1 The Space Environment

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

Space debris, both naturally generated and man-made, represents a growing threat to spacecraft. The impact of space debris upon space security is related to a number of key issues examined by this chapter, including the amount of space debris at various orbits; space surveillance capabilities which track space debris to enable collision avoidance; and efforts to reduce existing space debris populations.

All space missions inevitably create space debris — rocket booster stages are expended and released to drift in space and exhaust products are created. The testing of anti-satellite (ASAT) weapons has also created hundreds of pieces of space debris, some 500 of which were reportedly still in orbit in 1994 from USSR ASAT tests in the 1960s, 1970s, and 1980s.[1]

A growing awareness of the impact of space debris upon the security of space assets has encouraged space actors to take steps to mitigate the production of new debris through the development and implementation of national and international debris mitigation guidelines, also examined by this chapter. This chapter does not address natural phenomena such as solar flares and near-Earth asteroids, except in cases where the development of technologies and techniques are developed to mitigate their impact.

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

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

Space Security Impacts

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

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

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

Resource allocation, including the assignment of orbital slots and radio frequency spectrum to space actors, has a direct impact on the abilities of actors to access and use space. Growing numbers of space actors, particularly in the communications sector, have led to more competition and sometimes friction over such allocations.

New measures to increase the number of available orbital slots and frequency bands, such as technology to reduce interference between radio signals, can reduce competition pressures and increase the availability of these scarce resources. There are strong incentives for space actors to cooperate in the allocation and use of spectrum and orbital slots — namely confidence in the sustainability of their use. Cooperation in this area can also strengthen support for the application of the rule of law to broader space security issues.

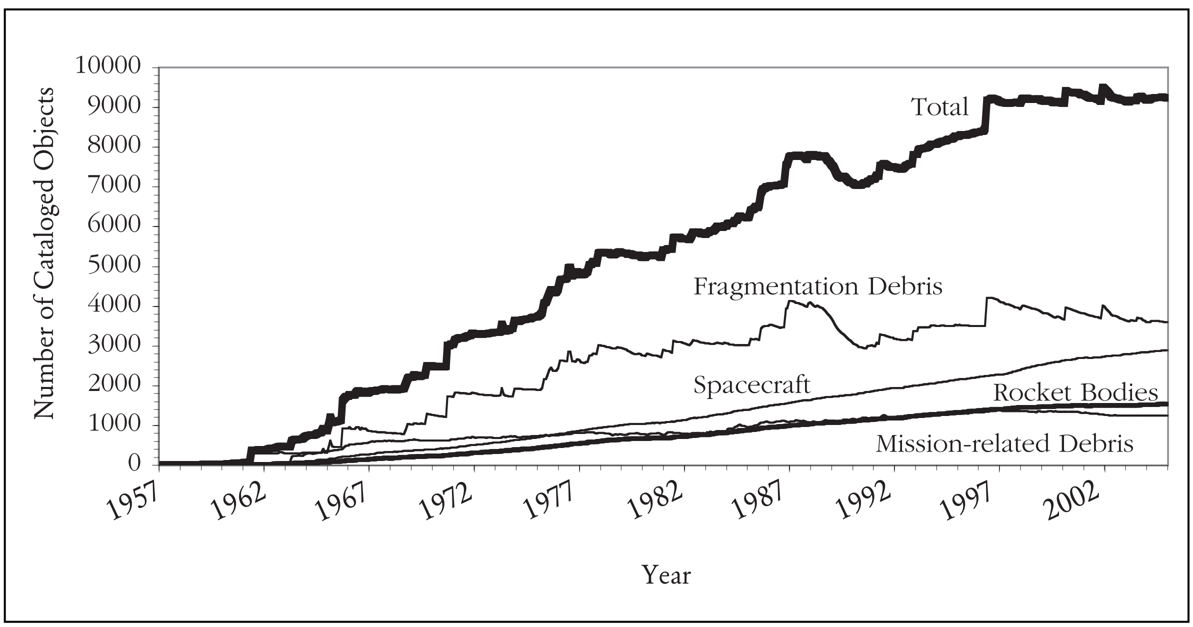
Key Trends and 2004 Developments

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

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

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

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



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

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

Hypervelocity space debris particles one to two millimeters or larger constitute a serious hazard to the security of spacecraft, threatening unprotected fuel lines and other sensitive components.[6] Protection against particles one to 10 millimeters in size can be achieved by shielding spacecraft bodies, while protection against larger debris can only really be achieved through collision avoidance procedures. Debris fragments between one to 10 centimeters "will penetrate and damage most spacecraft," according to the Center for Orbital Re-entry and Debris Studies. Moreover, "if the spacecraft bus is impacted, satellite function will be terminated and, at the same time, a significant amount of small debris will be created."[7]

Today, collisions between space assets like the International Space Station and very small pieces of debris are a daily but manageable problem, and occur in LEO which has the highest concentration of space debris.[8] A 1995 US National Research Council study found that within the orbital altitude that is most full of debris (900-1,000 kilometers), the chance of a typical spacecraft colliding with a large fragment was only about one in 1,000 over the spacecraft's 10-year functional lifetime, with even larger odds against impact in higher orbits.[9]

However, the same study noted that "although the current hazard to most space activities from debris is low, growth in the amount of debris threatens to make some valuable orbital regions increasingly inhospitable to space operations over the next few decades."[10] According to US National Aeronautics and Space Administration (NASA) models, without further implementation of orbital debris mitigation measures, the number of objects 10 centimeters and greater in orbit — which can be fatal to an average-size satellite — could grow rapidly in the second half of this century.[11] Indeed, some experts at NASA believe that collisions between space assets and larger pieces of debris will remain rare only for the next decade, although there is ongoing discussion about this assessment.[12] However, it is clear that the consequences of collisions between space debris and spacecraft can be disastrous. While major collisions have so far been rare, as noted in Figure 1.2 below, there have been several incidents of varying severity.

FIGURE 1.2: Space debris incidents[13]

The French military satellite Cerise had its stabilization arm severed in 1996 by a briefcase-sized portion of an Ariane rocket, and was temporarily put out of commission.
The Space Shuttle has been hit several times by particles bigger than one millimeter, and the first 33 Shuttle flights sustained debris damage to some of the tiles on the Shuttles' undersides.
The 10-year old Hubble Space Telescope, which orbits in LEO, has a three-quarter inch hole in its antenna that is believed to have been created by debris.
The Russian Kosmos 1275 military navigation satellite experienced an unexpected breakup in July 1981, generally thought to have been a result of space debris.
The Long Duration Exposure Facility, a school-bus-sized satellite, recorded more than 30,000 impacts by debris or meteoroids during six years in orbit.

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

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

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

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

2004: Progress in debris mitigation technologies

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

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

Net assessment

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

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

Growing awareness of space debris threats has led to the development of a number of international and national debris mitigation guidelines. The Scientific and Technical Subcommittee of the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) began discussions of space debris issues in 1994 and published its Technical Report on Space Debris in 1999. In 2001, COPUOS asked the Inter-Agency Space Debris Coordination Committee (IADC) to develop a set of international debris mitigation guidelines. The IADC brings together representatives of the space agencies of China, ESA, France, Germany, India, Italy, Japan, Russia, Ukraine, the UK, and the US.

At the national level, NASA issued guidelines on limiting orbital debris in the August 1995 NASA Safety Standard 1740. The 1996 US National Space Policy makes it the policy of the US to "seek to minimize the creation of space debris."[21] In December 2000, the US Government issued formal orbital debris mitigation standards for space operators developed by the Department of Defense and NASA. The ESA first introduced a space debris mitigation effort in 1998. In 1999, it published the *ESA Space Debris Mitigation Handbook*, with revisions released in 2002.[22] Also in 2002, the ESA issued the European Space Debris Safety and Mitigation Standard[23] and in 2003, it announced new debris mitigation guidelines.

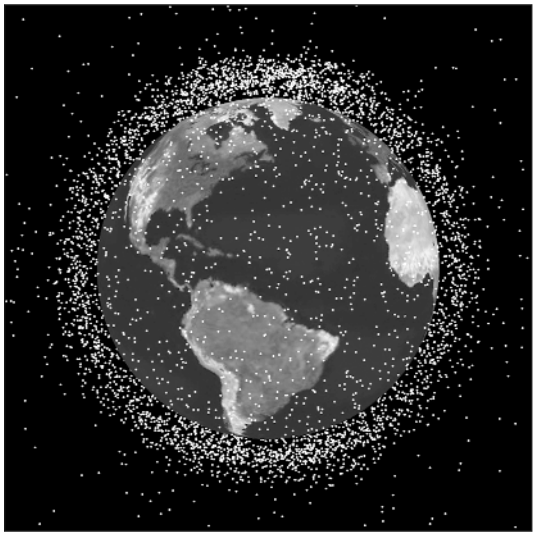
Japan and Russia, as well as several other space-faring states, also appear to strongly support the mitigation of space debris production. While there are some differences among national debris mitigation guidelines, they are broadly consistent. For example, all national guidelines address issues related to the minimization of debris released during normal operations. Most states require residual propellants, batteries, flywheels, pressure vessels, and other instruments to be depleted or made passive at the end of their operational lifetime.[24] All major national debris mitigation guidelines address the disposal of GEO satellites, typically in graveyard orbits some 235 kilometers above the GEO orbit, and most seek the removal of dead spacecraft from LEO within 25 years.[25]

China, although a member of the IADC, has not formally adopted debris mitigation guidelines, although it is reportedly working to adopt national guidelines in line with those recommended by the IADC. At the 2003 COPUOS annual meeting, China committed to "undertake the study and development of Chinese design norms to mitigate space debris, in conformity with the principles appearing in the space debris mitigation guidelines developed by the Coordination Committee."[26]

2004: IADC submits revised guidelines for debris mitigation and protection

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

FIGURE 1.3: Space debris in LEO[28]



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

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

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

Net assessment

The failure of the COPUOS Science and Technical Subcommittee to approve the IADC recommended debris mitigation guidelines was cause for concern in 2004. However, the overall trend towards the development of progressively more detailed national and international space debris mitigation guidelines and regulations is clearly a positive space security development. Indeed, the partial implementation of these measures already appears to be having a positive impact upon the annual rate of new debris production. However, some of these mitigation measures are expensive, which could present challenges for commercial and emerging space actors, suggesting potential restrictions upon their abilities to access and use space.

TREND 1.3: Growing demand for radio frequency spectrum

Radio frequency spectrum — the part of the electromagnetic spectrum that allows the transmission of radio signals — is divided into portions known as frequency bands, measured in hertz. Higher frequencies are capable of transmitting more information. Communications satellites tend to use the L-band (one to two gigahertz) and S-band (two to four gigahertz) for mobile phones, ship communications, and messaging. The C-band (four to eight gigahertz) is widely used by commercial satellite operators to provide services such as roving telephone services, and the Ku-band (12-18 gigahertz) is used to provide connections between satellite users. The Ka-band (27-40 gigahertz) is now being used for broadband communications. It is US policy to reserve the Ultra-High Frequency, X-, and K-bands (240-340 megahertz, eight to 12 gigahertz, and 18-27 gigahertz, respectively) for the US military.[33]

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

Growth in the number of operational satellites in space at any given time has led to a corresponding increase in the demand for bandwidth with which to communicate with these assets. For example, in Operation Enduring Freedom in 2001, the US military used some 700 megabytes per second of bandwidth, compared to about 99 megabytes per second during Operation Desert Storm in 1991.[36] During Operation Desert Storm, it is reported that certain air tasking orders and time-sensitive intelligence information were delivered by hand, due to a lack of available bandwidth.[37] As an example of the kind of growth being planned for by the US military, the Wideband Gapfiller Satellite system is being designed to provide transmission capacity of up to 2.4 gigabits per second per satellite, more than 10 times the capacity of the most advanced Defense Satellite Communications System satellite.[38]

While crowded orbits can result in signal interference between satellites, new technologies are being developed which address the need for greater frequency usage, allowing more satellites to operate closer to one another's frequencies without interference. Technologies, such as frequency hopping, lower power output, laser technology, digital signal processing, frequency-agile transceivers, and software-managed spectrum, have the potential to significantly improve bandwidth use, and hopefully alleviate certain existing and potential future conflicts over bandwidth allocation. In general, present-day receivers are also being produced with higher levels of tolerance for interference than they were decades ago, reflecting the need for increased frequency usage and sharing.[39]

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

Today, issues of interference arise primarily when spacecraft either want to use the same frequencies or when their fields of view overlap. While interference is not currently at epidemic proportions, it is a daily fact of life for satellite operators. For example, AsiaSat's general manager of engineering has noted that "frequency coordination is a full-time occupation for about five percent of our staff, and that's about right for most other satellite companies."[41]

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

Adopted in 1992, the current ITU Convention[44] governs the international use of the finite radio spectrum and orbital slots used to communicate with and house satellites in orbit. Article 35 of the Convention stipulates that "all stations (…) must be established and operated in such a manner as not to cause harmful interference to the radio services or communications of other members."[45] Military communications are exempt from the Convention, though they must nonetheless observe measures to prevent harmful interference as much as possible.

International negotiations over radio frequency allocations have tended to become politicized, involving bargaining over systems and capabilities which can take years.[46] Moreover, there is growing concern within the US that the open discussion of certain system characteristics and positioning information necessary to identify and resolve frequency and interference disputes among systems could compromise the security of the systems in question. The Aerospace Corporation noted in 2002 that "the spectrum-management community is moving toward more confidentiality, including the use of generic or non-identifying names instead of actual program names for registration submissions."[47]

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

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

2004: FCC announces spectrum-sharing decisions

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

2004: World Broadcasting Union submits procedures to reduce interference

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

2004: Vietnam's efforts to coordinate frequency usage fail

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

Net assessment

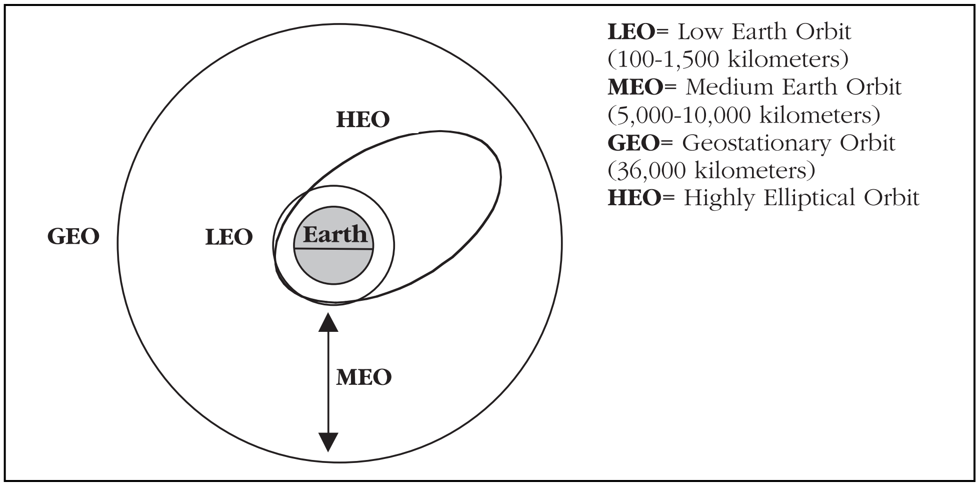
Against a general trend of growing demand for radio frequency spectrum, some developments in 2004, such as the US FCC spectrum sharing decision and the World Broadcasting Union proposals to reduce satellite signal interference, suggest some progress in addressing this challenge. While increased demand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

TREND 1.4: Growing demand for orbital slot allocations

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

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

FIGURE 1.4: Types of orbits



The best GEO slots are those located above or close to the equator, which facilitates a greater communications footprint, since satellites in an orbit with an inclination too far north of the equator may not be able to communicate with parts of the southern hemisphere. Around three-quarters of the Earth's surface is water, with little demand for satellite communication in those regions. "The orbital arc of interest to the United States lies between 60 and 135 degrees west longitude because satellites in this area can serve the entire continental United States."[53] Similar limitations are true for all geographic regions, and in the case of the US, its range of desirable slots is also optimal for Canada, Mexico, and parts of Latin America, resulting in competition amongst these actors.

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

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

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

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

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

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

2004 saw mixed developments in the allocation and use of orbital slots. Telesat Canada and DirecTV came to an agreement in August 2004 in which Telesat Canada allowed DirecTV to move an existing satellite into its slot at 72.5 degrees West, in exchange for Telesat Canada's use of DirecTV's satellite in the orbital slot at 82 degrees West. DirecTV, the largest satellite TV service provider in the US, wanted the slot in question in order to be able to offer local programming to an additional 24 US-based markets. Conversely, Telesat Canada had a use for DirecTVs on-orbit spare at 82 degrees West as a replacement for a faulty satellite, using it to offer direct-to-home services in Canada. DirecTV's vice-president Bob Marsocci described the exchange as a "creative spectrum-sharing agreement that reflects the increasingly [sic] value of orbital slots."[62]

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

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

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

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

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

The ITU's Ad Hoc Group on Cost Recovery for Satellite Network Filings recommended to the 2004 ITU Council that there be no change in cost recovery methodology until 2005, to allow more time for analysis of true costs associated with satellite filings. Although the decision to look into filing methodology more thoroughly seems to have eased difficulties between the ITU and satellite operators, tensions still remain. As Via Satellite noted, "If the cost recovery fee issue remains unresolved, operators may be forced to look for an alternative for coordinating satellite networks. Without the participation of satellite operators, the ITU cannot sustain its role as an international spectrum manager."[69]

Net assessment

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

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

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

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

Russia also has a Space Surveillance System (SSS), which functions using Russia's early warning radars in space and more than 20 optical and electro-optical facilities at 14 locations on Earth.[75] The main optical observation system, Okno, allows detection of objects up to 40,000 kilometers,[76] although its capacity to detect smaller objects is unclear. The Russian Academy of Sciences also participates in Russia's SSS.[77] However, the SSS cannot track satellites at very low inclinations, and operation of their surveillance sites is reportedly erratic, with systems coming and going online.[78] The network as a whole carries out some 50,000 observations daily, contributing to a catalogue of approximately 5,000 objects, mostly in LEO.[79] Furthermore, while information from the system is not classified, Russia does not have a formal system in place for widely disseminating information about observations.

Other states, France and Germany in particular, have also emphasized surveillance for debris monitoring. Since 1999, France has operated the Graves radar, which tracks satellites over French territory below 1,000 kilometers. The development of this system was reportedly motivated by a desire for independence from US and Russian space surveillance capabilities.[80] The German Defense Research Organization also operates the High Power Radar. The 34-meter diameter antenna carries out observations in the L- and Ku-bands and can see objects as small as two centimeters in size at altitudes of 1,000 kilometers.[81]

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

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

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

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

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

2004: US changes practices on orbital data sharing

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

2004: Japan's new space debris radar becomes operational

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

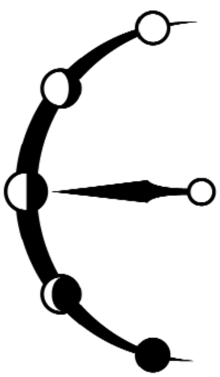
Net assessment

In general terms, space surveillance capabilities continue to improve as more actors become involved in this area critical to collision avoidance. However, important constraints remain, such as technology limitations, cost considerations, and barriers to cooperation and transparency caused by concerns that surveillance information might be used in an adversarial manner. This dual nature of surveillance technology also tends to hinder international cooperation, with the potential to undermine the degree to which these capabilities are used effectively to enable collision avoidance efforts and maintain the security of space uses.

Space Security 2004 Survey Results

Overall, how have developments related to the space environment in the past year affected space security?

Space Security Survey (14 January-21 February 2005)			Space Security Working Group Survey (24-25 February 2005)		
Enhanced	1	1%	Enhanced	0	0%
Somewhat Enhanced	40	32%	Somewhat Enhanced	10	38%
Little or No Effect	65	52%	Little or No Effect	13	50%
Somewhat Reduced	15	12%	Somewhat Reduced	2	8%
Reduced	3	2%	Reduced	1	4%
Total	124		Total	26	



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

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