications. One medical technology application of the Hubble Space Telescope is the Space Telescope Imaging Spectrograph, "a cancer detection application [that] grew out of [the Hubble's] need for highly sophisticated imaging capability."[36]

In addition, global utilities have led more countries to consider space a part of their economic and national security; hence they have given a wider range of actors a stake in maintaining the security of space. Cooperation also realizes certain economies of scale: instead of developing and operating satellite navigation systems of their own, countries can simply utilize GPS and direct funds to another endeavour. Furthermore, global utilities create positive interdependence: by virtue of a large number of actors relying on common assets, actors will be more risk adverse to policies that could interfere with the proper functioning of these assets.

International Transparency

Transparency is another feature of civil space programs and global utilities, as international cooperation inevitably involves the exchange of expertise and technology, some of which may be dual-use and which may increase the capabilities of some of the nations involved. The ESA, for example, notes that it works with other organizations worldwide to "share the benefits of space with all mankind."[37] Naturally, much technical information is protected from sharing, but the personal contact that comes with cooperation allows for a degree of transparency that is hard to attain through any other means. Cooperation can also be used to encourage nations to abide by the guidelines of international agreements on non-proliferation and on the use of space, efforts that will militate against interference of access and the development of space-based threats.

However, the levels of transparency are not currently sufficiently advanced to quell the concerns of some actors. For example, the Chinese and Brazilian space agencies have cooperated on the China-Brazil Earth Resources Satellites (CBERS). Of particular interest, however, is CBERS-2, which was launched in 2001. While it is officially another remote sensing satellite with an environmental remit, the fact that not a great deal of information regarding the satellite has been released to the public has led many analysts to conclude that it is being used for military reconnaissance.

2003 DEVELOPMENTS

Overall, civil space programs and global utilities achieved several successes and suffered debilitating failures in 2003. Key developments occurred in the US, Russia, Brazil, Japan, Europe, China, India, as well as other countries.

United States

Figure 6-6
Space shuttle Columbia lifts off of launch pad 39-A from the Kennedy Space Center, 16 January 2003.

The defining moment for the American civil space program this year was the Columbia disaster. This was the first shuttle loss since the Space Shuttle Challenger exploded in 1986 and only the second Shuttle accident ever. This accident put an immediate halt to all planned shuttle missions for the year, although unmanned American launches continued. NASA hopes to recover from this event and fly new Space Shuttle missions in September 2004.[38] In addition to putting an immediate halt to all shuttle missions, the Columbia tragedy interfered with two important policy reviews underway at the time of the crash: the White House was close to completing a broad review of US space policy, while NASA itself was conducting its own internal policy review that was to have great implications for the future of the International Space Station. Both of these policy reviews were halted immediately in light of the tragedy.[39]

Russia

While the destruction of Columbia was tragic for the United States, it also posed considerable problems for those countries and civil space programs that depend on American manned spaceflight capabilities. For example, the tragedy placed a further burden on the already cash-strapped Russian space program. Because of the grounding of the American shuttle fleet, Russia became the only country with the capability to re-supply the International Space Station. While Russia has performed this task admirably, it is unknown how sustainable this arrangement is in the short term and what impact it will have on the state of the International Space Station in the next few years.[40] Still, in spite of its relatively small budget, Russia retains a unique role in the civil space sector and in the ability to influence space security overall in that it still does have significant launch capabilities. This demonstrates further how civil space actors can enhance space security: the greater the number of civil space actors the more avenues there are to reach outer space, thus increasing access, thus enhancing space security.

Russia also continued to expand its partnerships with the ESA in 2003. In November, France and Russia signed an agreement that will see Russian Soyuz spacecraft be launched from the French Kourou spaceport in French Guiana. Russia wanted access to Kourou because of its proximity to the equator, which will allow Russia to launch “heavier cargoes to higher orbits” than it can from its current launch facilities in Kazakhstan. The first launch is scheduled to take place in 2006.[41]

Brazil

The United States was not the only country to suffer a loss of life in the civil space sector. In late August, Brazil’s third attempt to become the first Latin American nation able to send its own satellites to orbit ended in disaster as the VLS rocket exploded on the launch pad killing twenty-one people. This disaster was a ponderous setback for Brazil’s still incipient space program.[42] In terms of space security, the Brazilian explosion, together with the Columbia tragedy, demonstrates how fragile space technology continues to be.

Figure 6-7
Veiculo Lancador de Satelites (VLS) at Alcantara.

Japan

While no lives were lost, Japan suffered a setback in its space exploration plans when a quarter-scale model of its unmanned Hope-X mini-shuttle crashed on its first flight on 2 July.[43] For comparative purposes, Japan has not launched a research mission into space since August 2001. Japan’s civil space program was further set back in 2003 by the failure of its Nozomi mission to mars. As the probe, which was launched in 1998, neared its destination, Japan was unable to recover from a series of setbacks it suffered, including damage induced by a solar flare and problems with its fuel system.[44] Japan also lost touch with the Midori 2 environmental observation satellite.[45]

However 2003 did see Japan form its first consolidated space agency, when different government agencies responsible for space activities were brought together in October, under the name of the Japanese Aerospace Exploration Agency (JAXA).[46] JAXA's annual budget is currently $1.6 billion.[47]

Europe

European countries demonstrated their continued commitment to space with the publication of two important studies. In January, the EU and the ESA published a joint *Green Paper* on European Space Policy that indicated the EU's desire to play a greater role in space by working even more closely with the ESA.[48] This report was followed in November by a *White Paper*, subtitled *An action plan for implementing the European Space Policy* (for more discussion, see chapter I-03 National Space Security Policies and Doctrines).

The Galileo frequency dispute between the US and ESA remained unresolved in 2003, though tangible steps forward were taken with the program. In June, the first Director of the Galileo Joint Undertaking was named, while the first contracts for Galileo satellites were awarded in July. While these first contracts are for experimental satellites due to be launched in 2005, ideally they will be the precursors to a network of thirty satellites that the ESA hopes to have operational by 2008.[49] Galileo received a further boost when China and India announced investments of $250 and $350 million in the project, while Israel and Brazil also expressed interest.[50]

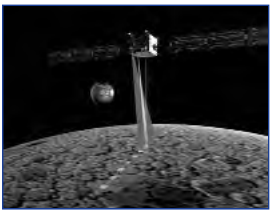


Figure 6-8
Remote-sensing instruments on SMART-1 will scan the moon's surface.

This all bodes well for the establishment of a new global utility. Yet if China decides to adopt Galileo widely, it is expected to use the system for both civilian and military applications.[51] Such a development could lead to further tensions with the US. Overall, certain experts see Galileo as a positive development because it will increase international cooperation and offer even wider availability of satellite navigation technology,[52] while others see it presenting a continued source of disagreement that relates directly to the equitable use of space.

Finally, scientific achievements were also accomplished. On 2 June, ESA's Mars Express probe was launched with the objectives of searching for sub-surface water and studying both the atmosphere and martian geology.[53] This spacecraft, which reached mars by the end of 2003, is one of six international missions currently on mars, or on the verge of arriving, for research purposes. On 29 August, the ESA launched its first lunar exploration mission, the Smart-1 probe, that will orbit the moon, produce highly detailed colour images, and allow scientists to test technologies such as an innovative new solar-electric propulsion system.[54]

Figure 6-9
Yang Liwei, China's first taikonaut.

China

Yet perhaps the biggest civil space accomplishment of the year was China's launch of a man into space on 15 October, making China just the third country to launch a human into space. China's launch of a taikonaut indicated its commitment to the civil space sector and suggests that China will want to play a greater role in influencing issues relevant to space use and exploration in the future. China is working to expand its manned space program further and is also launching a new series of communications and earth-imaging satellites.[55] Indeed, China presently has plans to have its own orbiting space lab by 2007 and is in the process of performing a serious study on the feasibility of a moon launch.[56]

China further demonstrated its increasing prominence in the civil space sector by virtue of its other successful missions throughout the year. In May, a third Beidou navigation and positioning satellite was launched to join two others which have been in orbit since 2000, thus completing "China's own satellite navigation and positioning system."[57] This is an important development in that it illustrates China's strong desire to be able to rely on indigenous assets.

India

India launched spacecraft quite actively throughout 2003 and is expanding its indigenous space capabilities. Since 1999, India has launched one satellite per year as part of the Indian National Satellite System (INSAT). This year witnessed the launch of INSAT-3A, a satellite that will be used for "telecommunications, television broadcasting, meteorological and search and rescue services."[58] More importantly, India also performed its second test launch of its Geosynchronous Satellite Launch Vehicle (GSLV), which brought the experimental GSAT-2 telecommunications satellite into GEO.[59] This was India's first indigenous GEO launch, and moves it into the field of advanced space-faring nations.

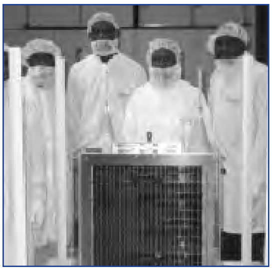


Figure 6-10
Nigeria joined the space race in September with the launch of NigeriaSat-1.

Other Countries

Nigeria launched its first satellite, a new addition to the multinational Disaster Monitoring Constellation (DMC), in September. The Nigerian National Space Research and Development Agency's (NASRDA) NigeriaSat-1 ushers Nigeria into the space age and will be used to monitor pollution, land use, and other medium-scale phenomena. In another example of small- and medium-sized actor collaboration, Nigeria contracted Surrey Satellite Technology Ltd., a UK leader in small satellite technology.[60]

Canada launched its first space telescope, MOST (Microvariability and Oscillations of Stars), on 30 June 2003 from northern Russia. Despite its modest price ($7.5 million) and the size (no bigger than a suitcase), the MOST will make "specialized astronomical observations beyond the capacity of any other instrument on Earth or in space," even the Hubble. According to the CSA, "MOST is designed to probe the interior of stars, set a limit on the age of the Universe, and for the first time, detect light reflected by little known planets beyond our Solar System."[61] Canada also announced participation in Galileo to the initial tune of $8 million, and will send equipment to mars for the first time in 2007 aboard NASA's Phoenix mission.[62]

The South Korean civilian space program also gathered steam in 2003, with a budget of $135 million. In August construction began on the space center in Goheung, while in September Science and Technology Satellite-1 was successfully launched into orbit. Development of Communication, Oceanography, and Meteorology Satellite-1 was also initiated in September for launch in 2008, while Multipurpose Satellite-2, a cooperative endeavour with Israel, is to feature a high-resolution (1 meter) camera.[63]

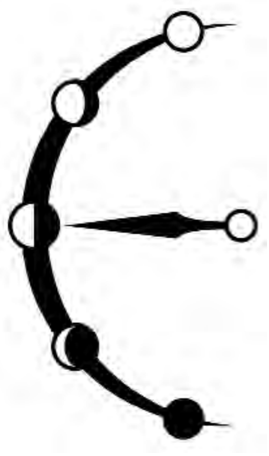
SPACE SECURITY SURVEY 2003: KEY ASSESSMENTS

Space Security 2003: Survey Results

Space Security Survey (20/10/2003-14/11/2003)		Space Security Working Group (24/11/2003-25/11/2003)	
Question: Taking into account your views on developments in the previous three areas (national civil space programs, international cooperation in space, and global utilities) in the past year, how have overall changes in this area affected space security?		*Question:* In your view, space security with respect to this indicator has been…?	
Enhanced:	4	Enhanced:	0
Somewhat enhanced:	7	Somewhat enhanced:	8
Little or no effect:	**48**	**Little or no effect:**	**11**
Somewhat reduced:	30	Somewhat reduced:	4
Reduced:	10	Reduced:	0

- The ongoing importance of international cooperation across civil space programs was underscored by developments during 2003 in particular Russia's agreement to continue servicing the International Space Station following the Columbia tragedy.
- China's entry into manned space flight was also an important civil space development which appeared to stimulate the civil space activities of others.
- The continued dispute between Europe and the US over Galileo spectrum allocation was a concern regarding global utilities.

There was little or no effect on space security in 2003 with respect to this indicator.



LITTLE OR NO EFFECT

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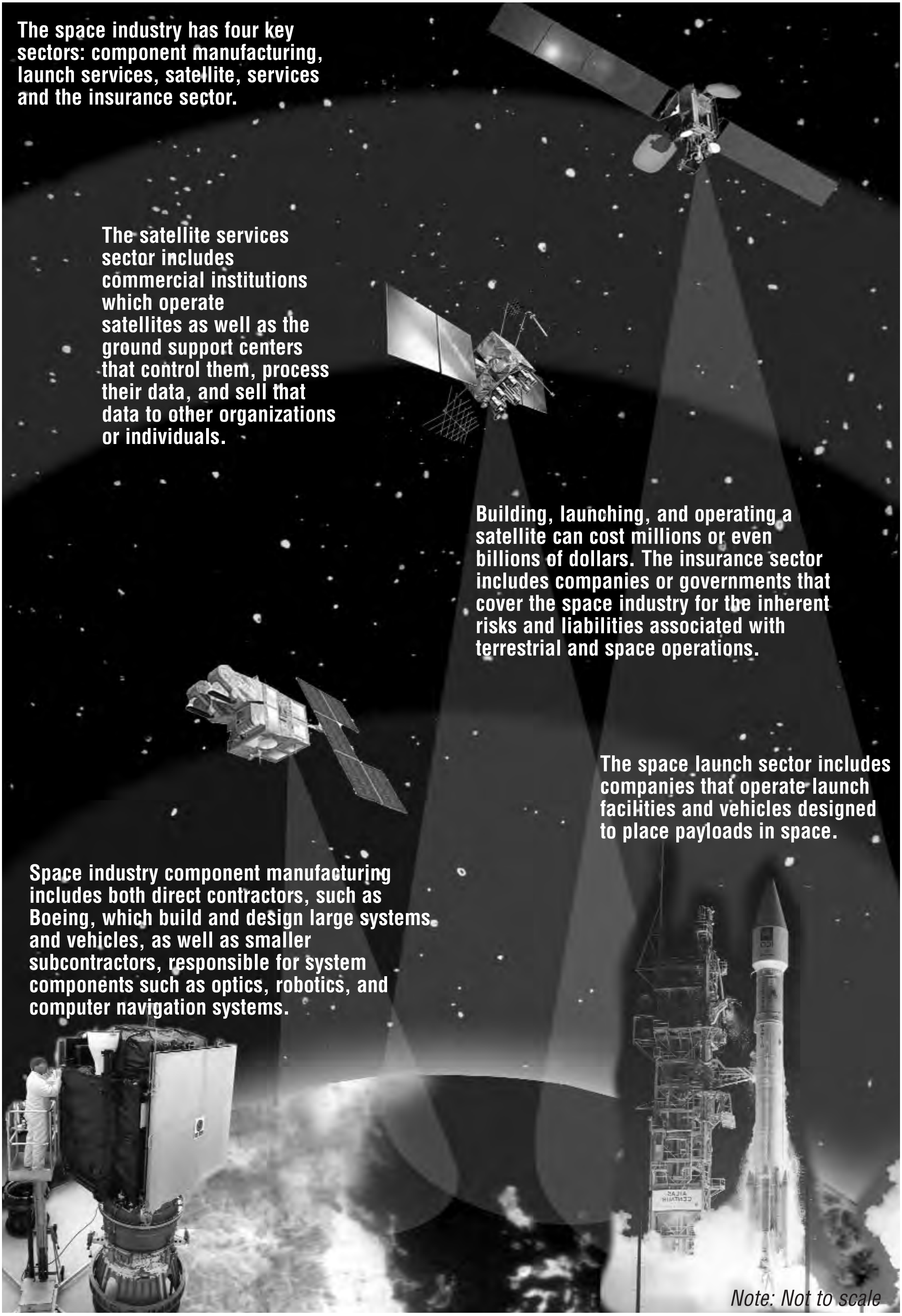
Figure 7-1



The space industry 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.

The space launch sector includes companies that operate launch facilities and vehicles designed to place payloads in space.

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.

Note: Not to scale

7

This chapter assesses trends and developments in the space industry sector related to component manufacturing, launch services, and operational services. The insurance sector is also examined, as the owners of satellites use insurance for protection against liability for damage caused by a malfunction of their launch vehicles or satellites.

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 operational services (or satellite services) sector includes commercial and non-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.

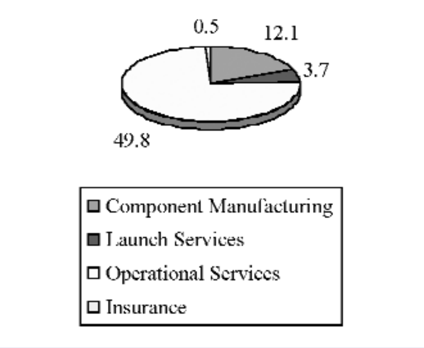
The space launch sector includes companies that operate launch facilities and vehicles designed to place payloads in space. The insurance sector includes companies or governments that cover the space industry for the inherent risks and liabilities associated with terrestrial and space operations. In addition to those directly engaged in the space industry are satellite service providers, end users, and the industry's spin-off products. The bulk of revenues in the satellite services sector are generated in three main areas: telecommunications, earth observation, and remote sensing.[1]

The space industry is directly related to space security considerations because it provides many actors with the capabilities to access space (launchers), operate in space (satellites and ground stations), and make use of products generated from space applications. The space industry represents a rapidly growing community of actors who use space for commercial utilities or benefit from its commercial research and development spin-offs, underscoring the benefits of secure and sustainable access to space.[2]

A healthy space industry, populated by a wide range of actors will tend to increase commercial competition and the prospect of decreasing prices leading to improved space access. The insurance sector also links to space security because it both reflects the state of space security and affects the cost of space access. At the same time, the intensive use of space by the space industry and the growing use of commercial space by military actors highlights concerns about potential damage to the space environment and, over the longer term, the security of commercial space assets.

Box 7-1

Space Industry Sub-Sector Size, 2002 [65]



*-all figures in billions of dollars. Insurance revenues measured in terms of premiums.

BACKGROUND

There are many sub-divisions within the space industry, including component manufacturing, launch services, satellite services, and insurance. Manufacturing is mostly commercial in nature, while operational services is a greater mix of commercial and governmental organizations—thus industry revenues do not necessarily reflect the total size of these sub-industries. In 1980, the worldwide commercial space sector accounted for just $2.1 billion in revenues, yet by 2000, the sector collected $94.5 billion in revenue.[3] By 2002, the satellite (operational) services industry alone comprised $49.8 billion, accounting for some three-quarters of the entire industry that year (see Box 7-1). Not yet included in industry totals for revenues is the small but growing space tourism industry.

The Component Manufacturing Sector

At the beginning of the space age, the existing aerospace industry was well-positioned to develop the capabilities to support access to and use of space. Primarily, these giant aerospace companies such as US-based Lockheed Martin, Boeing, Raytheon, Northrop Grumman, General Dynamics, and their respective predecessors, were able to adapt to the needs of the first government satellite programs and then to commercial programs. As early as 1958, the US government contracted out construction to aerospace companies Martin and General Electric for its second satellite, the Vanguard.[4]

However, it was communications satellites which truly gave birth to the commercial space industry. In 1960, The US Federal Communications Commission (FCC) received the first proposal for launch of an experimental communications satellite. The early 1960s saw widespread debate over control of satellite communications in the US. In response, in 1962 the US Congress passed the Communications Satellite Act, which launched the government corporation known as the Communications Satellite Corporation (COMSAT), in an attempt to balance both public and private interests in control over satellite information channels.[5] Today, COMSAT still exists and serves as the US representative to the UN-sponsored International Mobile Satellite Organization (IMSO), the intergovernmental organization that oversees INMARSAT, which operates an international global mobile satellite communications network.[6]

The first commercial satellite was the Telstar 1, launched by NASA in July 1962 for AT&T.[7] By 1964, AT&T, RCA, and Hughes Aircraft Company had each launched two TELSTAR, RELAY, and SYNCOM satellites, respectively, with contracting and/or launch services still coming from NASA. Interestingly, it was the intergovernmental organization Intelsat, credited with developing the first commercial communications satellite in 1965 and the first global satellite communications system,[8] that broadcast the 1969 moon landing of Neil Armstrong to some 500 million television viewers.[9]

The first revenues of the satellite industry were reported in 1978, when the *US Industrial Outlook* published 1976 COMSAT operating revenues of almost $154 million.[10] In 1986, Spot Image Corporation, a French company, began operation of the first commercial remote sensing satellite system.

Today, there are five satellite manufacturers that dominate the industry. Commonly referred to as the Big Five, they are: Boeing (US), Loral (US), Lockheed Martin (US), Alcatel (Europe), and Astrium (Europe).[11] Complementing these Large Systems Integrators are Small Systems Integrators and Subsystem Suppliers (including OHB, Volvo, and Siemens), and Equipment and Component Suppliers, as well as software providers and firms that provide services to space industry.[12]

The Space Launch Sector

The development of commercial launch capability only emerged as manufacturers began to work closer with launch vehicle manufacturers. Originally, NASA saw the selling of launch services as a way of offsetting its operating expenses. However, the early 1980s saw the emergence of Ariancespace's Ariane,[13] spurring international competition. European and Russian companies chose to pursue commercial launching via rocket technology, which allowed them to undercut the prices of American institutional competitors during the shuttle-only period. Increasing demand for launch services, and NASA's 1986 Challenger disaster, which led to a ban of commercial payloads on the Space Shuttle, caused a void to be created for launch of private payloads.

China, for its part, was active in the commercial launch market through the Great Wall Industry Corporation, with five total launches in 1998 and 1999. Although its commercial capabilities remain, it has since performed only non-commercial launches.[14] Japanese commercial efforts have suffered from technical difficulties, with the Japanese-designed H-2 launch vehicle shelved in 1999 after flight failures.[15] India's Augmented Satellite Launch Vehicle (ASLV) performed India's first 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.[16] Brazil is also trying to develop an autonomous commercial launch capability. Finally, the international consortiums Sea Launch and International Launch Services (ILS) also provide commercial access to space. Sea Launch, an enterprise comprised of the US' Boeing, Norway's Aker Kvaerner, Russia's RSC-Energia, and Ukraine's SDO Yuzhnoye/PO Yuzhmash, performs its launches from a converted oil rig in the North Sea.[17] ILS is a partnership between the Khrunichev State Research and Production Space Center, Lockheed Martin Space Systems, and RSC Energia. Today, key commercial launch providers in the US include Lockheed Martin and Boeing Launch Services.

American, European, and Russian companies remain world leaders in the commercial launch sector. Indeed, the top commercial launch service providers include Lockheed Martin and Boeing Launch Services in the US, Arianespace in Europe, Energia in Russia, and the international consortiums Sea Launch and ILS. In 1998, US companies performed twenty-two launches, Russia five, Europe nine, and China five (see Box 7-2). Total launch revenues were $4.3 billion. By contrast, in 2002 Europe dominated the industry, with ten launches to the US's five, Russia's eight, and multinationals' two, for a total of $3.7 billion.

Box 7-2

Select World Commercial Launches, 1998-2002 [66]

Country	1998	1999	2000	2001	2002
USA	22	15	7	3	5
Russia	5	13	13	3	8
Europe	9	8	12	8	10
China	4	1	0	0	0
Multinational	0	2	3	2	1

As access to space increased in the 1980s and 1990s, the number of companies looking to profit from this new industry also increased. With growing market projections and continued government contracts, a wave of companies were founded in the 1980s to take advantage of the predicted growth in the space services industry; in particular, telecommunications. There was a sense throughout the 1990s that as space infrastructure grew, demand would increase, costs would decline significantly, and a truly viable commercial space industry would be born.

Hard Times

Despite the predictions, the space industry has recently seen significant economic hardships, with satellite manufacturers being particularly hard hit. In 2000, the technological sector, which in many ways was driving the expected cost decreases, suffered the start of a massive downturn, and significantly curbed the growth of the space sector worldwide. From a record high of $12.4 billion revenues in 1998, satellite manufacturers worldwide collected just $9.5 billion in 2001, a drop of close to 24 percent.[18]

As an illustration of the effects of this downturn on regional business, European space business dropped in 2000, following a relatively flat business cycle that lasted from 1994 onwards,[19] and consolidated European space industry revenues dropped 6 percent between 2000 and 2001 and then another 11.3 percent between 2001 and 2002.[20] While revenues during this time remained positive, "other indicators—such as prices, profit margins, stock prices, and new orders" were negative.[21] And while the sector did see a rebound in 2002 back to $12.1 billion (see Box 7-3) (due to several large contracts being awarded in 2000 and 2001), 2002 did not see this increase sustained, and thus this rebound may not continue in the longer term.[22]

Box 7-3

World Satellite Manufacturing Revenues [67]

Year	Revenue*
1996	8.3
1997	10.6
1998	12.4
1999	10.4
2000	11.5
2001	9.5
2002	12.1

*-all figures in billions of dollars

One of the greatest symbols of this downturn was the satellite company Iridium, which launched services in 1998 based on a constellation of sixty-six satellites, with the intention of providing mobile phone services anywhere on the planet.[23] However, the hardware and services appeared to be too expensive and the phones too bulky to attract enough customers, and the company had filed for bankruptcy by August 1999.[24] With $6.6 billion in contracts with Motorola alone (the company's major backer), including $3.4 billion for satellite design and launch, the Iridium bankruptcy was, at the time, one of the top twenty bankruptcies in all of US history.[25]

As a result of the industry's troubles, especially in the global telecommunications industry—which has cut deep into the confidence of commercial space industrialists as well as the orders for their satellites—several sectors of the space industry have undergone waves of consolidation in recent years to reduce overcapacity, first in the US and then in Russia. Today, there are but three giant commercial aerospace companies in the US—Boeing, Lockheed Martin, and Loral—with S.P. Korolev RSC Energia leading in Russia. Europe has also experienced several consolidations and today there are only two major space conglomerates operating at prime contractor level including EADS Astrium, and Alcatel, with more consolidations expected for the state-sponsored industries of France and Italy. However, new entrants are poised in Israel, China, Japan, and India to increase global commercial competition for both hardware and services.

The total number of commercial launches today remains quite small. While 1998-2000 witnessed about forty commercial launches per year, current rates stand at about half that number. By contrast, the number of non-commercial launches held steady at around forty per year from 1998-2002.[26] However, despite fewer launches, the commer-

Box 7-4

World Operational Services Revenues [68]

Year	Revenue*
1996	15.8
1997	21.1
1998	24.4
1999	29.7
2000	39.2
2001	46.2
2002	49.8

*-all figures in billions of dollars

cial portions of the launch revenues stood at $2.7 billion, $1.5 billion, and $1.9 billion for 2000, 2001, and 2002 respectively.[27] As is the case throughout the space industry, these overall launch figures mirror a smaller than expected demand for broadband satellite services toward the end of the 20th century.[28]

Despite the overall industrial downturn, operational services revenues continue to rise, as more customers are found for the satellites already in orbit, and newer satellites are able to perform a greater number of functions (see Box 7-4).[29]

The Insurance Sector

In 1988 the US government legislated a guarantee that insurers would only have to pay up to $500 million for a single claim, with the US government covering up to an additional $1.5 billion.[30] This law was drafted in response to the 1972 Liability Convention, which established that if a space object causes harm to a third party state or that state's citizens, the resulting case is to be dealt with under international law.[31] Barring such an occurrence, however, private insurance outfits are the main actors in this sub-sector of the space industry.

As for the state of the industry, prior to 1998, the typical rate for launch plus twelve months of in-orbit coverage could be purchased for 7 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 have said has precipitated a rise in the going rate to 16 percent, itself a 129 percent increase.[32] In 2002, the space insurance industry paid out $830 million in claims while it collected just $490 million in premiums.[33] The insurance industry has blamed more complex satellites with less quality control in the manufacturing process, while the satellite industry has countered that insurers are simply overreacting. Regardless, insurers have begun offering shorter terms, with higher rates and deductibles, and insurance exclusions for events such as terrorism.[34]

While space insurance is the smallest sub-sector of the space industry, it is not trivial. In terms of space security, high insurance rates could harm space security by making it more costly for actors to access and use space. For example, greater numbers of anomalies or man-made space debris would force insurers to pay for the damages incurred to satellites, thus raising the costs of putting new satellites into space.

End Users and Spinoffs

Figure 7-2
A selection of channels carried by Asiasat's satellite fleet.

The space industry universe is wider than simply the companies or institutions directly engaged in the production or operation of space assets. Indirectly, the space universe is an immense expanse that includes the billions of buyers or end users who every day directly or indirectly use and benefit from satellite-enabled services like banking, talking on a cellphone, driving a GPS-enabled car, surfing the internet, watching television, or listening to radio stations provided by satellite signals.[35] As an illustration, even a single satellite like Asiasat's Asiasat 2 carries the signals for the Kuwait Space Channel, Saudi TV-1, Voice of Islamic Republic of Iran radio, Fashion TV, EuroSport News, Macau Satellite TV, the Cartoon Channel, BBC, Voice of America, Reuters, Deutsche Welle-TV (Germany), RAI (Italy), RTPi (Portugal), TVE (Spain), Radio France, and Radio Canada, among others (see Figure 7-2). Though many individuals are unaware of the ubiquity of satellite-enabled functions in their everyday lives, each individual that benefits from the space industry has a stake in ensuring its sustainability and accessibility. Satellite service providers, which turn data gathered from space into commercial utilities, are also included under end users. Like many other space industry sectors, the satellite services sector is led by a small number of large companies: Intelsat, SES-Global, Loral, Hughes, and Eutelsat. Seventy percent of all transponders, the devices that broadcast satellite signals, are operated by these five companies.[36]

Moreover, space industry proponents routinely point to the space industry's manifest spinoffs and downstream products as evidence of its

Box 7-5

Select NASA Space Spinoffs or Improvements

As a result of NASA's space program, the following items or procedures were created or greatly improved upon:

- TV Satellite Dish: NASA developed ways to correct errors in the signals coming from the spacecraft;
- Bar Coding: Originally developed to help NASA keep track of millions of spacecraft parts;
- Smoke Detector: First used in Skylab to help detect any toxic vapors;
- Cordless Tools: Portable, self-contained power tools were originally developed to help Apollo astronauts drill for moon samples;
- Breast Cancer Detection: A solar cell sensor is positioned directly beneath x-ray film, and determines exactly when film has received sufficient radiation and has been exposed to optimum density;
- Laser Angioplasty: Performed with a "cool" excimer laser, does not damage blood vessel walls and offers precise non-surgical cleanings of clogged arteries with extraordinary precision and fewer complications than in balloon angioplasty;
- Medical Imaging, Ear Thermometer, Fire Fighter Equipment, Shock Absorbing Helmets, Ski Boots, Scratch-Resistant Lenses, and Virtual Reality among others.

ingenuity and importance. The GPS is probably the most famous of the space industry's downstream products, and is an example where a greater portion of space component manufacturing revenue is associated with the downstream production of ground terminals than the satellites themselves. In terms of spinoffs (see Box 7-5), NASA also maintains several webpages devoted to exploring the most famous spinoffs of the civil space program that have become commonplace or have led to further technological or commercial development.[37] Whether generating advances in the space field, which could, for example, allow greater space access or reduce debris, or in other fields, the health of the space industry is important to space security at its broadest level.

Industry Constraints and Interdependencies

In spite of the prevalence of private sector principles across the space industry, due to the sensitive nature of much of the equipment manufactured and many of the services offered, as well as the potential dual-use nature of many of these goods and services, there are many limits placed on the sector. One limitation comes in the form of the Missile Technology Control Regime (MTCR). Because the same technology that can be used to launch objects into outer space can also be used to deliver warheads, the MTCR was formed in 1987 as a way to prevent the sale of technology and equipment that could be used to transform a conventional rocket into a delivery system for a nuclear weapon or other type of weapon of mass destruction.[38]

Moreover, certain companies have been unable to take advantage of low cost launches because of political interference and regulation. For example, at the end of the 1980s Australia wanted to upgrade its Aussat domestic satellite communication system. To do this, Australia planned to use satellites built in the US by Hughes to be launched on Chinese Long March rockets. However, the US government initially placed an export ban on the satellites because of "political unrest" in China. While the exports were allowed eventually, the event illustrates the degree of influence government wields over the space industry.[39] As is a country's sovereign prerogative, it can set export controls as it sees fit for its own national interest. For example, while the Iran Nonproliferation Act of 2000 in the US sets out to limit the transfer of ballistic missile technology to Iran, Russia is willing to provide such expertise.[40]

Like a number of other sectors, the issue of subsidies is also one that affects the space industry. In the launch sub-sector, for example, the Director of Space and Technology for Boeing, Robert Bocek, noted that despite the fact that the six primary large boosters available today—Ariane 5, Atlas 5, Delta 4, H-2A, Proton, and Zenit 3SL—have a combined capacity of seventy-eight launches a year, they are currently performing only fifteen to twenty per annum. In a truly competitive and open arena, market forces would purge the marketplace of some of the competitors, but this has not taken place in the launch sub-sector. The reason, according to at least one industry expert, is that

> [the] launch [industry] is far from a strictly commercial industry, and is heavily influenced by issues of national security and national prestige. As a result, we see today efforts like 'assured access to space' in the US, a bid to ensure that there are at least two major domestic launch vehicle providers; and 'guaranteed access to space' in Europe, where ESA will help to underwrite costs associated with the Ariane 5 to make sure it remains competitive in the global marketplace.[41]

Certainly, as the space industry has expanded into more and more commercial fields, it has gained certain degrees of independence. The international nature of many commercial space projects has made it more difficult for any one country to control or regulate access to space. Nonetheless, space remains politically delicate and nationally integral and prestigious, and as such government support remains an option in the arsenals of national governments.

One of the most controversial forms of government purchasing is military spending. While the commercial industry was struggling with sagging revenues and overcapacity, the US military in particular was increasing its use of space to support terrestrial operations (see chapter I-09). The US Department of Defense realized it could use this extra capacity to launch and support its own assets, while saving on technology development. Thus due to the time and expense of designing and launching its own satellites, the military often purchases the services provided by commercial satellites. For example, the Canadian armed forces buys imaging services from the commercial Radarsat satellite, and, during NATO's military campaign in Kosovo, over 80 percent of military communications were provided by commercial service providers. In another illustration, when the US began its military campaign in Afghanistan in late 2001 it purchased all of the imagery available for the country from the private satellite-imaging firm Space Imaging Corp. This deal was not a form of shutter control, but rather a strictly commercial arrangement.[42] Furthermore, military use of commercial services is the result of a demand that outstrips the military's own satellite capacity. Consequently, military purchases can be quite beneficial to space industry. One significant reason why performance in the satellite manufacturing sector was significantly better in 2003 (see below) than in 2002 was because of work done on the $1 billion Milstar 5, a satellite used by all branches of the US armed forces for communication purposes as part of a network of five satellites.[43]

Such interdependence increases space security because of the reliance on common assets. Moreover, it could lead to improvements being made to make assets more secure, such as hardening satellites against electro-magnetic pulses; increased use of commercial space assets by the military has made industry more aware of the need for protective measures.[44] Still, disproportionate military-to-commercial purchasing of satellite services could potentially negatively affect space security, as military tenders can be less open to competing bids from other countries' companies, thereby reducing their revenues and possibly competitiveness. Further, with the relationship between military and commercial assets sometimes blurred, such as in the purchase of satellite imagery, the security of international actors' abilities to access these resources may also be challenged.

2003 DEVELOPMENTS

Overall, 2003 was not a good year for the space industry. Some companies suffered considerable losses while others reported stable or marginally improving figures. Key developments occurred in the component manufacturing, launch, and operational services sub-sectors, while other developments also impacted this indicator.

Component Manufacturing

The biggest news of 2003 was Loral Space & Communications Corporation's bankruptcy filing and selling of "present and future satellite assets" worth $1 billion to Intelsat.[45] While Loral continues to operate and could recover, the troubles of this member of the Big Five were emblematic of the space component manufacturing industry. Boeing suffered from "weak" satellite sales,[46] while Lockheed Martin and Alcatel enacted large job cuts.[47]

Launch

Commercial launches were expected to drop from the previous year, with a total of seventeen commercial launches over the course of 2003.[48] However, fewer launches do not necessarily equal a reduction in space security: if fewer satellites are being launched into space, then actors are sharing a greater number of common assets. As one respondent to the 2003 Space Security Survey (see below) replied bluntly "If everybody uses the same resources, then it is not a wise thing to harm them."[49] Arianespace, the manufacturer of launch vehicles for the ESA, received a $1 billion bailout from the ESA.[50] Arianespace posted a small profit in 2003, but only after spending the past two years "in the red" and subjecting the company to "deep cuts in operating and payroll costs."[51] Boeing pulled its new Delta 4 booster out of the commercial launch business and its Integrated Defense Systems Chief was quoted as saying that Boeing would "eliminate all commercial launches over the next five years." Though Boeing said it would continue non-commercial launches and its participation in the Sea Launch commercial launching endeavor, this announcement did not bode well for the launch sub-sector in 2003.[52]

Operational Services

The operational services sub-sector did not fare as poorly as its other space industry cousins. Demand for commercial satellite services began to rise during 2003.[53] Projected figures suggested that twenty-nine out of the ninety-four payloads to be put into space during 2003 would be commercial.[54] Eutelsat's 2002-2003 annual report was buoyed by an 8.6 percent increase in revenues, to €715 million.[55] To 30 September 2003 Intelsat reported revenues of $237.2 million, a 4 percent decrease over 2002 figures, and a backlog worth $3.7 billion.[56] SES Global reported revenues of €642 million to 30 June 2003, a decline of 10 percent over 2002 numbers, which it attributed to currency exchange factors. SES Global's contract backlog stood at €6.1 billion.[57]

Other Developments

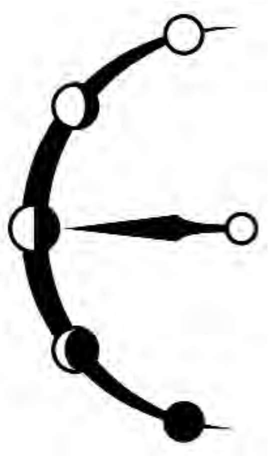
The other important trend identifiable in 2003 was an increase in military demand for space industry products. For example, there was significant spending in 2003 on the $1 billion Milstar 5 satellite,[58] and 80 percent of the satellite bandwidth used in the Iraq war was commercial.[59] Such spending has the potential to make national security spending on satellite communications worth 60 percent of US satellite communication activity, a huge turnaround from the 1990s when commercial spending dominated.[60] During the year, the US military space budget rose from $15 billion to over $20 billion.[61] 2003 also witnessed the US using commercial remote sensing services for military and government purposes to a greater degree than ever before. In early 2003 Space Imaging and DigitalGlobe received government imaging contracts that could be worth as much as $500 million each over five years.[62] This policy was formalized in April when the US implemented a new commercial remote sensing policy that aims to "rely to the maximum practical extent on US commercial remote sensing space capabilities for filling imagery and geospatial needs for military, intelligence, foreign policy, homeland security, and civil users."[63]

In Europe, on 27 May 2003 a meeting of ESA government ministers proposed the European Guaranteed Access to Space (EGAS) Ariane Program, which deigned to "secure the availability of Ariane-5 for the launch of the European institutional missions" by placing the industry "on a level playing field compared to competitors through to 2009 by covering selected fixed costs activities." This program was to be put to a vote in 2004.[64]

SPACE SECURITY SURVEY 2003: KEY ASSESSMENTS

Space Security 2003: Survey Results

Space Security Survey (20/10/2003-14/11/2003)		Space Security Working Group (24/11/2003-25/11/2003)	
Question: Taking into account your views on developments in both space industry and commercial space in the past year, how have overall changes in this area affected space security?		*Question:* In your view, space security with respect to this indicator has been...?	
Enhanced:	2	Enhanced:	0
Somewhat enhanced:	21	Somewhat enhanced:	0
Little or no effect:	24	**Little or no effect:**	**15**
Somewhat reduced:	**29**	Somewhat reduced:	8
Reduced:	8	Reduced:	0



LITTLE OR NO EFFECT

- The general trend in recent years within the space industrial sector has been an ongoing economic downturn. Even though civil and military actors turned increasingly to the commercial sector to meet their needs for space services, the space industry sector itself remained burdened by overcapacity in 2003.
- While overcapacity within the space industry sector was assessed by some as having a negative impact on space access, it also tended to increase market competition within the sector and contributed to pressures for lower space access costs.

There was little or no effect on space security in 2003 with respect to this indicator.

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[20] *Facts & Figures: The European Space Industry in 2002*, Eurospace, 2004, p.4.

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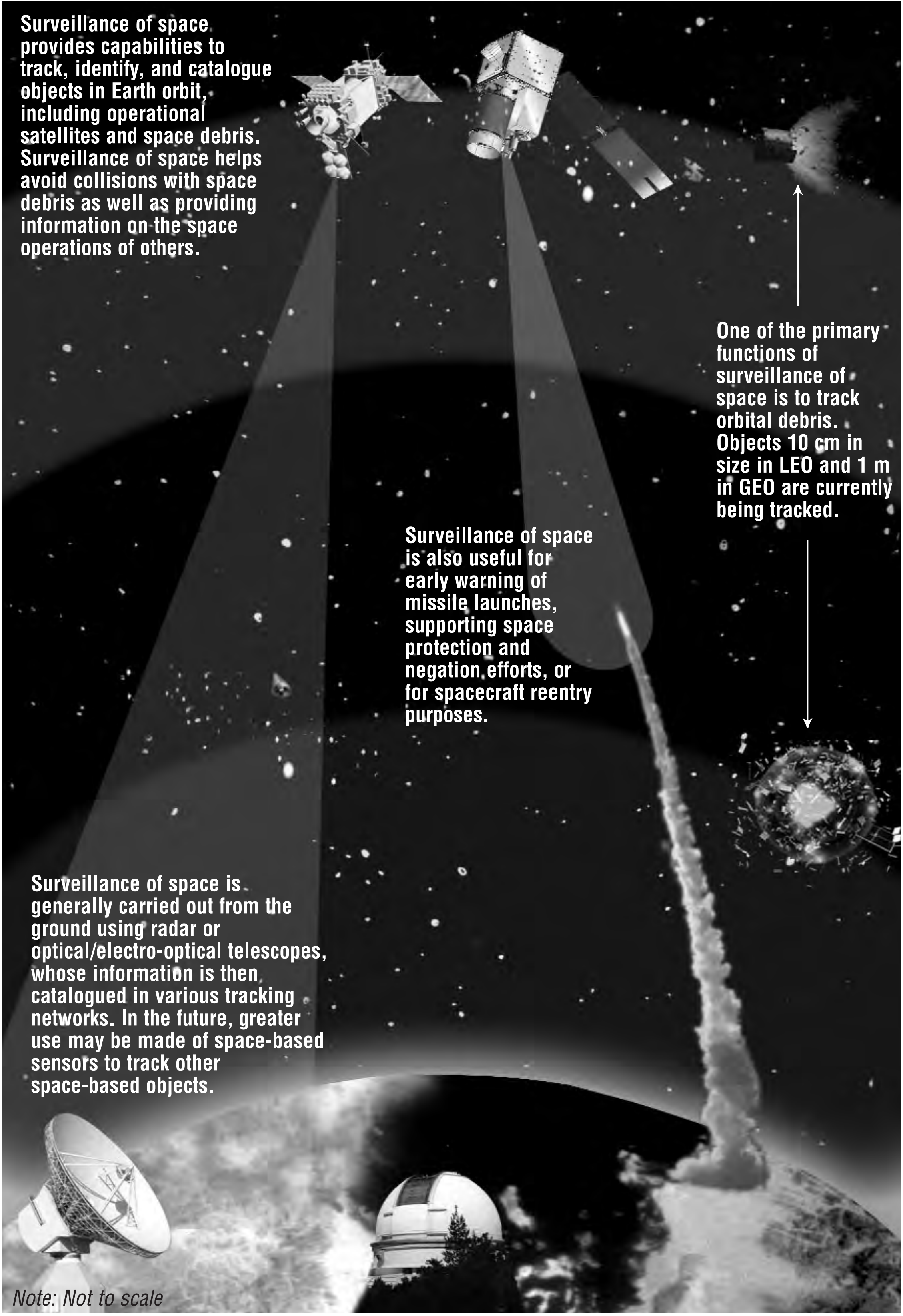
Figure 8-1



Surveillance of space provides capabilities to track, identify, and catalogue objects in Earth orbit, including operational satellites and space debris. Surveillance of space helps avoid collisions with space debris as well as providing information on the space operations of others.

One of the primary functions of surveillance of space is to track orbital debris. Objects 10 cm in size in LEO and 1 m in GEO are currently being tracked.

Surveillance of space is also useful for early warning of missile launches, supporting space protection and negation efforts, or for spacecraft reentry purposes.

Surveillance of space is generally carried out from the ground using radar or optical/electro-optical telescopes, whose information is then catalogued in various tracking networks. In the future, greater use may be made of space-based sensors to track other space-based objects.

Note: Not to scale

8

This chapter assesses trends and developments related to capabilities to track, identify, and catalogue objects in earth orbit, including operational satellites and space debris. These space surveillance capabilities are currently provided by a range of technologies, including ground-based radars, optical and electro-optical telescopes, and one space-based sensor. Algorithmic models are also used to predict where a given space object will be at a given time.


Figure 8-2
If an object is predicted to pass within a box measuring 2 km x 5 km x 2 km along the flight path of the Space Shuttle, an avoidance maneuver may be performed.

Space surveillance capabilities enhance space security by facilitating collision avoidance with a growing population of space debris within the earth's orbit (see chapter I-01 Space Debris). Because even small fragments of space debris can threaten the structural integrity of spacecraft, there is a continual effort to see smaller particles at greater distances. About 93 percent of the objects regularly monitored for the space catalogue are orbital debris.[1] For example, the Space Shuttle and International Space Station use a collision avoidance strategy that relies on surveillance data to map potential collisions.[2] Collision avoidance is also critical to efforts to mitigate the creation of new debris which could threaten the sustainability of space access and use in the future. Space surveillance capabilities also support efforts to predict an object's reentry into the atmosphere, and thus where debris will land.

Space surveillance capabilities can also provide space actors with information on the space operations of others including the identity, function, and location of civil, commercial, and military satellites. They can also provide early warning of ballistic missile and anti-satellite attacks. Such capabilities can affect space security in potentially contradictory ways. Thus, while space surveillance capabilities can increase the transparency of space activities, support space protection efforts, and build confidence among space security actors, these same capabilities can also be used to support efforts to negate the access to and use of space by others.

The key actors providing surveillance of space include the US, Russia, China, Europe, Canada, and Japan, among others. The US is the predominant provider of space surveillance information, with Europe at the lead of international cooperative efforts. Private citizens, either as individuals or in groups, also contribute to the surveillance of space.

Space Surveillance Systems

United States—The Space Surveillance Network (SSN)

The US SSN is the world's most extensive space surveillance system, and the primary supplier of data on space objects. From the original US Minitrack satellite tracking system, designed to monitor the radiowaves emitted by the Vanguard satellite, the SSN has evolved over fifty years to track nonradiating, or uncooperative, satellites and space objects.[3] The US 2001 *Quadrennial Defense Review* noted that "as the foundation for space control, space surveillance will receive increased emphasis. DoD [Department of Defense] will pursue modernization of the aging space surveillance infrastructure, enhance the command and control structure, and evolve the system from a cataloguing and tracking capability to a system providing space situational awareness."[4]

The SSN now consists of thirty radar and optical sensors at sixteen locations worldwide, one space-based sensor, a communications network, and operations centres for data processing. The SSN provides data on 9,000 catalogued objects as small as 10 centimeters in diameter in LEO and larger than 1 meter in GEO. A further 4,000 objects, some as small as 5 centimeters, are routinely monitored, but not yet formally catalogued.[5] Updates on these objects are collated in the Space Catalogue, which includes the numbers, types, and orbits of objects in orbit.[6] To date, the SSN has tracked and accumulated data on over 27,000 orbiting objects, from initial detection through to re-entry. Although it remains the most comprehensive space surveillance system in the world, the SSN has some limitations, including aging sensors, a limited capacity to view objects smaller than 10 centimeters (LEO) and 1 meter (GEO), and a gap in coverage in the southern hemisphere.[7]

The SSN's coverage is provided by dedicated sensors, which undertake space surveillance as a primary mission, contributing sensors, which are smaller or multifunctional telescopes or radar, and collateral sensors, which undertake space surveillance as an auxiliary or secondary mission.

Dedicated Sensors

Designed by the Navy Research Laboratory in 1958 and still a critical data source for the SSN, the Navy Space Surveillance System (NAVSPASUR) is a continuous-wave multistatic radar which acts like a fence of electromagnetic energy emitted from three transmitters across the southern US. Orbiting objects up to a range of about 24,000 kilometers passing through the fence reflect this energy back to earth, where six receiving stations interpret the signals and determine the object's position.[8]

The AN/FPS-85 radar at Eglin Air Force Base in Florida, with a range of about 40,000 kilometers, is the only phased-array radar within the SSN that is dedicated to space surveillance. Phased-array radars have fixed antennas that are electronically steered, and are therefore capable of tracking multiple objects simultaneously.[9]

The X-band Globus II radar was built and tested at Vandenberg Air Force Base and then moved to Vardø, Norway, in 1998. The dual-use nature of surveillance of space capabilities was highlighted when it was revealed that the Globus II had been used in missile defense testing by the US, and then moved to a location less than 100 kilometers from the Russian border. Some have argued that the new location of the system is "nearly the last place on Earth one would choose for a radar with the purpose of tracking space debris," but the right place for obtaining precision signature data at mid-course—the critical point at which warheads and decoys separate from the "bus" in preparation for the penetration of a missile defense system used to defend against Russian ballistic missiles."[10]

The three 102 centimeter electro-optical telescopes of the Ground-Based Electro-Optical Deep Space Surveillance (GEODSS) system are the primary sources of space object identification in GEO. These three telescopes scan at the rate that stars appear to move, so while stars are fixed objects in the images, satellites and space debris appear as streaks. Computers analyze and measure the streaks to identify the objects and determine their positions.[11]

The most recent addition to the SSN is the first space-based surveillance of space systems, the Space-Based Visible (SBV) sensor. Launched in 1996, the SBV was designed to address the need for increased deep-space surveillance. The sensor uses a visible-band electro-optical camera and has proven to be as productive as ground-based electro-optical systems producing equal numbers of observations with considerably more accuracy. The SBV now functions as a dedicated sensor in the SSN.[12] The SBV has the benefit of being in orbit, and therefore is not limited by the effects of weather, in addition to having a wide field of view and coverage of the entire geosynchronous belt. Still, acquiring real-time access to the data gleaned by the sensor is not yet a reality.[13]

Contributing Sensors

The Lincoln Space Surveillance Complex operated by MIT is a research and development station for space surveillance technologies and includes the Haystack Long Range Imaging Radar, Haystack Auxiliary Radar, and Millstone Hill Radar. The X-band Haystack Long Range

Imaging Radar can image satellites in GEO to a range of more than 40,000 kilometers in near real-time as well as space debris in LEO in the 1-10 centimeter range. The smaller Haystack Auxiliary Radar was built to supplement the work of the larger radar, with which it shares its control systems, while the Millstone Hill Radar performs deep space tracking functions.[14]

The Maui Space Surveillance Complex is an operational and research facility operated by the US Air Force dedicated to space surveillance. It includes one of the three Ground-Based Electro-Optical Deep Space Surveillance telescopes, and the Maui Space Surveillance System, known as AMOS. The electro-optical sensors that comprise AMOS make up one of the most advanced facilities for space surveillance and research and development within the US, and act as contributing sensors for the SSN.

The sensors located at the Ronald Reagan Ballistic Missile Defense Test Site in the Kwajalein Atoll, Republic of the Marshall Islands, primarily provide tracking and surveillance for the ballistic missile defense test range. However, the ARPA Long-Range Tracking and Instrumentation Radar (ALTAIR) and ARPA Lincoln C-Band Observables Radar (ALCOR) contribute to space object identification when available.[15]

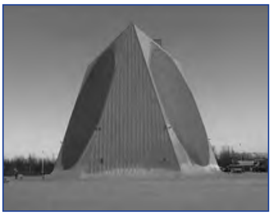


Figure 8-3
The Clear phased array radar, Alaska.

Collateral Sensors

The SSN includes several Solid State Phased-Array System radars, which act as collateral sensors, serving a primary mission of early warning and attack assessment for ballistic missiles and a secondary mission of space surveillance. These include:

- Ballistic Missile Early Warning (BMEWS) radars: Thule (Greenland), Fylingdales (United Kingdom), and Clear (Alaska);
- The Perimeter Acquisition Radar Characterization System (PARCS) radar: Cavalier AFB (North Dakota);
- PAVE Phased Array Warning System (PAVE PAWS) radars: Cape Cod (Massachusetts) and Beale (California)—automatic phased-array antennas are capable of both detecting and tracking multiple objects almost simultaneously; and
- Range Radars: Ascension Island and Kaena Point (Hawaii)—mechanical tracking radars track satellites in LEO.[16]

Russia—The Space Surveillance System (SSS)

Russian surveillance sensors are an important source of information on catalogued space objects. Beginning with thirteen measurement sites to track Sputnik, by the mid-1960s the Soviet Union had built its first generation of early warning radars and optical (later electro-optical) sensors for ballistic missile detection and tracking. However, it was determined that the radars would be dual-purposed, also serving a space surveillance mission: "The project called for close integration of all existing and future radar facilities that would provide the capability to track objects in outer space and determine parameters of their orbits."[17]

However, Russia's space surveillance system is in a weakened state: the operational Dnestr and Dnepr radars have long outlived their intended service lives; high power costs limit usage of the radars; there are gaps in coverage; and financial concerns impede upgrades. The Russian Federation's Reconnaissance and Airspace Control System Improvement Program for 2001-2010 identified the need to upgrade the early warning system and progress has been achieved slowly (see below).[18]

Radars

The SSS is distributed around the perimeter of former Soviet territory to provide the broadest view for its functions. The Dnestr phased-array radar was first deployed in 1967-68, with two Dnestr radar sites at Mishelevka (Russia) and Balkhash (Kazakhstan) still serving the SSS.[19]

Dnestr-M and Dnepr radars, upgrades of the Dnestr system developed through the early 1970s, are still operational at five sites: Olenegorsk and Pechora (Russia); Sevastopol and Mukachevo (Ukraine); and Gabala (Azerbaijan). With increased capacity to process incoming signals using pulse compression and a Y-shaped antenna array, these radars are believed to be similar to the early BMEWS radars.[20] Russia built one Daugava radar, as a prototype system for a second generation of radar, the Daryal, and it is still in use at Olenegorsk, north of Moscow, using the onsite Dnestr-M radar as its transmitter.[21] The first Daryal radar was commissioned in 1975, using phased-array for both reception and transmission, with two now in operation.[22]

By 1979 plans called for several more Daryal and Daryal-U radars to be built in addition to upgrades to the Dnepr radars and the construction of several Volga continuous wave phased-array radars—which together would have provided complete coverage of Soviet territory.[23] Modernization of the early warning radar system was delayed and frustrated by financial limitations in the 1980s. There was one successful upgrade: the new Don 2N large phased-array radar replaced the ground-based radars of the Moscow BMD system at Pushkino. It continues to provide both missile defense battle management and space surveillance.[24]

The collapse of the Soviet Union in 1991 forced Russia to negotiate access to their radar sites outside of Russian territory. Through agreements with Latvia, Belarus, and Ukraine, Russia managed to retain some radar stations for limited terms. For example, use of the Dnestr-M radars at the Skrunda site in Latvia was extended to 1998 but it was dismantled in 1999 and the unfinished Skrunda Daryal-UM radar was dismantled in 1995. The loss of the Skrunda site left a gap in northeast coverage, making retention of the Belarusian facility a priority and a twenty-five-year lease of the Baranovichi site was agreed upon.[25] A 1999 leasing agreement with Ukraine allowed continued operation of the Dnepr radars at Sevastopol and Mukachevo. Ukrainian operators staff the stations, but Russia processes the data and subsequently provides Ukraine with early warning and space monitoring information. In 2002 Russia and Azerbaijan finally reached a ten-year leasing arrangement with regard to the Gabala radar station.[26]

Optical and Electro-Optical Sensors

Figure 8-4
The Russian electro-optical Okno telescopes at Dushanbe.

In addition to its ground-based early warning radars, the Russian SSS relies on several optical sensors for surveillance of GEO. Established in the 1950s with the Zvenigorod Experimental Station as the core, fourteen observatories form this network of optical tracking stations.[27] Now serving primarily as research facilities, the Institute of Astronomy of the Russian Academy of Sciences and the SSS support these observatories and gain access to data from their instruments. The Okno electro-optical sensor, which became operational in 2002, significantly improved Russia's deep-space surveillance capabilities, filling some of the gaps identified in the Reconnaissance and Airspace Control System Improvement Program. Equated to the US GEODSS telescopes, Okno is located in central Tajikistan and is capable of tracking objects in GEO.[28]

China

Since commencing its space program in the 1960s, China has emphasized tracking, telemetry, and communications, developing a domestic network of sensors to monitor its rockets and satellites, taking measurements of their location. Coordinated by China Satellite Launch and Tracking Control General, China has built up a Telemetry, Tracking, and Control (TT&C) system consisting of ground stations dispersed across the country, mobile tracking sites, Yuanwang tracking ships, and phased-array radars. The Xi'an Satellite Control Center in Shaanxi Province was established as the control centre for the network in 1987.[29]

In the 1990s, China built two foreign tracking sites, including a location on South Tarawa Island in Kiribati (see below), and another near Swakopmund, Namibia, to meet the needs of its expanded space program. Cooperative initiatives with Brazil, France, and Sweden established agreements to access data from tracking facilities in those countries.[30] Most recently the system was upgraded to include S-band tracking capabilities. China's limited space tracking capacity currently supports only its domestic space program and has limited ability to track uncooperative space objects. However, some assert that it "serves as the foundation for future efforts to develop a more robust tracking system which can accurately track foreign systems as well."[31]

In 1995, China joined the Inter-Agency Space Debris Coordinating Committee and in 2001 it established a five-year action plan for space debris monitoring and research.[32] Prioritizing mitigation and monitoring, the plan calls for, amongst other things, acquiring a monitoring capacity with one fixed and two mobile telescopes.[33] The Commission of Science, Technology, and Industry for National Defense received $3.6 million for the five-year period to begin this work.[34]

China has a long legacy of work in the area of astronomy and has several observatories with optical systems engaged for this purpose. In 2001 the National Astronomical Observatories of the Chinese Academy of Sciences brought together the national observatories with a common research policy.[35] One of the research priorities for the observatories is the dynamics of bodies within the solar system, including artificial satellites. The Schmidt telescope at Xinglong Station of the Beijing Astronomical Observatory has been engaged in asteroid detection[36] and several other observatories are under construction.[37]

Japan

As a relatively new contributor in the space surveillance field, Japan is applying a cooperative approach with government, academic, and non-governmental organizations working together to establish a space-monitoring project. The Japan Spaceguard Association, affiliated with the Safeguard Foundation and primarily concerned with discovering Near Earth Objects (NEOs), provided technical and financial support for the project.[38] Located in Okayama prefecture, the Bisei Spaceguard Center began operations in February 2000 with two optical telescopes, 25 centimeters and 50 centimeters in diameter. In 2002, a third optical telescope with a 1 meter diameter was added to the site, capable of tracking space debris in GEO to 50 centimeters and designated to search for asteroids, while the smaller telescopes will provide tracking. The radar site, the Kamisaibara Spaceguard Center, includes a phased-array radar capable of monitoring small debris in LEO.[39]

Figure 8-5
The Japanese Bisei Spaceguard Center.

The Tsukuba Space Center is the central hub of Japan's space program. The Tracking and Control Center there processes satellite telemetry data to monitor Japanese satellites in orbit. Data from the Bisei and Kanisaibara facilities will eventually be processed at the Tsukuba Central Processing Center, to track, monitor, and catalogue orbital debris.[40]

The Middle and Upper Atmosphere (MU) radar at the Radio Atmospheric Science Center at Kyoto University has also been engaged in orbital debris monitoring. The powerful MU radar operates a Doppler pulse at 46.5 Megahertz and has a phased-array antenna.[41] The Japanese Institute of Space and Astronautical Science (now part of JAXA) operates two dish radars, in Uchinoura and Usuda, which also can be used for debris monitoring. All three of these radars can view objects of 2 centimeters at 500 kilometers.[42]

Canada

Canada currently operates the Canadian Automatic Small Telescopes for Orbital Research (CASTOR), which are essentially small-scale versions of the US GEODSS electro-optical telescopes.[43] Russian Molniya satellites were the primary subjects of CASTOR satellite tracking testing; however, the system is suitable for tracking other satellites and rocket bodies in GEO, and potentially asteroids and comets as well.[44]

Figure 8-6
Canada's first microsatellite, housing its first space telescope, MOST.

Canadian researchers have also undertaken research to use microsatellite technology for space surveillance in the Microvariability and Oscillations of Stars (MOST) program. Although designed to conduct photometric measurements of stars, MOST incorporates similar telescope, CCD camera, electronic, and computer technology as would be required for general surveillance of space. One proposal, the High Earth Orbit Space Surveillance program (formerly Near Earth Surveillance System) proposes to mount a space-based telescope on a microsatellite to search for near-earth asteroids, specifically Aten-class NEAs, and to track satellites.[45] Not limited by daylight or weather, HEOSS would be based on a microsatellite bus of 60 centimeters by 60 centimeters by 20 centimeters weighing less than 60 kilograms.[46] Cheaper to build and to launch, with the potential to acquire significant data, this option is attractive for a country like Canada.

The HEOSS project is considered a "technology demonstration" of the feasibility of using microsatellite-based optical sensor technology for satellite tracking.[47] A larger space-based surveillance system, Sapphire, is currently scheduled for launch in 2007. It would incorporate similar optical technology on an operational satellite to monitor foreign satellites, orbital debris, and search for asteroids, and could contribute to the catalogue of the US SSN.[48]

Europe

Although the European Space Agency has limited capacity to track uncooperative space objects, and no coordinated space surveillance network, it is actively addressing the debris issue. As a member of the Inter-Agency Debris Coordinating Committee, it is primarily concerned with debris mitigation and modeling of the threat, but has identified radar and optical observation campaigns for future priority.[49] The ESA operates its Space Debris Telescope at the Teide Observatory in Tenerife, Canary Islands, including a recently upgraded 1 meter Zeiss telescope and a large-array CCD camera, capable of almost real-time imaging of objects in the 10-20 centimeter range. National space centers and the ESA cooperate in the Network of Centres, which is currently engaged in a space debris pilot project. Space-based optical observation of debris has been identified as one of the priorities for technical cooperation.[50]

Germany

As a member nation of ESA, Germany is making a major contribution to the Agency's efforts at space surveillance. The Research Establishment for Applied Science (FGAN) near Bonn, Germany, operates the powerful FGAN Tracking and Imaging Radar system. It consists of an L-band radar, a Ku-band radar and a 34 meter computer-controlled parabolic antenna. Targeting debris in LEO, the L-band is used primarily for detection and tracking of space objects, while the Ku-band radar simultaneously images the same targets.[51] Also in Germany, the European Space Operations Center is headquarters for both ESA debris programing and satellite tracking. Estrack is the ESA's network of ground stations for satellite telemetry, command, and tracking. It includes seven ground stations operating 15 meter antennas in S-band, with one Deep Space Ground station operating in X-band.[52]

France

France has experienced the worst impacts of orbital debris, including the 1996 damage of the Cerise satellite, impacted by debris from the Ariane launcher stage explosion of 1986. After the 1996 disaster, France committed to assessing the debris problem and focusing its expertise in related fields on debris monitoring and mitigation. The Schmidt telescope at the Cote d'Azur Observatory was designated for debris monitoring and in 1996 a CCD camera was added to the system, allowing for computerized image processing. The upgraded system was capable of viewing objects between 10 centimeters and 1 meter in GEO over a small area of sky.[53] However, in January 1999 the Schmidt program was temporarily closed down, and has never resumed operations.[54]

France is pursuing debris monitoring in GEO through two projects: the "Télescope à Action Rapide pour les Objets Transitoires" (TAROT) and the ROSACE optical telescope. TAROT is a 25 centimeter telescope with a wide field of view, using a CCD camera and specialized computer software for debris imaging and orbit determination. The agility of the telescope makes it useful for detecting orbital debris, and it is capable of viewing objects in the 50 centimeter range in GEO, or smaller in LEO. The larger ROSACE telescope has a GPS receiver that allows it to be precisely steered, and is used primarily for orbital measurements in GEO. These systems have been called complementary and the "basic components of a future system for the observation and cataloguing of the population of objects in geostationary orbits."[55]

India

Having made significant advances in its space program in recent years, India has some capacity in space surveillance, although it has prioritized satellite telemetry, tracking, and command. The India Space Research Organisation's Satellite Tracking, Telemetry, and Command (ISTRAC) network operates five ground-stations in India and one in Mauritius. In 1977, India and Russia cooperated to establish the Satellite Tracking and Ranging Station (STARS) at the Vainu Bappu Observatory in Kavalur, which is capable of tracking Indian and foreign satellites.[56]

Independent Space Monitors

Figure 8-7
The late Geoffrey Perry was the founder and most famed member of the KSOG.

In addition to the various national space surveillance efforts currently underway, there are several organizations, both amateur and professional, which are active in the field of space surveillance. These independent observers are primarily involved in observing and tracking satellites, and compiling orbital information. They obtain satellite location data from a variety of sources, including: optical observations undertaken with binoculars or astronomical telescopes; short-wave receivers that receive radio signals from satellites passing overhead; and, official government sources which make available element sets for unrestricted satellites.[57] However, with the security of space assets becoming increasingly linked to national security, the availability of such data has lessened.

Although working with relatively rudimentary equipment, the limitations resulting from their reliance upon optical observations are overcome by the sharing of observational data among groups, largely via the internet.[58] Just as national space agencies and commercial actors share space surveillance information, so do satellite trackers, resulting in the creation of publicly available, common databases. Perhaps the most renowned group is the UK's Kettering Space Observer Group (KSOG). The relatively simple nature of the instrumentation necessary for basic tracking capabilities allows amateur groups to be very effective in this research.

2003 DEVELOPMENTS

Key developments occurred in the United States, Russia, China, Canada, and Europe.

United States

In 2003 the Pentagon transferred authority for the Navy Space Surveillance System to the Air Force, and the Service Life Extension Program upgrades, including $17 million worth of new S-band radio transmitters, were put on hold.[59] Indeed, there is evidence that the Air Force may shut down the system completely—a move that would result in annual savings of $33 million. However, an exercise held in September 2003—in which the Air Force did not have access to data from the fence—appeared to demonstrate the utility of the system. In the exercise "several potentially threatening orbital events, including the break-up of a spent rocket stage, went undetected."[60] It is still unclear what will be done with the system.

In 2003 the Air Force also expressed its intent to speed up the launch of the successor to the Space Visible Sensor. Soon after its 1996 launch its success was recognized and plans were put in motion to build a constellation of satellites for the space-based surveillance of space. The MSX satellite hosting the sensor will reach the end of its intended lifespan in 2006 and the replacement Space-Based Space Surveillance System will not be operational by that time. However, the Air Force announced its intention to speed up the launch to 2006, in order to ensure there is no loss of coverage when the MSX satellite ceases functioning. Still, no contract has been awarded for construction of the first satellite and there is evidence the Air Force is considering alternative plans, including potentially using microsatellites to host the sensors.[61]

Figure 8-8
The Cobra Dane phased array radar.

Research also progressed on the space-surveillance sensors within the ground-based missile defense system, including the sea-based X-band radar. This technology is not new, but the current challenge is to base the system on a modified oil rig, off the coast of Alaska.[62]

2003 also witnessed upgrades to the single-faced Cobra Dane phased-array radar on Shemya Island, Alaska. The L-band radar was originally built to track ballistic missiles over eastern Russia and the Pacific Ocean, and recent hardware and software upgrades have increased its sensitivity to objects in LEO in the range of 5-7 centimeters.[63] This radar is expected to play a key role in a future ground-based missile defense system, but is also expected to continue providing surveillance data.

Progress was made over the past year on recent space surveillance programs funded by DARPA. In 2003 work proceeded apace on the Space

Surveillance Telescope, primarily on its unique camera component. Intended to eventually replace the GEODSS electro-optical systems, the Space Surveillance Telescope will be a large-aperture optical telescope with a very wide field of view for observing primarily debris, but also asteroids in deep space.[64] In addition, in 2003 fabrication and testing of the first transmitter tube of the Deep View Program took place.[65] The Program is designing a radar system with high power transmitters operating at W-band to monitor space objects in both LEO and GEO.[66] Finally, DARPA's Rapid On-Orbit Anomaly Surveillance and Tracking (ROAST) program aims to use microsatellite technology for increasing space situational awareness. Merging a moderate-sensitivity optical telescope with microsatellite technology, the proposed system will allow for space-based detection and tracking of space objects. Research continued in 2003 on the necessary lightweight optics for such a system.[67]

As the dominant source of space surveillance data, the US controls its distribution. Until 2001, open access to unclassified data from the Space Catalogue was provided through a website managed by the Orbital Information Group. This access was restricted to registered users in the wake of the 11 September terrorist attacks, and in 2003 Congress approved funding for a pilot project to re-structure the manner in which the data is distributed. This project would ensure data support is provided to commercial and non-US government entities, with no guarantee of public access and with the condition that access must be "in the national security interests of the United States."[68]

Russia

In 2003 two strategic Russian sensors were made operational after years of political debate about Russia's access to these assets: the Gabala radar station in Azerbaijan and the Dushanbe Okno optical site in Tajikistan. However, disagreements later in the year between Tajikistan and Russia have placed that arrangement in jeopardy. The Okno optical system is a strategic Russian facility, and Tajikistan is bargaining for its state debt to be written off in exchange for Russian rights to the site and permission to establish the 4th Military Base in Tajikistan.[69]

In another 2003 development, the Baranovichi radar site in Belarus witnessed the final construction, testing, and placing into operation of the Volga radar in October 2003. The most advanced of Russian radar systems, the Volga uses digital systems and has a tracking capacity—useful for both ballistic missile tracking and space surveillance.[70] The Baranovichi site also fills the northeast coverage gap in the SSS, left open by the Latvian Skrunda radar decommissioning.

China

As noted above, China maintains two foreign tracking stations for its space program, in Kiribati and Namibia. However, in 2003 Kiribati concluded a diplomatic and trade agreement with Taiwan, one in the latest of a series of diplomatic spars between Taiwan and mainland China. As a result of the Kiribati recognition of Taiwanese independence, China promptly closed the strategic tracking site, thereby reducing its space surveillance capabilities.[71]

Canada

On 20 June 2003, Canada launched its first microsatellite carrying the Microvariability and Oscillations of Stars (MOST) space telescope, from the Plesetsk Cosmodrome in Russia.[72] MOST is considered a potential model for the High Earth Orbit Space Surveillance project. In 2003 it was announced that Canada was pushing forward with its initiative to launch two HEOSS microsatellites, to track satellites and search for asteroids.[73] As noted above, Canada has proposed that the eventual space-based surveillance sensor could contribute to the SSN's Space Catalogue.[74]

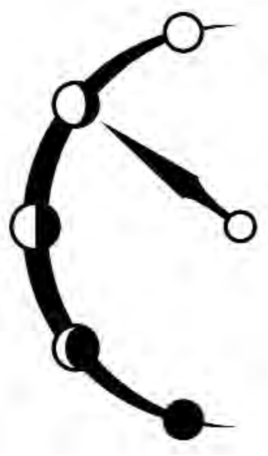
Europe

In its November 2003 *White Paper*, the European Commission identified space surveillance as an area for future work, in the interest of enhancing space security: "In addition to telecoms and observation satellites already used for security purposes, further developments are needed in the field of global monitoring, positioning, navigation and timing and communication, signal intelligence, early warning and space surveillance, to meet the security objectives of the EU and of its Member States." Coordinated work in space debris monitoring and mitigation has been prioritized through the Network of Centres.

SPACE SECURITY SURVEY 2003: KEY ASSESSMENTS

Space Security 2003: Survey Results

Space Security Survey (20/10/2003-14/11/2003)		Space Security Working Group (24/11/2003-25/11/2003)	
Question: Taking into account your views on developments in both space monitoring and transparency in the past year, how have overall changes in this area affected space security?		*Question:* In your view, space security with respect to this indicator has been...?	
Enhanced:	3	Enhanced:	0
Somewhat enhanced:	**34**	Somewhat enhanced:	**17**
Little or no effect:	28	Little or no effect:	4
Somewhat reduced:	15	Somewhat reduced:	0
Reduced:	4	Reduced:	0



SOMEWHAT ENHANCED

- Space actors continued to demonstrate a growing interest in developing enhanced capacities to support cooperative surveillance of space capabilities.
- Development of an experimental US space-based optical sensor suggested the potential for improvements in the capability of the US Space Surveillance Network to detect smaller objects. Space surveillance capabilities were also critical to collision avoidance and protection against orbital debris.
- Space surveillance capabilities are generally based on dual-use technologies that can be detrimental to space security. There was an indication of US interest in applying these technologies in support of space control and ballistic missile defence missions. However, on balance, it was assessed that there had been an increase in the transparency of space activities related to the management of space for peaceful purposes.

Space security was somewhat enhanced in 2003 with respect to this indicator.

ENDNOTES

[1] "Introduction to Space Debris," European Space Agency Fact Sheet, 2000. Available at http://www.esoc.esa.de/pr/activities/spacedebris.php3.

[2] Protection strategies described in *Technical Report on Space Debris*, Report adopted by the Scientific and Technical Subcommittee of the United Nations Committee on the Peaceful uses of Outer Space, (New York: United Nations, 1999), p.36.

[3] The 1955 Minitrack system "led to the concept of tracking nonradiating, or noncooperative, satellites by signals reflected off them," the technology later incorporated in the NAVSPASUR fence. Bradford W. Parkinson, et al., "A History of Satellite Navigation," *Navigation: Journal of The Institute of Navigation*, vol. 42, no. 1, 1995, p.120.

[4] *Quadrennial Defense Review*, 30 September 2001, p.44. Available at http://www.defenselink.mil/pubs/qdr2001.pdf.

[5] About 2,000 objects with diameters greater than 10 cm, and a further 2,000 as small as 5-7 cm, are routinely tracked by the SSN, although these objects are not yet formally catalogued. Personal correspondence with Nicholas Johnson, Chief Scientist and Program Manager, Orbital Debris Program Office, NASA Johnson Space Center.

[6] "Space Control," US Strategic Command Fact File. Available at http://www.stratcom.af.mil/factsheetshtml/reentryassessment.htm.

[7] RAND has outlined some of the SSN's limitations: "the SSN has instantaneous coverage gaps and not all space objects can be detected directly at any instant in time. Consequently, accurate orbit-prediction algorithms are a necessary element in producing an accurate real-time space surveillance picture." Daniel Gonzales, "The Changing Role of the US Military in Space," RAND Corporation, 1999, p.47.

[8] "By observing the target satellite from several stations, the position can be determined; using multiple penetrations, the orbit can be inferred." The six receiver stations are located at Tattnall, Ga., Hawkinsville, Ga., Silver Lake, Miss., Red River, Ark., Elephant Butte, N.M., and San Diego, Calif. Bradford W. Parkinson, et al., "A History of Satellite Navigation," *Navigation: Journal of The Institute of Navigation*, vol. 42, no. 1, 1995, p.120.

[9] Unclassified Space Surveillance Briefing, Gene H. McCall, Chief Scientist, United States Air Force Space Command, 23 January 2001, p.12-13.

[10] Theodore A. Postol, "The Target is Russia," *The Bulletin of the Atomic Scientists*, March/April 2000, p.32.

[11] National Security Space Road Map, July 1999. Available at http://www.fas.org/spp/military/program/nssrm/initiatives/navyss.htm. See also, "Ground-Based Electro-Optical Deep Space Surveillance," Air Force Link. Available at http://www.af.mil/factsheets/factsheet.asp?fsID=170.

[12] Grant H. Stokes, et al., "The Spaced-Based Visible Program," *Lincoln Laboratory Journal*, vol. 11, no. 2, 1998, p.228.

[13] The MSX satellite was originally shared by eight projects and was not designed for continuous use. This limits the ability to gain real-time access to SBV data. Grant H. Stokes, et al., "The Spaced-Based Visible Program," *Lincoln Laboratory Journal*, vol. 11, no. 2, 1998, p.220.

[14] *Introduction to Haystack*, (Boston: Massachusetts Institute of Technology, 1996), p.23-25. Available at http://web.haystack.mit.edu/haystack/files/brochure.pdf.

[15] Website of the Ronald Regan Ballistic Missile Defense Test Site. Available at http://www.smdc.army.mil/KWAJ/KMRINST.HTM.

[16] National Security Space Road Map, July 1999. Available at http://www.fas.org/spp/military/program/nssrm/initiatives/navyss.htm.

[17] Pavel Podvig, "History and the Current Status of the Russian Early Warning System," *Science and Global Security*, vol. 10, no. 1, 2002, p.26.

[18] The Russian Federation's Reconnaissance and Airspace Control System Improvement Program for 2001-2010 includes upgrades to the SPRN command network (including the introduction of micro-processor-based computers), development of new radar technologies, and modernization of existing radars. Michael Jasinski, "Russia: Strategic Early Warning, Command and Control and Missile Defense Overview," Center for Non-Proliferation Studies, March 2001. Available at http://www.nti.org/db/nisprofs/russia/weapons/abmc3/c3abmovr.htm.

[19] Pavel Podvig, "History and the Current Status of the Russian Early Warning System," *Science and Global Security*, vol. 10, no. 1, 2002, p.24-34. See also, Michael Jasinski, "Russia: Strategic Early Warning, Command and Control and Missile Defense Overview," Center for Non-Proliferation Studies, March 2001. Available at http://www.nti.org/db/nisprofs/russia/weapons/abmc3/c3abmovr.htm.

[20] The Dnestr-M radar "for the first time used a pulse compression method destined to process the incoming signals emitted by powerful radars. This made it possible to take full advantage of the radar's high accuracy and resolution characteristics." Victor Sloka, "50 Years of the Mints Radiotechnical Institute," *Military Parade*, July-August 1996, quoted in the Federation of American Scientists Space Policy Project. Available at http://www.fas.org/spp/starwars/program/soviet/hen_house.htm.

[21] Pavel Podvig, "History and the Current Status of the Russian Early Warning System," *Science and Global Security*, vol. 10, no. 1, 2002, p.29.

[22] Victor Sloka, "50 Years of the Mints Radiotechnical Institute," *Military Parade*, July-August 1996, quoted in the Federation of American Scientists Space Policy Project. Available at http://www.fas.org/spp/starwars/program/soviet/hen_house.htm.

[23] Pavel Podvig, "History and the Current Status of the Russian Early Warning System," *Science and Global Security*, vol. 10, no. 1, 2002, p.29-31.

[24] Pavel Podvig, "History and the Current Status of the Russian Early Warning System," *Science and Global Security*, vol. 10, no. 1, 2002, p.31.

[25] The Volga radar at Baranovichi has subsequently been completed—see 2003 Developments section.

[26] Jasinksi outlines the difficulties of maintaining the Russian radar system throughout the 1990s. Michael Jasinski, "Russia: Strategic Early Warning, Command and Control and Missile Defense Overview," Center for Non-Proliferation Studies, March 2001. Available at http://www.nti.org/db/nisprofs/russia/weapons/abmc3/c3abmovr.htm.

[27] At one time the Soviet Union also operated optical sensors at sites in Bolivia, Chile, Ecuador, and Egypt. The remaining optical sensors are in Irkutsk, Kourovka, Krasnodar, Uzhno-Sakhalinsk, and Zvenigorod in Russia; Kiev, Odessa, Simeiz, and Uzhgorod in Ukraine; Alma Ata in Kazakhstan; Burakan in Armenia; Abastumani in Georgia; Dushanbe in Tadjikistan; and Ashgabad in Turkmenistan. "The SSS Space Surveillance System," in *Jane's Space Directory*, updated 18 March 2003.

[28] "Russian Space Forces Inaugurate New Space-Tracking Facility," Associated Press report, 18 July 2002.

[29] The original TT&C system included five ground tracking stations at Weinan (near Xi'an) and Min'xi (Fujian Province) for LEO/GEO monitoring; Nanning (Guangxi Province), Changchun (Jilin Province), and Kashi/Kashgar (Xinjiang Uygur Autonomous Region) for LEO monitoring. Mark

Stokes, *China's Strategic Modernization: Implications for the United States*, (Carlisle, PA: Strategic Studies Institute, September 1999), p.40.

[30] Mark Wade, "Chinese Space Programme Fact Sheet," *Encyclopedia Astronautica*, 2003. Available at http://www.astronautix.com/articles/china.htm.

[31] Mark Stokes, *China's Strategic Modernization: Implications for the United States*, (Carlisle, PA: Strategic Studies Institute, September 1999), p.40.

[32] "China Reports Progress in Space Debris Research," *People's Daily*, Online English Version, 13 August 2003. Available at http://english.peopledaily.com.cn/200308/13/eng20030813_122263.shtml.

[33] Wei Long, "China Plans Space Debris Monitoring and Research Program," SpaceDaily, 7 March 2001. Available at http://www.spacedaily.com/news/china-01w.html.

[34] It is reported that the Commission "is working to improve observation methods, enhance studies into space debris environments and set up a data bank to help China's space exploration." "Alarm system warns of space debris," *China Daily*, 11 August 2003.

[35] The Beijing Astronomical Observatory coordinates observatories at Yunnan, Urumqi, and Changchun, as well as the Nanjing Institute of Astronomical Optics and Technology. The historic Purple Mountain Observatory and Shanghai Astronomical Observatory have retained their independent status.

[36] Wei Long, "China Builds New Observatory to Detect Near Earth Asteroids," SpaceNews, 15 August 2000. Available at www.spacedaily.com/news/asteroid-00l.html.

[37] "Introduction," National Astronomical Observatories Chinese Academy of Sciences. Available at http://www.bao.ac.cn/english/Introduction.asp.

[38] Near Earth Objects or Near Earth Asteroids are comets or asteroids which orbit the sun, approaching earth. The Spaceguard Foundation was established in 1996 and coordinates several observatories worldwide that are actively searching for NEOs. See http://spaceguard.esa.int/index.html.

[39] "Space Debris Optical Observation and Orbit Determination Experiment Initiated," NASDA Report 99, September 2000. Available at http://www.nasda.go.jp/lib/nasda-news/2000/09/head_e.html.

[40] The new Central Processing Station was expected to be operational in 2003. Erik Baard, "Increased Traffic Around Earth Calls for Stronger Spacecraft; Earlier Warning," Space.com, 10 July 2002.

[41] "MU Radar," Radio Atmospheric Science Center, Kyoto University. Available at http://www-lab26.kuee.kyoto-u.ac.jp/study/mu/mu_e.html.

[42] "Technical Report on Space Debris," Report Adopted by the Scientific and Technical Subcommittee of the U.N. Committee on the Peaceful Uses of Outer Space, United Nations, New York, 1999, p.6-7. Available at http://www.oosa.unvienna.org/isis/pub/sdtechrep1/index.html.

[43] Michael A. Early and Thomas J. Racey, "Progress Report for the Canadian Automated Small Telescope for Orbital Research (CASTOR) Satellite Facility," Presented at the Space Control Conference, Boston, Mass., April 2000. Available at http://www.rmc.ca/academic/physics/castor/equipment_e.html.

[44] Michael A. Early and Thomas J. Racey, "Progress Report for the Canadian Automated Small Telescope for Orbital Research (CASTOR) Satellite Facility," Presented at the Space Control Conference, Boston, Mass., April 2000. Available at http://www.rmc.ca/academic/physics/castor/equipment_e.html.

[45] Divided by the parameters of their orbits, Aten-class Near Earth Asteroids comprise only 7 percent of the known NEAs. Because their orbit keeps them closer to the sun than the earth, they would be best observed from space where sky-glow is not a problem. Kieran A. Carroll, et al., "NESS: Using a Microsatellite to Search for and Track Satellites and Asteroids," 7 November 2000. Available at http://www.dynacon.ca/pdf/files/newspdf_64.pdf.

[46] Kieran A. Carroll, et al., "NESS: Using a Microsatellite to Search for and Track Satellites and

Asteroids," 7 November 2000. Available at http://www.dynacon.ca/pdf/files/newspdf_64.pdf, MOST System Description.

[47] Personal correspondence with Dr. Brad Wallace, Principle Investigator, Satellite Tracking Science Team, High Earth Orbit Space Surveillance TDP, Defence R&D Canada.

[48] Major Frank Pinkney, CAF quoted by David Pugliese, in Space News, 9 September 2003.

[49] "Space Debris Activities at ESOC," European Space Agency, Fact Sheet. Available at www.esoc.esa.de/pr/activities/spacedebris.php3.

[50] The Network of Centres pilot project on space debris was approved by the ESA Council in 2000. The Working Group on Space Debris includes members from Italy, France, the UK, Germany, and the ESA. Network of Centres Space Debris Pilot Project website available at http://www.estec.esa.nl/wmwww/wma/Collaborations/NoCDebris/General%20Information.html.

[51] Mehrholz, et al., "Detecting, Tracking and Imaging Space Debris," *ESA Bulletin*, no. 109, February 2002, p.130.

[52] The ground stations are located in Kiruna (Sweden), Malindi (Kenya), Kourou (French Guiana), Redu (Belgium), Villafrance (Spain), Odenwald (Germany), and Perth (Australia), which features the deep-space station. "European Space Operations Centre (ESOC)," *Jane's Space Directory*, 8 April 2003.

[53] Brigitte Thomas, "Schmidt keeps its eye on the sky," *CNES Magazine*, no. 4, 1999, p.34.

[54] The website of the Schmidt telescope at l'Observatoire de la Côte d'Azur includes an apology that the telescope has been "temporarily shut down." Available at http://wwwrc.obs-azur.fr/schmidt.

[55] The TAROT and ROSACE programs are surveyed in Fernand Alby, et al., "Status of CNES Optical Observations of Space Debris in Geostationary Orbit," COSPAR, 2002.

[56] "ISTRAC-ISRO Telemetry Tracking and Command network," *Jane's Space Directory*, 18 March 2003.

[57] Element sets are data sets that can be used for locating an orbiting satellite at a specific point in time, greatly facilitating optical observations by indicating the general position of the satellite.

[58] An example of one such limitation of optical observation tools is their dependence upon sunlight reflecting from the satellite to the observer.

[59] "SPAWAR Awards Space Surveillance System Contract," Space and Naval Warfare Systems Command News Release, 30 September 2002.

[60] Jim Rose, head of orbital analysis operations at Naval Network and Space Operations Command, quoted in Jeremy Singer, "Shutdown of Fence System Could Impair Tracking of Debris," Space News, 20 October 2003.

[61] Jeremy Singer, "Air Force Accelerates Space-Based Space Surveillance System," Space News, 25 April 2003.

[62] The US General Accounting Office, in its report entitled "Missile Defense: Additional Knowledge Needed in Developing System for Intercepting Long-Range Missiles," cautioned that weather may reduce the stability of the sea platform, and thus the radar's effectiveness. August 2003, GAO-03-600. Upon completion, the platform will be towed from shipyards in Texas around South America to Alaska because it is too large to fit through the Panama Canal. Philip Coyle, "Is Missile Defense on Target?" *Arms Control Today*, vol. 33, no. 8, October 2003, p.13.

[63] Personal correspondence with Nicholas Johnson, Chief Scientist and Program Manager, Orbital Debris Program Office, NASA Johnson Space Center.

[64] Fact File: A Compendium of DARPA Programs, Defense Advanced Research Projects Agency, August 2003, p.14. Available at http://www.darpa.mil/body/pdf/final2003factfilerev1.pdf.

[65] Fact File: A Compendium of DARPA Programs, Defense Advanced Research Projects Agency, August 2003, p.14. Available at http://www.darpa.mil/body/pdf/final2003factfilerev1.pdf.

[66] Tim Grayson, “Space Situational Awareness,” presentation at DARPA Tech 2002 Symposium, 2002.

[67] Fact File: A Compendium of DARPA Programs, Defense Advanced Research Projects Agency, August 2003, p.15. Available at http://www.darpa.mil/body/pdf/final2003factfilerev1.pdf.

[68] FY2004 Defense Authorization Bill Conference Report, Title IX—Department of Defense Organization and Management, Section 913: Pilot Program for Provision of Space Surveillance Network Services to Non-United States Government Entities, Item 2274: Space surveillance network: pilot program for provision of satellite tracking support to entities outside United States Government, 7 November 2003.

[69] “Russian and American Interests Clash in Tajikistan: Tajikistan’s military infrastructure will depend on the US dollar,” by Vladimir Mukhin for the Nezavisimaya Gazeta, 12 August 2003. Available at http://www.cdi.org/russia/269-13.cfm.

[70] “Russian radar put into operation in Belarus,” Russian Information Agency Novosti, 1 October 2003, and “Radar system to guard northwest,” *The Russian Journal Daily*, 2 October 2003.

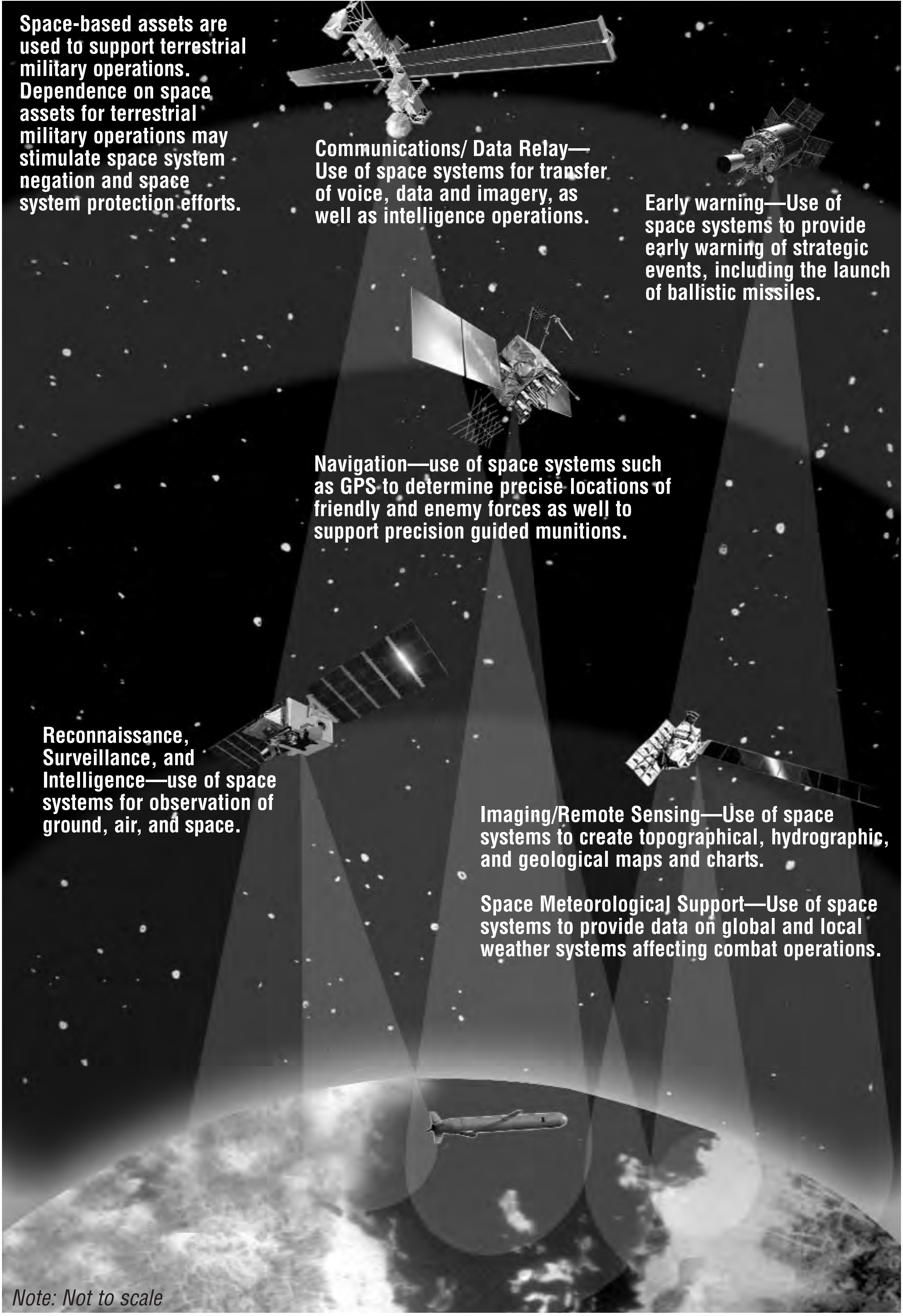
[71] Through its ‘One China’ policy, China severs ties with states that recognize Taiwan. “China Pulls Kiribati Space Center,” 26 November 2003. Available at http://edition.cnn.com/2003/TECH/space/11/25/china.kiribati.ap.

[72] “Canada’s First Space Telescope Successfully Launched into Space,” Canadian Space Agency Press Release, 30 June 2003.

[73] David Pugliese, Space News, 9 September 2003.

[74] Major Frank Pinkney, CAF quoted by David Pugliese, in Space News, 9 September 2003.

Figure 9-1



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 and charts.

Space Meteorological Support—Use of space systems to provide data on global and local weather systems affecting combat operations.

Note: Not to scale

9

This chapter assesses trends and developments related to the research, development, testing, and deployment of space systems that support terrestrial military operations. This includes an examination of the degree to which various actors have become dependent upon space systems to provide critical communications, reconnaissance, surveillance, intelligence, meteorological, navigation, and weapons guidance support functions.

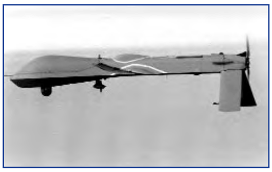


Figure 9-2
UAVs like the Predator are space-enabled and consume large amounts of bandwidth.

Space systems have been used to support terrestrial military operations from the very early days of the space age. However, recent years have witnessed an unprecedented migration of military support functions from ground- and air-based to space-based systems - significantly increasing the range of military functions provided by space assets. Whereas space systems have historically provided strategic support functions such as instant global communications, early warning of nuclear attack and verification of compliance with security treaties, by the early 1990s space systems were beginning to support large operational-level military forces through reconnaissance, surveillance, navigation, and weapons guidance functions.

More recently, the ongoing revolution in military affairs has encouraged the development of space systems capable of supporting tactical-level units and even individual soldiers by providing nearly instant access to the intelligence and communications systems necessary to bring precision-guided weapons to bear on local adversaries. China, Europe, Russia and a range of other actors are slowly developing these capabilities, but few actors come close to the capabilities of those currently enjoyed by the US.

Trends and developments related to space systems’ support to terrestrial military operations affects space security in two general ways. First, by making greater use of space systems to support military operations, an actor provides greater incentives to its potential adversaries to develop space system negation capabilities to neutralize the advantages these systems provide. In short, actors that integrate space systems into military operations encourage their adversaries to view space as a source of military threats and an extension of terrestrial battlefields. Second, as an actor becomes more dependent upon space systems to support military operations, its incentives increase to develop capabilities to protect its space systems through a combination of defensive and, of greater concern from a space security perspective, offensive space negation capabilities.

BACKGROUND

United States

The US leads the world in the use of space systems to support terrestrial military operations, including the range of functions performed and the number of military and commercial satellites available to perform these functions. At the end of 2001, the US had approximately 110 operational military-related satellites, representing over two-thirds of all military satellites in orbit.[1] Following Operation Desert Storm, the migration of military support capabilities to space systems accelerated considerably, and by the end of 2002 included a broad range of strategic, operational, and tactical functions (see Box 9-1).

By providing a critical support function to America's way of warfare, space systems have also driven up demand for and dependency upon their services. According to one US government report, "satellite bandwidth used in Operation Allied Force in Kosovo was 2.5 times greater than that used in Desert Storm, while forces used were only one-tenth the size."[2] By the time of Operation Enduring Freedom in Afghanistan, military demand for commercial satellite bandwidth increased eight-fold.[3] Space systems now enable US forces to be warned of missile attacks, to instantly communicate worldwide, to obtain and transmit near real-time information on adversaries to attack platforms, to navigate safely through conflict zones, and to identify and strike targets from air, land, or sea with unprecedented speed, precision, and economy of force.[4]

Some within the US have expressed concern about this growing US dependency upon space systems to support military operations. The *Report of the Commission to Assess United States National Security Space Management and Organization* warned that the US's 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.[5] The fact that the US has indeed developed the most advanced and comprehensive range of space protection and space negation capabilities suggests that dependency upon space systems to support military operations does stimulate the development of space systems protection and negation capabilities.

Russia

While economic challenges have constrained Russian abilities to develop significant new space systems capable of supporting military operations, Russia is second only to the US with respect to these types of capabilities. The development of Soviet space-based early warning systems began in 1973 and an initial operating capability was achieved in 1978.[6] In 2001, Russia had ninety-three operational satellites but the military could only rely upon forty-three military spacecraft and

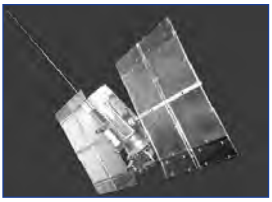


Figure 9-3
A Russian Glonass satellite.

Box 9-1

Major US Satellite Assets [46]

Function	Military Asset (# of satellites)	Civilian Asset (# of satellites)
Navigation	Navigational Satellite Timing and Ranging (NAVSTAR) (24), Global Positioning System (36 [includes NAVSTAR systems])	N/A
Meteorology	Defense Meteorological Satellite Program (3)	Geostationary Operational Environmental Satellite (1), NOAA/Television Infrared Observation System (1)
Communications	Global Broadcast System (3), Defense Satellite Communications System III (10), Milstar Satellite Communications System (4), Polar Military Satellite Communications (4), UHF Follow-On Satellite (7)	Multiple satellites: Advanced Communications Technology Satellite, Globalstar, Inmarsat, Intelsat, Iridium, Telstar, Orbcom, Pan Am Sat, TDRSS
Reconnaissance and Surveillance	White Cloud (1), Wide-area Surveillance Follow-on (1), Electronic Ocean Recce (1), Onyx/Lacrosse (2), KH-12 (3), EIS (1)	N/A
Intelligence	Advanced/Orion (1), Trumpet (3), Mercury (1), New Signint (2)	N/A
Imaging/Remote Sensing	Improved Crystal (1)	Ikonos (1), Quickbird 2 (1), SPOT (3)
Data Relay	Satellite Data System (1)	N/A
Early Warning	Defense Support Program (3)	N/A
Mapping	N/A	Landsat (1)

approximately twenty dual-use satellites (see Box 9-2).[7] The Russian Federation has not been able to maintain the high launch rates associated with Soviet programs, and between 70 percent and 80 percent of its spacecraft have now exceeded their designed lifespan.[8] Indeed, despite the fact that Russia has four operating highly elliptical orbit early-warning Cosmos series satellites,[9] in 2001 Russia had none operating in GEO, as the last working satellite of this kind stopped functioning in June 1999.[10]

Box 9-2

Major Russian Satellite Assets [47]

Function	Asset (# of satellites)
Navigation	Glonass (8), Parus (3)
Earth Observation	Okean-1 (1)
Communications	Strela-3 (1), Molniya (5)
Reconnaissance and Surveillance/Imaging	US-PU (1), Kobalt (1), Cosmos (4), Globus/Raduga (2), Arkon (1)
Intelligence	Tselina-2 (1)
Data relay	Geizer (1)
Early Warning	Oko (4)

Russia is planning to improve its Glonass global positioning system by increasing its number of satellites in orbit within this system to seventeen by 2007 and twenty-four by 2010.[11] It is estimated that by 2006-2008 up to 50 percent of Russian spacecraft will be dual-purpose, providing one example of how actors can enhance their military space system capabilities with limited resources.[12] It is expected that by 2005, additional satellites will eliminate the ‘silent zones’ in the Russian air defense system left by the disintegration of the Soviet Union.[13] Thus, while Russia is continuing to migrate force enhancement systems to space, these capabilities are primarily directed at strategic support functions. With respect to its concentration of space systems and its degree of dependency, Russia has expressed significant concerns about the vulnerability of its space assets. Russia argues that the most effective way to counter incentives for states to develop space negation capabilities is to ban the development of space-based weapons.

China

China has an advanced and comprehensive military space program, ranking number three internationally behind the US and Russia. China launched its first imagery intelligence satellite in 1975, but its last IMINT satellite was reportedly decommissioned in 1996. China is now believed to be purchasing commercial satellite imagery from Russia to satisfy its intelligence needs.[14] Military communications are provided by its Feng Huo series satellite which reportedly enables "theatre commanders to communicate with and share data with all forces under joint command" through C-band and UHF systems.[15] 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 use the system even in the face of US efforts to deny GPS services in times of conflict.[16] The PRC also maintains two Zi Yuan series satellites in LEO for tactical reconnaissance and surveillance functions.[17]

Figure 9-4
The Chinese Beidou navigational satellite.

While China is migrating some force enhancement systems to space, including systems capable of providing operational and limited tactical support, these capabilities are embryonic in comparison to US and Russian systems. The Chinese response to its growing dependence upon space systems is unclear. Some assessments suggest that China is developing extensive space systems protection as well as space systems negation capabilities, while other assess that "Beijing, although interested for strategic reasons in counterspace and ASAT capabilities, is not keen to enter into an expensive and potentially open-ended space race."[18] Publicly, China has joined Russia in calling for an international treaty to prevent the weaponization of space.

European States and European Union

European states have developed a range of relatively modest space system capabilities to support military operations. France, Germany, Italy, and Spain jointly operate the Helios 1 military observation satellite system in LEO which provides images with a 1 meter resolution and also supplies images to the EU. France, Germany, and Italy are scheduled to launch Helios 2 in 2004 which will offer enhanced resolution and day/night capabilities. France, Germany, and Italy are planning to launch six low-orbit imagery intelligence systems to replace the Helios series by 2008.[19] France, Germany, and the UK began working together in 1998 to develop four Skynet 5 military communications satellites.[20]

France also maintains the dual-use Telecomm-2 communications satellite, in addition to the purely military Syracuse 2 system.[21] Italy's purely military Sicral satellite provides secure UHF, SHF, and EHF communications for the Italian Ministry of Defense.[22] Spain operates the dual-use Hispasat satellite system, which provides X-band communications to the Spanish military. The United Kingdom maintains a constellation of three dual-use Skynet 4 satellites in geosynchronous orbit to provide worldwide UHF and SHF communications.[23]

Figure 9-5
The UK Ministry of Defence/NATO Skynet 4/NATO IV undergoing tests.

The European Union is beginning to demonstrate a coherent approach to the development of space systems capable of supporting military operations. The Galileo program, initiated in 1999 and jointly funded by the EU and the ESA, will provide location, navigation, and timing capabilities through the first major space capability supported by the EU.[24] The Global Monitoring for Environment and Security system, another joint EU and ESA effort anticipated to be operational by 2008, 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.[25] While some European states and the EU are gradually migrating military support functions to space, concerns about the vulnerability of these systems have generally emphasized the need to seek space systems protection rather than negation capabilities.

Israel

Israel operates the Eros-A system which is capable of providing both civil and military clients with images with a resolution of about 1.8 meters.[26] Israel also operates the Ofeq-5 system, which provides both panchromatic and color imagery at resolutions of less than 1 meter for reconnaissance and surveillance purposes.[27] The Ministry of Defense is also managing four satellite programs for targeted 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.[28] Israel thus seems intent on making full use of the advantages offered by the migration of military support functions to space, and is also interested in developing its space-based assets for tactical and operational mission support.

Figure 9-6
The Ofeq-5 is one of Israel's latest reconnaissance satellites.

India and Pakistan

India maintains the Technology Experimental Satellite, which provides images with resolution between 1 and 2.5 meters. India operates a remote sensing ocean satellite which was deployed in 1999.[29] 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.[30] While there seems to be a clear interest on behalf of India and Pakistan in developing space-systems capable of supporting military operations, significant progress in this area remains a longer term objective.

Japan, South Korea, and Thailand

Japan operates the commercial Superbird satellite system, which also provides military communications. 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."[31] It also bought ten Hawker 800 series satellites from the US, which South Korea has operated for signals intelligence purposes since 1999.[32] South Korea also maintains the KITSAT-3 satellite, which was developed domestically beginning in 1995 and delivered in 1999.[33] Thailand placed an order for a reconnaissance satellite with France, but delivery has been delayed since late 1997.[34]

2003 DEVELOPMENTS

United States

According to the US Air Force Deputy Undersecretary for Military Space, Operation Iraqi Freedom marked a crucial turning point with respect to space and American military power. Whereas even as recently as Operation Desert Storm, US space assets had largely been limited primarily to strategic- and operational-level tasks. By the time the US commenced operations against Iraq in 2003, space systems were providing extensive support at the tactical level as well. Indeed, Operation Iraqi Freedom marked the first time that satellites were widely integrated into weapon systems, sensors, command posts, and fielded units. As the Undersecretary noted, Operation Iraqi Freedom demonstrated that satellites have transcended the traditional force enhancement role and now "enable just about everything we [the US] do" in war.[35]

Second, US satellite bandwidth requirements continued to grow in the period between Operation Desert Storm and Operation Iraqi Freedom. According to one senior official, while 99 megabytes of bandwidth were used by the US military to support Desert Storm, fully 380 megabytes were required to support Iraqi Freedom. By some projections, military satellite bandwidth demand may grow by as much as 90 percent over those levels by 2005.[36] Closely related to this was an increase in the use of commercial bandwidth which, according to one official report, reached levels of 80 percent of all the bandwidth used in Iraqi Freedom.[37]

Lastly, American military equipment orders for the DSP and NAVSTAR satellite systems increased from $98 million and $162 million in FY 2002 to $113 million and $258 million in FY 2004 respectively.[38] Overall, UHF F11 was launched into LEO, while eleven military satellites (Coriolis, DMSP 5D-3-F16, DSCS 3-13 and 3-14, Milstar F6, NAVSTAR GPS 2R-8 through 2R-10, USA 171, USA 173, and XSS-10) were launched to GEO in 2003.[39]

Russia

In April 2003 the Commander of Russian Space Forces announced that Russia was testing a new generation of communications and navigation satellites, and that the next generation of surveillance satellites was in development: "The crisis-like occurrences that were previously caused by a lack of funding have been stopped."[40] In June, Russia announced the decision to mount a Russian military presence in LEO. Russian Minister of Defense Sergei Ivanov said that there were thirty-five launches of both military and dual-use design planned for 2003, aimed at reinforcing the orbital group.[41] In September the Larets satellite was launched into LEO, while eleven other military satellites (Gruzomaket, Molniya 1T, Molniya 3-53, and Kosmos 2397 through 2404) were launched into GEO in 2003.[42]

Japan

Breaking with over thirty years of non-military use of space, in March 2003 Japan launched four Information Gathering Satellites, IGS 1a/b and IGS 2a/b, for reconnaissance and surveillance purposes.[43] One pair of the satellites utilizes optical cameras to provide black-and-white imaging with a resolution of about 1 meter. The other pair makes use of synthetic aperture radar technology capable of seeing at night or through cloud. This is an important development for space security in that it might provide an incentive for North Korea (which has called this a hostile act) to develop ASAT capabilities.[44]

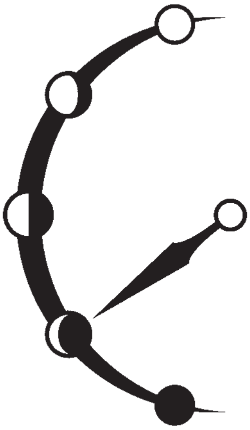
France

The French Defense Ministry announced the projected launch of the new Syracuse IIIA and IIIB military satellites for 2004 and 2006 respectively. The new satellites will offer better information rates, protection, and flexibility to the French military and its allies.[45]

SPACE SECURITY SURVEY 2003: KEY ASSESSMENTS

Space Security 2003: Survey Results

Space Security Survey (20/10/2003-14/11/2003)		Space Security Working Group (24/11/2003-25/11/2003)	
Question: Taking into account your views on developments in both military dependence on space assets, and on the vulnerability of those assets in the past year, how have overall changes in this area affected space security?		*Question:* In your view, space security with respect to this indicator has been...?	
Enhanced:	4	Enhanced:	0
Somewhat enhanced:	13	Somewhat enhanced:	5
Little or no effect:	13	Little or no effect:	4
Somewhat reduced:	**37**	**Somewhat reduced:**	**13**
Reduced:	21	Reduced:	1



SOMEWHAT REDUCED

- The trend towards greater dependency on space assets to support terrestrial military operations continued in the 2003 as the US launched an attack on Iraq that relied heavily upon the use of space-based systems.
- While the dependency upon space assets to support precision-guided munitions had some positive dimensions, it also increased the incentives on the part of other nations or entities to develop capabilities to negate, these systems. Consequently, there was a corresponding trend on the part of nations dependent upon space assets to seek greater protection for these assets against such negation capabilities.
- These trends and developments underscored the need for the careful management of the protection/negation dynamic in order to mitigate incentives to develop more destructive oriented negation capabilities such as anti-satellite weapons. Such a dynamic would have the potential to trigger an action-reaction cycle that could lead to the breaching of the normative barrier prohibiting the deployment of weapons in space, undermining the sustainability of space security.

Space security had been somewhat reduced in 2003 with respect to this indicator.

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[9] Pavel Podvig and Igor Sutyagin, "Chapter Seven: Strategic Defense," in Pavel Podvig, ed., *Russian Strategic Nuclear Forces*, (Cambridge, MA and London: The MIT Press, 2001), p.432.

[10] Pavel Podvig and Igor Sutyagin, "Chapter Seven: Strategic Defense," in Pavel Podvig, ed., *Russian Strategic Nuclear Forces*, (Cambridge, MA and London: The MIT Press, 2001), p.432.

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[12] Maria Tsvetkova, "Russian Military Moves Closer to Home," gazeta.ru, 19 June 2003. Available at http://www.cdi.org/russia/262-7.cfm.

[13] Dmitry Litovkin, "Thirty Years Is Not the Maximum: Russia's Missile Defence Capacities Will Be Updated," *Izvestiya*, 23 January 2003.

[14] Lothar Ibrügger, "Weapons in Space and Global Security, Draft Report," NATO Parliamentary Assembly, Sub-Committee on the Proliferation of Military Technology, 2003, p.6.

[15] Lothar Ibrügger, "Weapons in Space and Global Security, Draft Report," NATO Parliamentary Assembly, Sub-Committee on the Proliferation of Military Technology, 2003, p.6. We do not know the exact number of satellites in the FH system, and sources normally cite them as "several." IISS, *The Military Balance 2003-2004*, (Oxford: Oxford University Press, 2003), p.230.

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[20] IISS, *The Military Balance 2003-2004*, (Oxford: Oxford University Press, 2003), p.257.

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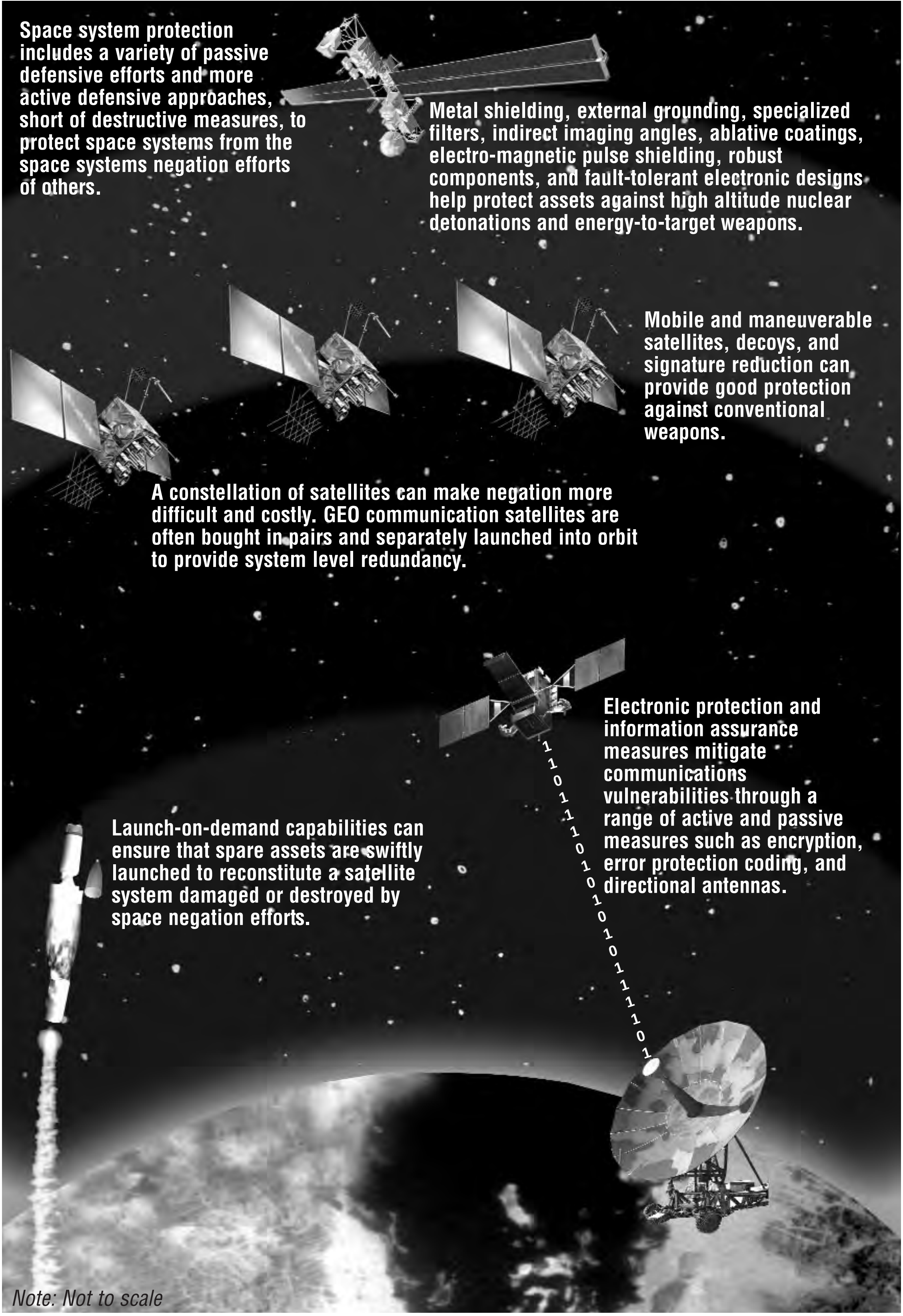
Figure 10-1



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.

Metal shielding, external grounding, specialized filters, indirect imaging angles, ablative coatings, electro-magnetic pulse shielding, robust components, and fault-tolerant electronic designs help protect assets against high altitude nuclear detonations and energy-to-target weapons.

Mobile and maneuverable satellites, decoys, and signature reduction can provide good protection against conventional weapons.

A constellation of satellites can make negation more difficult and costly. GEO communication satellites are often bought in pairs and separately launched into orbit to provide system level redundancy.

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.

Launch-on-demand capabilities can ensure that spare assets are swiftly launched to reconstitute a satellite system damaged or destroyed by space negation efforts.

Note: Not to scale

I-10 Space Systems Protection

10

This chapter assesses trends and developments related to the research, development, testing, and deployment of capabilities to protect space systems from potential negation by others. As noted in Figure 10-1, these space protection measures mitigate vulnerabilities within the ground-based components of space systems, the communications links to and from satellites, or the satellites themselves.

Space protection includes a variety of passive defensive efforts such as electronic attack protection, information assurance, dispersion, system redundancy, signature reduction, maneuverability, and weapons effects. Space protection can also include more active defensive approaches such as deceiving the radars of an approaching weapon. It does not include the use of destructive measures that are examined under space systems negation, Chapter I-11. As many traditional military protection measures are available for the ground segments and communication links between the ground and space segments of a space system, this chapter focuses largely on measures that can be applied to the satellites within a space system.

Figure 10-2
Space systems protection capabilities have the potential to enhance space security by providing actors with confidence that they will be able to securely access and use space.

Space systems protection capabilities are directly related to space security considerations because they support the security of an actor's access to and uses of space and tend to reduce an actor's sense of vulnerability. In addition to increasing the ability of a space system to survive an attack, protection capabilities may also assist in deterring other actors from undertaking space negation operations. For example, if an actor assesses that it is either futile or too costly to undertake an attack against a well-defended system, that actor may refrain from launching an attack against that space system. Unlike space negation as a means of protecting space assets therefore, a reliance on non-offensive defenses may be less likely to lead to a space arms race spiral among competitors.

The US, Russia, China, and the EU have all expressed concerns about the security of their civil, commercial, and military space systems. Concern regarding the possibility of a "space Pearl Harbor" as expressed in the US *Report of the Commission to Assess United States National Security Space Management and Organization* is undoubtedly the most prominent public example of this view.[1] However, while the US and Russia rely on a relatively large number of space systems, states with fewer satellites may be equally dependent if those systems perform critical civil, commercial, and military functions.[2]

Figure 10-3
ESA operates several ground stations, including this Kiruna S-band and X-band station in Sweden.

BACKGROUND

Protecting the Ground Segments and Communications Links within Space Systems

The ground segments and communications links within space systems are vulnerable to a broad range of conventional attacks. Beyond providing ground stations with physical security measures consistent with national defense and critical infrastructure protection measures, these segments of space systems also require both electronic protection and information assurance measures to safeguard their utility.

Electronic protection involves a range of active and passive measures designed to protect space system communications from electronic warfare efforts of an adversary, including, for example:

- Encryption of data so it can only be understood by the sender and the intended recipient;
- Error-protection coding that increases the amount of interference which can be tolerated before communications are effectively disrupted;
- Burst transmissions and frequency hopping methods which communicate data in short series of signals or across a range of radio frequencies in order to keep adversaries from ‘locking-on’ to communication signals in order to jam or intercept them;
- Narrow band excision techniques that mitigate the effects of radio frequency jamming by using smaller bandwidth than that normally used for the channel;
- Directional antennas that can be used to reduce the potential for interception or jamming of communications as well as selecting sites for ground stations which utilize natural or man-made barriers to protect antennas from line-of-sight electronic attacks; and
- Shielding and radio emission control measures that protect communications by reducing the radio energy which can be intercepted for surveillance or jamming purposes.[3]

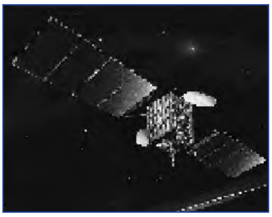


Figure 10-4
Commercial satellites - such as this Intelsat V - do not employ as extensive electronic protection measures as military satellites.

While most actors are able to take advantage of passive protection measures such as the use of shielding and directional antennas, more advanced measures such as encryption and burst transmissions are generally unique to military systems and the communications capabilities of more technically advanced states.

Information assurance is a range of software and hardware capabilities designed to protect electronic information to ensure that it is confidential (via encryption), authentic (establishes authorization), integrally secure, available, and non-repudiated (proof of delivery and receipt).[4] Especially important is the use of encryption for the command and control uplinks to a satellite, the cross-links between satellites within a constellation, and the data downlinks from the satellites to ground stations. Other systems networked to the satellite system also need to be protected with information assurance measures. The US has codified information assurance standards within its *National Information Assurance Policy for US Space Systems* that apply to military systems as well as commercial systems that the military uses to handle security related communications.[5]

Figure 10-5
Maintaining confidentiality of satellite uplinks via information assurance is a critical requirement for the effective operation of satellites.

Protecting Satellites from Conventional Attacks

The primary protection measure for satellites is the simple fact that they are difficult to reach with a direct physical attack. Anti-satellite engagements using conventional means such as kinetic energy mass-to-target weapons provide relatively limited options for strikes against satellites. For example, the launch of the Soviet co-orbital anti-satellite system was limited to timings when the longitude of the interceptor launch site matched that of the target satellite—something that might happen only twice per day. This introduced an average delay of six hours between a decision to attack a LEO satellite and the launch of an interceptor.

Once launched, satellite interceptors attempting to reach a target in LEO, MEO, or GEO would need between fifteen minutes and six hours to transfer from the earth to an orbit required for interception. In fact, it would not be unusual for interceptors to take a couple of days to achieve the necessary phased orbit to attack a satellite stationed in GEO. These timing constraints offer significant advantages for a defender that can simply take evasive action, forcing the interceptor to expend valuable fuel and more time to reorient its line of attack. This inherent defensive advantage can be enhanced through a number of general space protection measures including dispersion, autonomy, redundancy, reconstitution, signature reduction, and the use of decoys or evasive maneuvers.

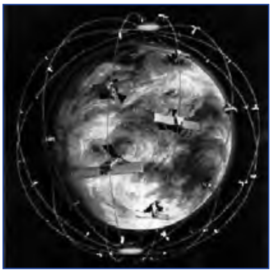


Figure 10-6
Constellations may permit the loss of a single satellite or even a handful of satellites without a complete network failure.

Dispersion is a well-established practice within terrestrial conflict that can be applied to satellite operations. The use of constellations of satellites can increase the survivability of the system. For example, the Iridium mobile communication satellite system consists of sixty-six satellites and seven in-orbit spare satellites. The satellite-to-satellite link capability of these constellations also mitigates their vulnerability to electronic jamming. Autonomous satellites, such as those used within the US Global Positioning System, use more sophisticated control systems to improve the survivability of satellites in the event that commands to the satellite are interrupted for an extended period of time.

Redundancy in satellite design and operations offers a number of protection advantages. Because 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. The growing use of satellites as in-orbit spares should increase the survivability of these systems. Over the longer term, in-orbit repair and robotic servicing capabilities will likely further improve the survivability of space systems. The US is actively exploring these capabilities through technology demonstration projects such as its Orbital Express Refillable/Upgradeable spacecraft and the Autonomous Space Transfer and Robotic Orbital vehicle.[6]

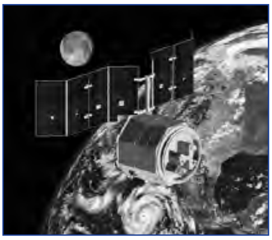


Figure 10-7
Artist's conception of Ball Aerospace's NEXTSat spacecraft for the Orbital Express autonomous on-orbit servicing demonstration, scheduled for 2006.

The capability to rapidly reconstitute satellite capabilities through launch-on-demand infrastructure and on-ground spares also offers significant space system protection advantages. However, work is needed to reduce the time between launch and the entry into service of a satellite. Here Soviet-era pressure vessel spacecraft designs hold promise over Western vented satellite designs that require a period of out-gassing before the satellite can enter service. Boeing's Space Maneuver Vehicle (X-37) project is also aimed at providing new launch-on-demand capabilities.[7]

To attack a satellite, an adversary must be able to detect and track it with sufficient accuracy to guide its interceptor to a point where it will be effective. Target acquisition can be frustrated by signature reduction strategies such as orbit selection and satellite design. Lower altitude orbits make it more difficult to detect satellites closer to the earth's atmosphere using space-based infrared sensors. Conversely, higher operational orbits raise the power demands for terrestrial radars, leaving only optical tracking for satellites in altitudes in excess of 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.

An interceptor is particularly vulnerable to deception by decoys deployed from a target when the interceptor's sensors must take over the function of tracking its quarry from 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.

Figure 10-8
Decoys, currently used by aircraft, may also be able to frustrate kinetic energy interceptors targeting spacecraft.

Finally, stemming from the primary advantage of distance, satellites can also undertake evasive maneuvers to avoid interception. 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 commitment can be exploited by the targeted satellite though evasive maneuvers. While such maneuvers use valuable fuel mass, and few satellites carry fuel for this purpose, all operational satellites have some fuel allocated to maintain their orbital positions in the face of natural orbital disturbances. A maneuver only needs to be large enough to avoid the weapons effects or target acquisition range of the interceptor.[8]

In addition to fuel considerations, evasive maneuvers require satellites with oversized rocket engines and reinforced structural designs capable of withstanding the accelerations associated with evasive maneuvers. While these structural requirements are particularly acute for solar arrays needed to generate the power for a satellite's operations, retrievable solar arrays have already been demonstrated within the ESA's Olympus mission and the US Hubble Space Telescope mission.

Figure 10-9
A close-up of the Hubble's retrievable solar arrays.

Protecting Satellites from Nuclear Weapons

Unhardened satellites are very vulnerable to the effects of nuclear weapons. Early space protection efforts undertaken by the US and USSR during the Cold War were aimed at increasing the survivability of satellites of strategic importance in the face of these weapons effects. US systems such as the Defense Support Program early warning, DSCS III communications, and GPS global navigation satellites were all hardened against the radiation and electromagnetic pulse effects of nuclear weapon detonations. Robust production lines, the use of satellite constellations, and responsive launch readiness contributed to the nuclear survivability of USSR space capabilities. Measures developed to protect satellites from nuclear weapons include radiation hardening, electromagnetic pulse shielding, and scintillation and blackout avoidance.

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 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.

Figure 10-10
Radiation hardening and EMP shielding can protect sensitive circuits from nuclear weapons attacks.

Electromagnetic pulse (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. Technical measures to protect satellites from external EMP effects include: metal shields and conductive coatings to prevent EMP radiation from entering satellite cavities; 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; and the use of microwave filters to isolate internal satellite electronics from external electromagnetic radiation.

Protection measures from EMP effects generated by the penetration of X-rays into a satellite include the enclosure of satellite sub-systems within Faraday cages, the use of grounding straps and surge arresters to maintain surfaces at the same electrical potential, and coating internal surfaces with specialized paints to reduce electron emission into cavities. 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 (scintillation) and denial (blackout) 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) frequencies can also be used

Protecting Satellites from Directed Energy Weapons

Although directed energy weapons are not yet capable of destroying a satellite, they are increasingly capable of damaging some satellite components. Protection against high power microwave weapons, which use very high powers over very short pulse durations to degrade or destroy unprotected electronics, can include over-voltage and over-current protection circuits in the front end receivers of the satellite's payload. Protection measures against high-energy laser weapons attempting to disrupt, deny, degrade, or damage sensitive optical or thermal imaging sensors include: spectral filters to protect them from intense laser illumination; the use of multiple imaging frequencies including those attenuated by atmospheric absorption to reduce the effectiveness of the laser weapon itself; and the use of indirect imaging angles to avoid direct ground-based laser illumination. Protection against future lasers capable of damaging the satellite itself 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.

Figure 10-11
Spectral filters, ablative coating, indirect imaging angles, and other means can be taken to protect satellites from directed energy weapons.

2003 DEVELOPMENTS

Key 2003 developments occurred in ASEAN countries, the European Union, and the United States, which exhibited information assurance, system redundancy, reconstitution, frequency management, and shielding measures.

ASEAN

While not purely space-related, the Southeast Asian information and communications ministers announced plans to establish an early warning system against computer viruses and form computer emergency response teams to deal with attacks from hackers or viruses.[9] By 2004, ASEAN members hope to put into effect a cooperation framework for sharing real-time information on computer threats as well as assessments of vulnerabilities.

European Union

Seeking system redundancy in space-based navigation, the EU's Galileo satellite navigation system development moved forward, launching the

EU on an independent track from the US Global Positioning System (GPS).[10] Disputes between the two actors involved conflicting proposed frequencies for Galileo and for the next generation of GPS. In a colorful expression of the importance of redundancy, Gilles Gantlet, spokesman for the EU Transport Commissioner, noted that "If you always use your parents' car, there will come a day when it's not available."[11] Furthermore, general protection doctrine was elucidated in the EU Green Paper on space policy, which underscored the requirement that "the services offered by space systems in normal times and in crises [be] adequately protected."[12]

Figure 10-12
Computer viruses are recognized as a threat to the systems that control satellites.

United States

Funding patterns in the US are illustrative of its emphasis on space protection systems. For FY2004 alone, the US Congress approved $14.7 million for space protection technologies including near-term protection measures designed to enhance spacecraft survivability by improving tactics, techniques, and procedures, and ensuring that future spacecraft will incorporate survivability measures.[13] The funding also accords with the latest *Strategic Master Plan FY04 and Beyond* of the US Air Force Space Command that states it will work over the mid- and far-term to transform its protection means by fielding revolutionary space-based capabilities including:

- Attack, detection, and reporting architecture capable of detecting, characterizing, and reporting attacks on space systems, and assessing the resulting mission impacts;
- Capabilities to protect US space systems from man made or environmental threats;
- Robust and responsive space lift and rapid satellite deployment to provide assured space access for time-sensitive military operations; and
- Orbital transfer vehicles to reposition or boost in-orbit assets.[14]

Figure 10-13
The rapid launch of on-ground spares is one of the protection measures outlined in US space policy.

Box 10-1

US Space Protection Systems Funding, FY2000-2004[16]

Fiscal Year	Requested*	Approved*
FY2000	9.8	12.8
FY2001	9.7	9.7
FY2002	33	32.3
FY2003	13.8	13.8
FY2004	14.7	14.7

*all figures in millions of dollars

While not all funding requests are approved, it is noteworthy that over the past five fiscal years virtually all programs have been fully funded (see Box 10-1).

Figure 10-14
Conception of Boeing's X-37 Reusable Spaceplane.

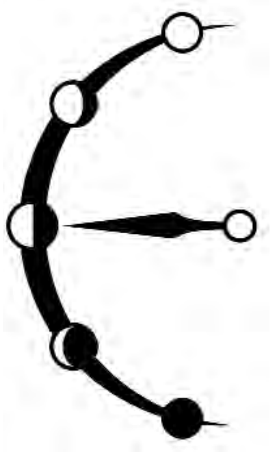
In terms of redundancy and reconstitution, the X-37 military space plane project continued its development in 2003 with a view to a demonstration flight planned for 2005. The US Orbital Express project, designed to demonstrate an in-orbit infrastructure for the refueling and servicing of satellites, also continued to make progress in 2003. These initiatives are aimed at improving US capabilities to reconstitute space systems after negation attempts.

However, in terms of negative developments, commercial US satellite providers continued to ignore the US General Accounting Office's report that recommended increased protection measures for commercial systems.[15] The report specifically recommended that commercial satellites be identified as critical infrastructure given the importance of this sector to US economic and security interests. In response to the report, the United States Space Command wrote that "the industry may be reluctant to invest in the different forms and levels of protection without monetary incentive by the US Government." Given the increasing concentration of commercial satellite services for military, civilian, and commercial purposes, the designation of commercial satellites as critical infrastructure—and the concomitant protection upgrades this would necessitate—would greatly improve space security.

SPACE SECURITY SURVEY 2003: KEY ASSESSMENTS

Space Security 2003: Survey Results

Space Security Survey (20/10/2003-14/11/2003)		Space Security Working Group (24/11/2003-25/11/2003)	
Question: Taking into account your views on the developments in both space protection doctrine and the various kinds of systems development in the past year, how have overall changes in this area affected space security?		*Question:* In your view, space security with respect to this indicator has been...?	
Enhanced:	2	Enhanced:	0
Somewhat enhanced:	25	Somewhat enhanced:	4
Little or no effect:	**27**	**Little or no effect:**	**15**
Somewhat reduced:	17	Somewhat reduced:	13
Reduced:	10	Reduced:	0



LITTLE OR NO EFFECT

- There continued to be a growing recognition on the part of key governmental space security players of the threats facing space systems, and the need to support greater efforts to put appropriate protective measures in place.
- In contrast to this move to protect government systems, there was inadequate effort devoted to protection measures for commercial space systems. Improved information assurance measures, electronic protection measures, increased encryption usage, and enhanced radiation hardening all add costs to space systems. Commercial providers in a competitive marketplace remained reticent to pay for such additional measures. Thus, there appeared to have been no significant changes in the level of protection for commercial space systems in 2003.

There was little or no effect on space security in 2003 with respect to this indicator.

ENDNOTES

[1] "Report of the Commission to Assess United States National Security Space Management and Organization," 11 January 2001. Available at http://www.defenselink.mil/pubs/space20010111.html.

[2] J. Logsdon, "Reflections on Space as a Vital National Interest," *Astropolitics*, vol. 1, no. 1, Summer 2003, p.78.

[3] M.R. Frater, and M. Ryan, *Electronic Warfare for the Digitized Battlefield*, (Artech House: Boston, 2001). The electronic warfare treatment of this chapter was largely drawn from the approach provided in this book. See also "Electromagnetic Pulse (EMP) and TEMPEST Protection for Facilities, Engineering and Design," Pamphlet EP 1110-3-2, U.S. Army Corps of Engineers, December 1990 and W.E. Burrows, *Deep Black Space Espionage and National Security*, (Random House: New York, 1986), p.182.

[4] "Government Security Policy," Government of Canada, Treasury Board Secretariat, 1 February 2002.

[5] "National Information Assurance (IA) Policy for U.S. Space Systems," NSTISSP no. 12, Fact Sheet, Washington D.C., January 2001.

[6] S.B. Wilson III, "Orbital Express: A Comprehensive Architecture for the 21st Century," Defense Advanced Research Projects Agency Presentation. Available at www.darpa.mil.

[7] S. Evers, "USAF to test space-based reconnaissance vehicle," *Jane's Defence Weekly*, vol. 28, no. 10, 10 September 1997, p.11, and W.B. Scott, "Space Shell Game," *Aviation Week and Space Technology*, 7 April 2003, p.74-76.

[8] Lt. Col. Richard E. Fitts, ed., *The Strategy of Electromagnetic Conflict*, (Peninsula Publishing: Los Altos, 1980).

[9] "ASEAN ministers agree to boost defences against cyber attacks," *AFX News*, 19 September 2003.

[10] "ESA Approves Galileo Satellite Program," *Satellite Today*, vol. 2, issue 94, 27 May 2003.

[11] Daniel Michaels, "Satellite Skirmish Looms Between Europe, the US - EU's Planned Galileo System Raises Ire of Washington, Which sees a Rival to its GPS," *The Asian Wall Street Journal*, 2 April 2003.

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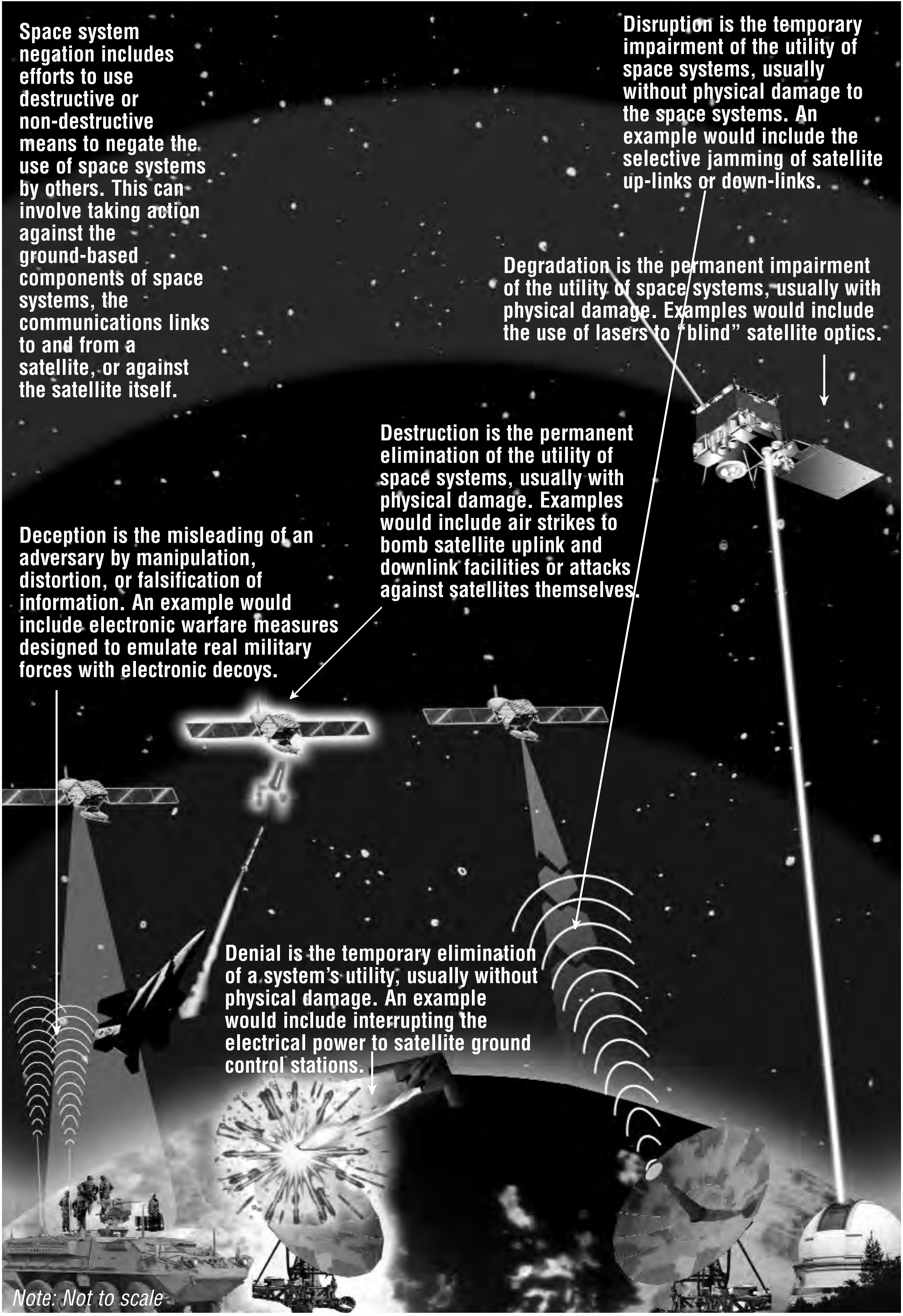
[15] "Critical Infrastructure Protection. Commercial Satellite Security Should Be More Fully Addressed," United States General Accounting Office, GAO-02-781, Washington, D.C., August 2002.

[16] M.S. Smith, "U.S. Space Programs: Civilian, Military, and Commercial," Congressional Research Service Report IB92011, The Library of Congress, Washington D.C., Updated October 6, 2003.

Figure 11-1



Space system negation includes efforts to use destructive or non-destructive means to negate the use of space systems by others. This can involve taking action against the ground-based components of space systems, the communications links to and from a satellite, or against the satellite itself.

Disruption is the temporary impairment of the utility of space systems, usually without physical damage to the space systems. An example would include the selective jamming of satellite up-links or down-links.

Degradation is the permanent impairment of the utility of space systems, usually with physical damage. Examples would include the use of lasers to "blind" satellite optics.

Destruction is the permanent elimination of the utility of space systems, usually with physical damage. Examples would include air strikes to bomb satellite uplink and downlink facilities or attacks against satellites themselves.

Deception is the misleading of an adversary by manipulation, distortion, or falsification of information. An example would include electronic warfare measures designed to emulate real military forces with electronic decoys.

Denial is the temporary elimination of a system's utility, usually without physical damage. An example would include interrupting the electrical power to satellite ground control stations.

Note: Not to scale

I-11 Space Systems Negation

11

This chapter assesses trends and developments related to the research, development, testing, and deployment of systems designed to use destructive or non-destructive means to negate the use of space systems by others. These space systems negation efforts can involve taking action against the ground-based components of space systems, the communications links to and from a satellite, or against the satellite itself. It can also involve taking action against the information space systems provide or the infrastructure that supports such systems. As noted in Figure 11-1, space negation systems represent a spectrum of capabilities that may be directed from earth into space, from space to space, or from earth to earth.[1] Space-based space negation systems have not been demonstrated thus far.

Space negation capabilities are not limited to space-faring powers. Indeed, given that most elements of a space system are located on earth, it is likely that most space negation efforts will be directed against ground stations or terminals, for example, through attacks against fixed and mobile ground-based space system infrastructure.

Unprotected satellite communication links are also vulnerable to intentional interference generated by terrestrial sources such as radio frequency jammers, while unhardened remote sensing satellites can also be vulnerable to ground-based low energy laser ‘dazzlers.’ Information warfare attacks can also strike at the facilities used to control satellites or distribute data generated by them, especially when space systems are networked to other communication or computer networks.

Figure 11-2
Conventional attacks against fixed or mobile ground stations are the mostly likely forms of negation given the technical complexity of directly attacking satellites.

Space negation doctrine has also been developed from both the offensive and defensive perspectives. Defensive negation consists of the same goals carried out in self-defense in order to protect one’s own space systems, and its non-offensive form is examined in I-10 Space Systems Protection. This chapter examines trends and developments related to space negation efforts for offensive purposes.

Space negation is directly related to space security as the use of negation capabilities, by definition, adversely affects the capacity of those targeted to gain access to and use space in a secure manner. Conversely, restraint in the development of space negation doctrine and systems has the potential to enhance space security by reducing threats to the secure access to and use of space.

BACKGROUND

Temporary or Reversible Space Negation - Deception, Disruption, and Denial

While space negation capabilities have been under active consideration since the launch of Sputnik in 1957, several temporary space negation capabilities are related to military practices which pre-date the space age. For example, electronic warfare capabilities designed to disrupt and deny radio transmissions were demonstrated during the Second World War.

Figure 11-3
A 4-watt Russian GPS/Glonass jammer, reportedly effective to a 200 km radius.

Electronic Warfare - The radio frequency spectrum is a crucial segment of all space systems because it is the means through which ground stations communicate with and control the operation of satellites. Controlled radio frequency emissions can negate the use of space systems via jamming or electronic deception. Jamming uses radio signals designed to prevent a radio receiver from receiving its intended signal in order to temporarily disrupt or deny communications. Equipment such as the Russian-developed GPS jamming device can, in theory, be used to interfere with GPS signals in localized areas to prevent GPS-guided munitions from hitting their targets (see Figure 11-3).[2]

The jamming of a communication satellite's uplink can prevent control stations from commanding satellites or can interfere with a ground station's downlink reception of relayed communications. The direct jamming of a satellite's downlink can also disrupt or deny the reception of these signals by the ground stations or terminals of the space system. Given that much of the technology required for jamming is now widely available, this form of space negation may become more common.

Electronic deception involves the use of false or misleading radio transmissions that can be used to conceal the true location and intentions of friendly military forces, thus negating the advantages offered by space-based surveillance and intelligence systems. Strategic stability considerations during the Cold War tended to restrain competition in the use of jamming to interfere with 'national technical means' of verification, early warning satellites, and certain communication satellites carrying 'hotline' channels. States with sophisticated electronics industries are better placed to practice this form of space negation.

Information Warfare. Space systems are controlled by computers and are also connected to communication networks. They are, therefore, vulnerable to cyber attacks. The two most common types of cyber attacks are anti-access and spoofing. Anti-access attacks attempt to deny the services being provided by a computer system and could, if successful, disrupt or deny the ability of satellite controllers to communicate with their satellites or disseminate information from them. Spoofing attacks that seek to gain unauthorized access to a space system by emulating an authentic user could permit an intruder to disrupt normal satellite operations.[3] Given the current state of telemetry and spacecraft reliability, an operator might never know whether such an anomaly was an ordinary onboard glitch or the work of a hostile actor.

Figure 11-4
StoptheNATO.org's Netstrike Against NATO campaign.

Cyber attacks are becoming more commonplace. On 28 May 2002 the grassroots Netstrike Against NATO campaign launched a distributed denial-of-service attack against the main website of NATO, coinciding with a meeting of its leaders in Italy.[4] While the US Department of Defense's computer systems have been attacked almost every day for years (estimated at 250,000 times in 1996), the real number of these attacks is difficult to assess because such a small number are actually detected.[5] While the military space assets of the most advanced space-faring states are relatively well protected, not all space security actors enjoy this level of protection, making this type of space negation capability an attractive and relatively low-cost option for many states.

Robotic Manipulation. Satellites are relatively fragile and ungainly systems; they often require devices dedicated to keeping them pointed in the right orientation to ensure their proper operation. Consequently, some satellites could be 'tipped over' by a robotic servicing device from which states they might never recover. Thus, in-orbit robotic manipulators represent a potential space negation capability. Concerns about this capability were expressed by the former Soviet Union over the development of the US space shuttle and its Canadian shuttle remote manipulator system, more commonly known as the Canadarm (see Figure 11-5). However, the likelihood of robotic manipulation systems being used as a space negation capability is remote as it would represent the use of very expensive and complex systems to allow missions that could otherwise be accomplished by less expensive means. This technology is assessed to be limited to the United States, the European Union, Russia, Japan, and Canada.

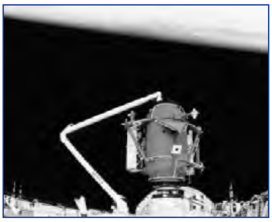


Figure 11-5
Canadarm being used to install the shuttle docking port on Mir.

Permanent or Irreversible Space Negation - Degradation and Destruction

Beyond temporary space system negation efforts, negation may also be undertaken through the application of force to degrade or actually destroy the ground or space segments of an adversary's space systems. Terrestrial satellite control and launch facilities are vulnerable to a wide range of military attacks that could degrade or completely destroy essential components of an actor's space systems or their access to space. Indeed, this approach is widely assessed to be the most cost effective and readily achievable space negation option for most actors. However, attacks against control stations would risk the creation of collateral space debris because satellites without effective ground stations would not receive orbit control or space debris mitigation commands.

Box 11-1

How A High Altitude Nuclear Detonation (HAND) Works

Approximately 80 percent of all the energy from a nuclear weapon detonated in outer space appears in the form of X-rays, in addition to small amounts of gamma radiation and neutrons, small fractions in residual radioactivity, and in the kinetic energy of bomb debris. An electromagnetic pulse (EMP) is also generated by a HAND when X-rays and gamma rays create an electron flux in the upper atmosphere of the earth that re-radiates its energy in the radio frequency portion of the electromagnetic spectrum. When this radio frequency hits space systems it induces currents and voltages that may damage or destroy electronic systems not hardened against these effects. Satellites in GEO would experience an EMP of smaller magnitude than either LEO satellites or ground facilities located within a line of sight of the HAND. Long after the initial detonation of a nuclear device, electrons liberated by the device would join the naturally occurring radiation in the Van Allen belts. Satellites not specifically designed for operations after detonation of a nuclear weapon may fail quickly in this enhanced radiation environment due to a rapid accumulation of total ionizing doses on the critical electronic parts of a satellite.[28]

Nuclear Space Negation Capabilities

The capability to negate space systems by directly attacking satellites was actively explored throughout the Cold War by the US and USSR. In the early 1960s, both the US and the USSR experimented with nuclear weapon detonations in space as well as nuclear-tipped ballistic missile defense interceptors. During these efforts it became clear nuclear weapons presented a particularly severe threat to space systems. For example, the US Starfish Prime nuclear test of 9 July 1962 detonated a 1.4 megaton device at a 400 kilometer altitude above Johnson Island in the Pacific Ocean, causing the failure of six or seven satellites within seven months.[6] Current assessments suggest that satellites hardened to twice the natural radiation environment in LEO would fail within two to four months of the detonation of a 10 kiloton nuclear weapon over Japan at a 150 kilometer altitude.[7] However, replacements launched eighteen months after the event would enjoy near-normal lifetimes.[8] GEO satellites, in contrast, are typically hardened to higher levels of natural radiation and would not be affected by such enhanced radiation belts.

China, the EU, India, Israel, Japan, Russia, Ukraine, and the US all possess space launch vehicles capable of launching the mass equivalent to a nuclear warhead into orbit, while 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.[9] Not all of these states are assessed to possess such warheads. Only the Russian operational *Galosh* ballistic missile defense system currently employs nuclear warheads.

The use of nuclear weapons to negate satellites would have several disadvantages that tend to discourage their use. A high altitude nuclear detonation (HAND) would likely damage unhardened friendly and neutral as well as hostile satellites, because the EMP effects of such HANDs can indiscriminately harm the critical information and electronic infrastructure of industrial societies within line of sight of the nuclear detonation. In addition, several legal implications would tend to mitigate against the use of nuclear weapons for space negation (see chapter I-04 Legal, Normative, and Institutional Developments for discussion of space-related legal issues).[10] The use of a nuclear weapon could also escalate the underlying conventional conflict to the status of an all out nuclear war.

Conventional Space Negation Capabilities

During the Cold War, the US and USSR also developed and tested conventional weapons as anti-satellite (ASAT) systems. The USSR tested their Polyot short duration co-orbital ASAT system between 1968 and 1982. This system used an SS-9 intercontinental ballistic missile to launch a chaser satellite on a one- or two-orbit rendezvous trajectory followed by the explosion of a package of pellets at the target satellite. Overall, the Polyot system had only a 50 percent success rate and generated a substantial amount of space debris. Tests incorporating radar homing sensors demonstrated a 64 percent success rate while all tests with an infrared optical homing sensor seem to have failed. All interceptions took place at altitudes of less than 2,000 kilometers, although some US analysts claimed the Soviet system could attack satellites as high as 5,000 kilometers.[11]

Figure 11-6
An ASAT is launched from an USAF F-15 on 13 September 1985.

In 1985 the US tested a single F-15-launched direct-ascent Miniature Homing Vehicle anti-satellite weapon against a US satellite (see Figure 11-6). While this test successfully demonstrated hit-to-kill technology using a thermal infrared homing device, the system was never deployed operationally. Since 1985, there have been no recorded flight tests of dedicated anti-satellite weapons systems and no actor has developed ASAT weapons capable of reaching beyond LEO. More recent efforts to develop a dedicated kinetic energy anti-satellite (KE ASAT) system in the US have not advanced to the integrated flight testing phase due to repeated congressional and presidential funding decisions.

Beyond co-orbital and direct ascent conventional weapons, concerns have also been raised about the development of long duration orbital weapons. These systems would either be launched to track and detonate near a target, remain dormant and be activated to maneuver towards and detonate near a target, or remain fixed in an intersecting orbital path of a target only to detonate on command when a target approaches. However, many long duration orbital interceptor concepts would require the demonstration of a rendezvous capability with a non-cooperative target. To date, only the United States and Russia have demonstrated rendezvous with artificial objects, while Japan and the European Space Agency have demonstrated rendezvous of spacecraft with celestial objects. No state has yet demonstrated the capability to rendezvous with non-cooperative artificial objects.[12]

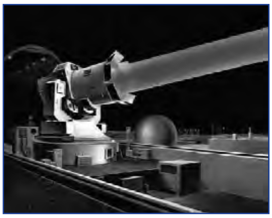


Figure 11-7
The former Soviet Union studied particle beam weapons for the purpose of destroying ICBMs.

Figure 11-8
The US MIRACL laser destroys a Titan rocket during one of its tests.

Directed Energy Weapon Space Negation Capabilities

Ground-based high-energy lasers capable of degrading or destroying the sensitive components of satellites are already available to the United States and Russia. China may already possess the capability to degrade or damage optical sensors on satellites under certain specific conditions and US military analysts assess that Beijing could probably develop ground-based ASAT weapons that could destroy satellites in the future.[13]

In 1997, the US illuminated one of its own imaging satellites with a ground-based high-energy laser developed for testing advanced ballistic missile defense technologies.[14] The test, at much lower power levels than required to destroy the satellite, was performed to determine the satellite's vulnerability to such attacks.[15] As many as thirty nations may already have the capability to use low-power lasers to degrade unhardened sensors on satellites.[16]

While the US and what is now Russia have observed a voluntary anti-satellite test moratorium since 1985, US doctrine has shifted somewhat in recent years from simply supporting the research and development of space negation capabilities towards a posture of developing the operational readiness of such systems. The 1996 US *National Space Policy* declared that "consistent with treaty obligations, the United States will develop, operate and maintain space control capabilities to ensure freedom of action in space and, if directed, deny such freedom of action to adversaries."[17] In its *Strategic Master Plan FY04 and Beyond*, the USAF Space Command postulates full spectrum, space-based counterspace systems capable of preventing unauthorized use of friendly space services and negating adversarial space capabilities from LEO to GEO altitudes.[18] It should be noted, however, that such plans are dependent upon on attaining annual congressional funding to fully develop such capabilities. As of 2002, the United States Government has taken no official policy decision to deploy space-based weapons and neither has any other national government.

2003 DEVELOPMENTS

Several important developments occurred in 2003 with respect to the operationalization of space negation systems related to China, Iran, Iraq, and the United States.

China

US officials assessed in 2003 that China was acquiring a variety of technologies that could be used to develop GPS jammers and a direct-ascent ASAT that could be fielded in the 2005-2010 timeframe.[19] Chinese reaction to this report was dismissive, claiming it gave a "distorted view" of China's military might.[20] One independent study argues that while

> Chinese strategists recognize the potential importance of ASAT weapons as a tool of asymmetrical warfare and…Chinese scientists are pursuing research with potential ASAT applications…, the available evidence is insufficient to determine if China has an active program to develop and deploy ASAT weapons.[21]

The study concluded by noting that "[g]iven China's limited space capabilities and stated interest in preventing an arms race in outer space, Beijing's ultimate commitment to developing ASAT weapons remains ambiguous."[22]

Figure 11-9
Electronic warfare in the form of jamming was a concern in 2003.

Iran

Persian language TV signals beamed into Iran via satellite originating from the United States were jammed on the uplink during July 2003.[23] A party operating out of Latin America or the Caribbean intentionally interfered with the transmissions rendering the Voice of America broadcasts unwatchable. Iranian officials have long regarded the US broadcasts as a "cultural invasion." US officials characterized the thirty minute nightly news broadcasts as part of their public diplomacy efforts to get the US government's message through Iranian government censors.

Iraq

During the US military operation Iraqi Freedom, the Iraqi military used jammers on the downlink against the US global positioning system, which the US acknowledged was the first time that an adversary tried to disrupt the GPS signals. Iraq is reported to have placed electronic jamming equipment on towers around Baghdad prior to the launch of the war.[24] While the Iraqi attempt failed to disrupt or deny the use of GPS to US and coalition forces, their presence gave cause for concern as 80 percent of the cruise missiles used in the conflict were reliant solely upon GPS as their method of guidance. US forces were reportedly able to use GPS-guided munitions to destroy these jammers, raising questions about the real effectiveness of the jammers themselves.

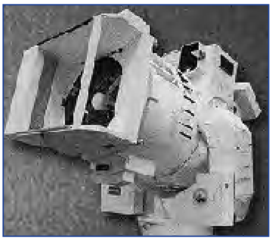


Figure 11-10
Reversible and temporary negation measures, including directed energy weapons, were funded by the US Congress during 2003.

United States

According to the 2003 US Department of Defense budget request for FY2004, it planned to allocate $82.6 million to the development of space negation systems that it calls counterspace systems.[25] Within this budget item, the Department requested $9.6 million for CounterComm, a system which aims to produce a "transportable system that can disrupt adversary satellite-based communications that are deemed to be hostile to the US or friendly forces using temporary and reversible, non-destructive means."[26] An operational CounterComm system is to be fielded during FY2005.

The Pentagon also requested $66.4 million dollars in FY2004 for the Counter Surveillance Reconnaissance System (CSRS, pronounced “scissors”). CSRS would also employ reversible negation means against military, civil, or commercial imaging systems and it is geared to the threat posed by enemy access to satellite imagery. The plan is to deploy operational units by FY2008. The program is to explore laser “dazzlers” as well as a number of other technologies designed to achieve the stated goal. As with CounterComm, transportable systems are envisaged for CSRS. The US Congress funded both programs in the FY2004 budget.

The US ground-based kinetic energy anti-satellite weapon program was, in practical terms, zero-funded in the FY2004 budget. Over $350 million had been invested in this program throughout the1990s, but concerns over the impact of space debris generated by its hit-to-kill technology, among others, has hampered its acceptance.[27]

SPACE SECURITY SURVEY 2003: KEY ASSESSMENTS

Space Security 2003: Survey Results

Space Security Survey (20/10/2003-14/11/2003)		Space Security Working Group (24/11/2003-25/11/2003)	
Question: Taking into account your views on developments in both space negation doctrine and the various kinds of systems development in the past year, how have overall changes in this area affected space security?		*Question:* In your view, space security with respect to this indicator has been...?	
Enhanced:	3	Enhanced:	0
Somewhat enhanced:	11	Somewhat enhanced:	3
Little or no effect:	21	Little or no effect:	4
Somewhat reduced:	**28**	**Somewhat reduced:**	**15**
Reduced:	21	Reduced:	1

SOMEWHAT REDUCED

- Despite what appeared to be a long term trend on the part of some space-faring nations to develop more robust space negation capabilities based on the physical destruction of satellites, there was little evidence in 2003 that such capabilities were being actively developed via funded programs.
- Concerns were raised that the jamming of navigation satellite signals during the Iraq war and the intentional interference with US satellite television signals during times other than war had helped to establish a state practice that could have a negative impact upon the sustainability of space security.
- A measured step was taken in 2003 by the US to enhance its capabilities for space negation through the temporary and reversible effects of electronic warfare.

Space security had been somewhat reduced in 2003 with respect to this indicator.

ENDNOTES

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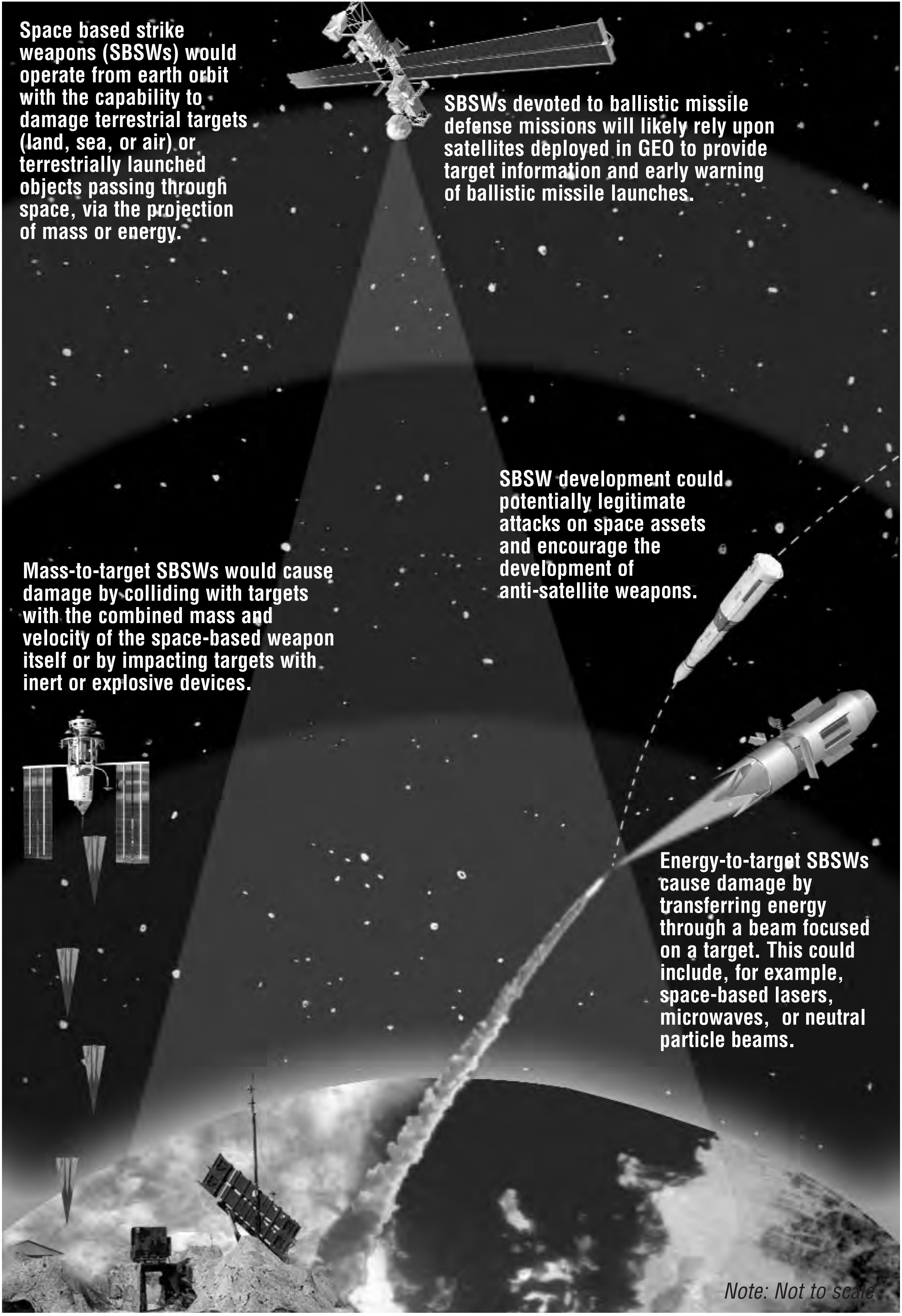
Figure 12-1



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 legitimate 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

12

This chapter assesses trends and developments related to the research, development, testing, and deployment of Space-Based Strike Weapons (SBSW). This includes key SBSW enabling technologies such as precision re-entry, attitude control and maneuverability, micro-satellites, directed energy weapons, and large deployable optics.

SBSWs are systems operating 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.[1] Space-to-space weapons are examined in I-11 Space Systems Negation.

There are two categories of SBSWs. Mass-to-target (MTT) SBSWs 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 (ETT) SBSWs cause damage by transferring energy through a beam focused on a target; for example, via lasers, microwaves, or neutral particle beams.

SBSW systems have the potential to directly affect space security. An actor with an SBSW capability to attack ballistic missiles would also be able to prevent other actors from accessing and using space by attacking satellite launch vehicles. An actor with the capability to attack terrestrial targets from space would be able to threaten others from that position with very little warning. Thus, the development of SBSWs would likely encourage the development of anti-satellite weapons and potentially legitimate attacks on space assets, undermining established legal prohibitions against such attacks. Moreover, the testing and deployment of SBSWs would likely generate space debris, potentially undermining the sustainability of space activities over the longer term.

According to available evidence, there are no strike weapons currently deployed in space. Indeed, SBSWs require significant capabilities beyond those required to simply access and use space. In particular, the challenges of propagating laser beams through the atmosphere are significant as are the re-entry, hypersonic guidance, and material science challenges associated with long rod penetrator designs. Thus, it is generally assessed that only the most advanced space-faring nations could overcome the technical challenges to deploying effective SBSWs within the next five to fifteen years. Therefore, this chapter largely focuses upon a select group of nations: the United States, Russia, and China.

BACKGROUND

Key Cold War SBSW Developments[2]

1950s: US sponsors concept studies and development programs for SBSWs in the form of 'bombardment satellites' to protect against ballistic missiles.[3]

1968: Following 24 launches, of which 17 were successful, the Soviet MTT fractional orbit bombardment system (FOBS)—which is capable of delivering a nuclear weapon from orbit and preempts early aircraft warning systems—is declared operational.[4]

1972: Anti-Ballistic Missile (ABM) Treaty prohibits the "development, testing, or deployment of sea-based, air-based, or space-based ABM systems and their components."[5]

1960s: Soviets test MTT orbital bombardment system as a potential substitute for ballistic missiles.[6]

1970s: New space-based missile sensors and submarine missiles combine to make MTT systems like FOBS less attractive. The sensors identified missiles early enough to employ conventional interceptors, while the submarines were able to launch missiles from close enough range to their targets as to render FOBS useless.[7]

1983: US announces the Strategic Defense Initiative (SDI), intending to develop and deploy technologies for comprehensive defense against ballistic missiles. This includes ETT weapons like space-based lasers and MTT weapons like the Brilliant Pebbles concept (see below).

1985-1990: USSR reportedly orbits, but does not successfully test, a directed energy experiment included on a 100-ton satellite launched by an Energiya rocket in 1985, and flight tests particle beam technology during the planetary probe programs.[8]

US conducts an underground test of a nuclear-pumped X-ray laser in 1985[9] but this is not a fully integrated system. There is also laboratory research into nuclear-pumped particle beams and free electron lasers.[10] The Relay Mirror Experiment is flight-tested in 1990, successfully demonstrating ground-based laser re-directing and pointing.[11]

Recent SBSW Developments

United States

The US maintained an active SBSW research program throughout the 1990s within the framework of the Ballistic Missile Defense program, including work on mass-to-target SBSWs such as the Space-Based Kinetic Interceptor, and energy-to-target SBSW systems such as the Space-Based Laser.[12]

Beyond missile defenses, the 2001 government-mandated *Report of the Commission to Assess United States National Security Space Management and Organization* appeared to provide justification for the development of additional SBSW systems. The Commission discussed the vulnerabilities of US space assets and called for the ability to "project power in, through and from space."[13] These views were consistent with the 1997 *US Space Command Vision for 2020*, which called for the development of capabilities for the "application of precision force from, to and through space," including the development of "space-based strike weapons."[14] The 2002 Air Force Space Command *Strategic Master Plan FY04 and Beyond* called for "a conventional global strike capability, possibly in the form of a Common Aero Vehicle [see below]…that will provide the President and the Secretary of Defense with a range of space power options."[15]

Figure 12-2
KEIs might involve de-orbiting tungsten rods at hypersonic velocities.

In terms of mass-to-target SBSWs, the most recent incarnation of the earlier US missile defense Brilliant Pebbles concept is the space-based Kinetic Energy Interceptor (KEI). The US Missile Defense Agency (MDA) describes the space-based KEI system as a boost phase missile defense system designed to supplement ground- and then sea-based interceptors.[16] In December 2002 the MDA announced its intention to place in orbit a test bed for the space-based boost phase kinetic energy interceptor in the 2007-2008 timeframe.[17] Estimates of the number of KEIs required for effective ballistic missile defense coverage range from forty-four[18] to the thousands,[19] depending on the configuration, and cost estimates vary almost as widely.

In the mid-1990s the US Air Force studied the concept of uranium-tipped tungsten rods, a few meters in length, which could be de-orbited for the purposes of a terrestrial strike.[20] In December 2002, a joint program office between the US Defense Advanced Research Project Agency and the USAF was established to accelerate development of the Common Aero Vehicle (CAV). The CAV concept includes a hypersonic glide vehicle that will place submunition packages within 3 meters of a target. Included in this suite of capabilities is a "rigid penetrator for hard and deeply buried targets."[21] While the CAV concept is currently based on suborbital technology, the hypersonic precision re-entry and maneuverability capabilities required for this system will provide key enabling technologies for space-to-earth force application. The Department of Defense is also considering a space-based platform as a delivery mechanism for CAV-type munitions.[22]

Figure 12-3
Illustration of CAVs dispensing submunitions.

Figure 12-4
Illustration of a Space-Based Laser constellation.

The US continued developing energy-to-target SBSW systems throughout the 1990s. The Space-Based Laser (SBL) program began during the 1980s, and continued to be the primary focus of these efforts. While the SBL faced considerable technological challenges, many of the key SBL enabling technologies have been separately demonstrated, including: high powered laser beam control; large, segmented mirrors with the characteristics necessary for weapons use; megawatt power generation in simulated space environments; and acquisition, tracking, and fire/pointing experiments with "near weapons level results."[23] Relay mirrors were flight tested in 1990, successfully demonstrating ground-based laser re-directing and pointing.[24]

In September 2002 the SBL program office was closed.[25] Remaining SBL research was moved into a MDA program called Laser Technologies. Lieutenant General Ronald Kadish, head of MDA, noted at the time that "space basing of this capability can be looked at as a later improvement as opposed to a near-term imperative."[26]

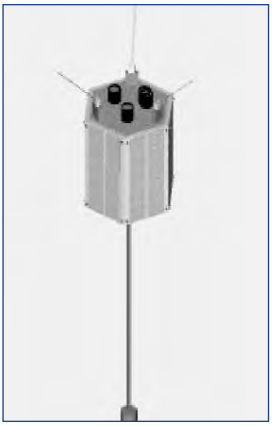


Figure 12-5
A Chinese version of a micro-satellite.

China

China's public position has been to oppose the weaponization of space and, thus, the development of SBSWs. This view has been expressed in several fora including a joint proposal with Russia within the Conference on Disarmament for an international treaty to prohibit the weaponization of space. Unclassified writings of Chinese military officers indicate that at least some officials are beginning to regard the development of SBSWs as inevitable:

> By the [21st] century, as high-tech space technology develops, the deployment of space-based weapons systems will be bound to make 'mastery of space' and 'mastery of outer space' prerequisites for naval victory…with space-based weapons systems probably directly attacking and intercepting warships and their cruise missiles.[27]

China has developed some key enabling technologies for SBSW systems including precision re-entry, micro-satellites, and directed energy systems in the form of high powered lasers. Indeed, US officials assess that China, with ongoing laser research and development programs, has the potential to become a world leader in military lasers by 2020.[28] China is also known to be conducting research on radio frequency weapons, both through indigenous technology development and cooperative technology transfer.[29]

Russia

Russia's public position has been to oppose the weaponization of space and, thus, the development of SBSWs. For years, Russia and China have submitted a proposal for a treaty on space weapons to the Conference on Disarmament, known as the Treaty on the Prevention of the

Deployment of Weapons in Outer Space, the Threat or Use of Force Against Outer Space Objects. The June 2002 version of this draft treaty included the core obligation “Not to place in orbit around the earth any objects carrying any kinds of weapons.”[30]

By the end of the 1980s, the USSR was assessed by US officials to be approximately fifteen years away from the development of an ETT (laser) SBSW.[31] It was also assessed that the USSR was approximately a decade away from the development of missile defense SBSWs.[32] While these may have been somewhat optimistic assessments, the former Soviet Union did appear to have expended considerable resources on SBSW development.[33] Since the end of the Cold War Russia is widely reported to be struggling to maintain its basic space capabilities.[34] This said, Russia retains a significant technological and knowledge base with respect to key SBSW enabling technologies such as precision re-entry, attitude control and maneuverability, micro-satellites, and directed energy weapons.

Figure 12-6
Soviet ground-based laser development was to lead to space-based platforms, but research efforts were reduced during the 1980s.

2003 DEVELOPMENTS

Overall, SBSW systems development continued to be funded in 2003, while doctrinal statements highlighted the potential for a negative action-reaction cycle. Key developments occurred in the United States, China, and India.

United States

During 2003 the US MDA combined its space-based kinetic energy interceptor with its sea-based kinetic energy interceptor efforts into a single program called the Ballistic Missile Defense System Interceptors.[35] In July 2003, the MDA announced that the projected date of 2007-2008 for the deployment of its in-orbit test bed of three to five space-based kinetic energy interceptors would be delayed to the 2012 timeframe, due to concerns about the maturity of the technology involved.[36] Congress authorized $14 million for fiscal year 2004 for work towards this test bed,[37] but noted that any further funds allocated to the design, development, or deployment of space would require explicit congressional approval.[38] In December, MDA declared that it would not use the funds until FY2005 at the earliest.[39] In November 2003 the USAF and the Defense Advanced Research Projects Agency announced the FALCON program, which supports the development of the CAV.[40]

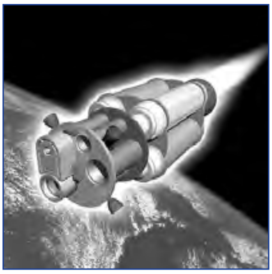


Figure 12-7
The space-based component of the KEI program was put on hold in 2003.

While the US Space-Based Laser office was closed in 2002, the US continues to devote considerable resources to the development of enabling technologies for directed energy weapons. Over $120 million was allocated to Defense Department Directed Energy Programs in FY2003.[41] For example, the US Air Force notes that its Bifocal Relay Mirror Spacecraft concept “can greatly extend the range of high power laser weapons.”[42]

Figure 12-8
While the SBL office was closed, work continues on laser-enabling technologies such as beam direction.

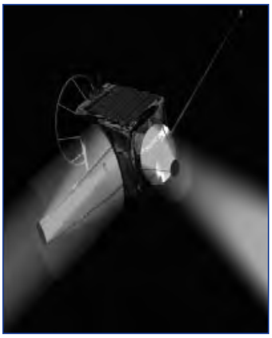


Figure 12-19
The Air Force Research Laboratory's Bifocal Relay Miror Spacecraft concept.

China

China accepted the 'Five Ambassadors' proposal that discussions—rather than negotiations—be held on the prevention of an arms race in outer space, removing a key obstacle to substantive work on the issue within the Conference on Disarmament.[43] Both China and the US expressed concerns about each other's space programs. While Chinese officials warned that "if one country leads in ushering weapons into outer space," the consequences would be "other states following suit."[44] US officials argued that China's manned space program would "contribute to improved military space systems in the 2010-2020 timeframe."[45] For example, General Lance Lord, Commander of Air Force Space Command, argued that the Chinese manned flight

> should give us cause to really be concerned about another space-faring nation involved in a competition that will seek to work against or maybe thwart our asymmetric advantage. They are going to be a substantial competitor. That's why I said we need to shape this environment as opposed to react to it. So we had better get ready. They represent a potential threat for us and we've got to get ahead and stay ahead.[46]

India

Just two weeks before the successful Chinese manned space launch, the Chief of the Indian Air Force announced that India had begun work on the "conceptualization" of weapons platforms in space. Citing weapons programs being pursued in other nations, the Air Force Chief was quoted as saying, "[a]ny country on the fringe of space technology like India has to work towards such a command as advanced countries are already moving towards laser weapon platforms in space and killer satellites."[47] Two weeks after the Chinese launch, he retracted this statement.[48]

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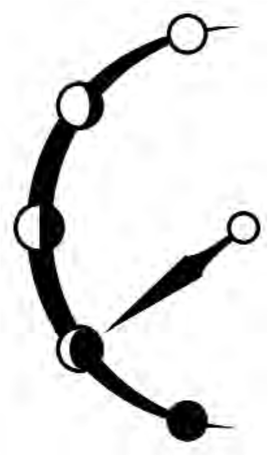
Space Security 2003: Survey Results

Space Security Survey (20/10/2003-14/11/2003)		Space Security Working Group (24/11/2003-25/11/2003)	
Question: Taking into account your views on developments within doctrine, orbital bombardment and space-based missile defenses in the past year, how have overall changes in this area affected space security?		*Question:* In your view, space security with respect to this indicator has been...?	
Enhanced:	1	Enhanced:	0
Somewhat enhanced:	7	Somewhat enhanced:	0
Little or no effect:	15	Little or no effect:	7
Somewhat reduced:	20	**Somewhat reduced:**	**12**
Reduced:	**35**	Reduced:	1

- Consistent with previous years, no space-based strike weapons (SBSW) were deployed in space during 2003, and few states possessed any of the key capabilities required for SBSW systems.
- The sustainability of space access and the degree to which states believed they will continue to enjoy freedom from space-based threats remained an issue of significant concern for many space actors. The US MDA plans to develop and deploy a space-based interceptor test bed by 2012, which, although a delay from previous estimates, was frequently cited in relationship to these concerns.
- The apparent reaction to these developments by Chinese and Indian officials underscored the risk that some space security actors were already beginning to plan for a time that space would become weaponized.



SOMEWHAT REDUCED

Space security had been somewhat reduced in 2003 with respect to this indicator.

ENDNOTES

[1] For discussions of definitions see for example Bob Preston et.al., "Space Weapons, Earth Wars," RAND Corporation, 2002. Available at http://www.rand.org/publications/MR/MR1209/, p.xvi; Michael Krepon and Christopher Clary, "Space Assurance or Space Dominance? The Case Against Weaponizing Space," The Henry L. Stimson Center, 2003, p.30; and Barry Watts, "The Military Use of Space: A Diagnostic Assessment," Center for Strategic and Budgetary Assessments, February 2002, p.86.

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ANNEX: Space Security 2003 - Research Methodology and Expert Participation

Space Security 2003 is the product of a joint research project initiated in December of 2002 between the Eisenhower Institute and the International Security Research and Outreach Programme (ISROP) maintained by the Foreign Affairs Canada.[1] A complete list of the expert participants in the meetings which structured the various phases of this project is included below.

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.[2] This work was undertaken by a Space Security Working Group (SSWG) convened by ISROP and the Eisenhower Institute which included 18 individuals with a range of expertise on space issues: legal (four), scientific/technological (two), political/policy (seven), civil/commercial (two), and military (three) dimensions of space security relevant issues.

To assist in the development of a working definition of space security and indicators of space security, the SSWG completed two sets of questionnaires, the first following the review of a discussion paper and the second following the discussions at a meeting in Washington in March 2003 which reviewed the results of the first questionnaire. This work 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,[3] the Outer Space Treaty,[4] the Liability Convention, and the Environmental Modification Convention.[5] 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.[6]

The objective of the second phase of this project (September 2003 - March 2004) was to complete an evaluation of the status of space security in 2003 using the working definition and the 12 indicators of space security. This effort was undertaken by a 26 member SSWG including individuals with a range of expertise on space issues: legal (four), scientific/technological (four), political/policy (nine), civil/commercial (four), and military (five) dimensions of space security relevant issues. SSWG members were asked to complete a pre-meeting questionnaire designed to evaluate their views on space security issues. This Space Security Survey was also completed via the web by a larger group of over 100 space security experts with the results being used to inform and/or challenge the views of the group itself.[7]

SSWG members were also provided with a series of draft 20-30 page research papers which examined each of the 12 indicators in some detail based on unclassified 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. At the conclusion of this process, SSWG members reviewed these results and were asked to provide an overall assessment of the status of space security for 2003. This work was reviewed by a second group of prominent space experts in May 2004.[8]

ENDNOTES

[1] The International Security Research and Outreach Programme, International Security Bureau, Department of Foreign Affairs, Canada, and The Eisenhower Institute, Washington, DC, USA. The views expressed in this volume represent the views of the experts engaged throughout this process and do attempt to reflect the views of the Government of Canada or Foreign Affairs Canada.

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

[3] Charter of the United Nations, http://www.un.org/aboutun/charter.

[4] The existing international legal agreements governing space related activities can be found at http://www.oosa.unvienna.org/SpaceLaw/treaties.html.

[5] Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques, http://www.state.gov/t/ac/trt/4783.htm.

[6] By space security actors or just actors, we mean states, institutions, firms, or agencies which have a direct interest in space, and a potential impact on space security.

[7] An invitation to participate in this Space Security Survey was provided to over 400 individuals with expertise on the legal, scientific/technological, political/policy, civil/commercial, and military dimensions of space security issues. Participants were asked to provide both quantitative and qualitative judgements and were assured anonymity of their responses. They were also asked to self-identify their level of expertise with respect to specific issues and also, on a voluntary basis, indicate their country of origin. A total of 115 respondents completed some parts of the survey. A total of 87 respondents indicated their country of origin with a clear majority from Canada and the United States. Other countries represented were Australia, China, France, Germany, India, Japan, Netherlands, New Zealand, Poland, Russia, Sweden, Switzerland, and the United Kingdom.

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Space is the only global commons that borders every community, providing an unprecedented potential nexus of social, economic, and military power. Space helps us monitor our weather and natural resources, produce food, communicate with each other, trade, and travel. Space is home to unprecedented achievements of international scientific cooperation. It generates tens of billions of dollars in commercial revenues. Space is rapidly becoming part of our critical national and international infrastructure; it supports our medical systems, our public services, our police forces, our militaries.

Space is also a global commons that is uniquely fragile, and its growing strategic importance raises concerns about the security of our space systems. How does the unique nature of the space environment shape the security of our access and use of space? How can we most effectively balance today's civil, commercial, and military space interests against our need for sustainable space use? Can space be secured for 'peaceful purposes' as defined by our collective obligations under the Outer Space Treaty?

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