

The Space Environment

Indicator Description

This chapter assesses trends and developments to the space environment as they affect space security, with an emphasis on *space debris and space resource issues*.

Key Trends

TREND 1.1: Growing debris threats to spacecraft, but annual rate of new debris production decreasing – The number of objects in Earth orbit has increased steadily and there are an estimated 35 million pieces of space debris in orbit today. Of these, any debris over a few mm in size can disable a satellite if a collision takes place and objects over a few cm in size can cause catastrophic breakup. Approximately 13,000 are large enough (> 10cm in size) to be routinely tracked and of these approximately 900 are satellites. However, the annual growth rate of tracked orbital debris has been decreasing since the early 1990s, due in large part to national space agency debris mitigation efforts.

TREND 1.2: Increasing awareness of space debris threats and continuing efforts to develop international guidelines for debris mitigation – There is widespread recognition, in light of tracking efforts and recorded on-orbit collisions, that space debris is a growing threat. Since the mid-1990s, many space-faring states, including China, Japan, Russia, and the US, and the European Space Agency have developed national debris mitigation standards. In 2001, the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) mandated the Inter-Agency Debris Coordination Committee (IADC) to develop a set of voluntary international debris mitigation guidelines.

TREND 1.3: Growing demand for radio frequencies – Expanding satellite applications are driving growing demand for radio frequencies. The number of satellites operating in the 7-8 gigahertz band commonly used by GEO satellites has been increasing. Satellite operators now spend about five percent of their time addressing frequency interference issues, including the US and European Union (EU) disagreement over frequency allocation for the proposed EU Galileo navigational system. The dramatic growth in military consumption of bandwidth could lead to increased pressure for frequency slots.

TREND 1.4: Growing demand for orbital slot allocations – There are more than 620 operational satellites in orbit today: about 46 percent in LEO, 6 percent in MEO, and slightly more than 47 percent in GEO. Increased competition for orbital slot assignments in GEO has caused occasional disputes between satellite operators. The International Telecommunications Union (ITU) has been pursuing internal reforms designed to address slot allocation backlogs and related financial challenges.

TREND 1.5: Space surveillance capabilities to support collision avoidance slowly improving – The US Space Surveillance Network uses 31 sensors worldwide to monitor over 9,000 space objects in all orbits, supporting collision avoidance and debris re-entry. Since 2004, the US has moderated public access to the two-line elements to registered users out of concern for national security. Russia maintains its Space Surveillance System with 14

sensors, and monitors some 5,000 objects (mostly in LEO), but does not widely disseminate data. The EU, Canada, China, France, Germany, and Japan are all developing new space surveillance capabilities.

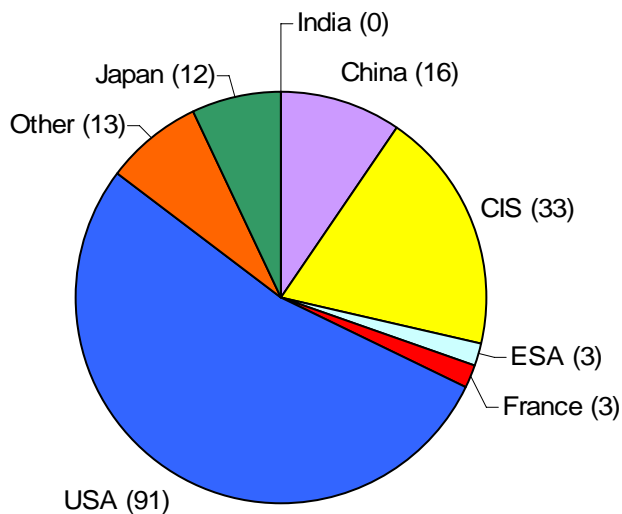
2006 Developments

TREND 1.1: Growing debris threatens spacecrafts, but annual rate of new debris production decreasing

2006: Population of large space debris increases by 5.52 percent

By the end of 2006 the number of large and medium-sized objects (>10cm) in orbit that are tracked by the US SSN stood at 9,948.¹ This number represents an increase of 521 objects or 5.52 percent when compared with yearend data for 2005.² The 2006 increase is notably larger than that of the previous year in which 195 pieces of debris representing a 2.1 percent increase were catalogued.³ Of the total increase in space debris from 2005 to 2006, 171 pieces were created by launches in 2006 (see Figure 1). Total launch-related debris stands at 6,900, of which US launch activity accounts for 45 percent, and CIS launch activity for 42 percent (see Figure 2).⁴ Most space debris orbits within 2,000 kilometers of the Earth's surface, with areas of concentration found near 800, 1,000, and 1,500 kilometers altitude. There is also a concentrations of debris in GEO and to a lesser extent in MEO. Space debris production in recent years has reversed the trend of declining annual debris production that began in the 1990s.

FIGURE 1: Debris created by launching state in 2006⁵

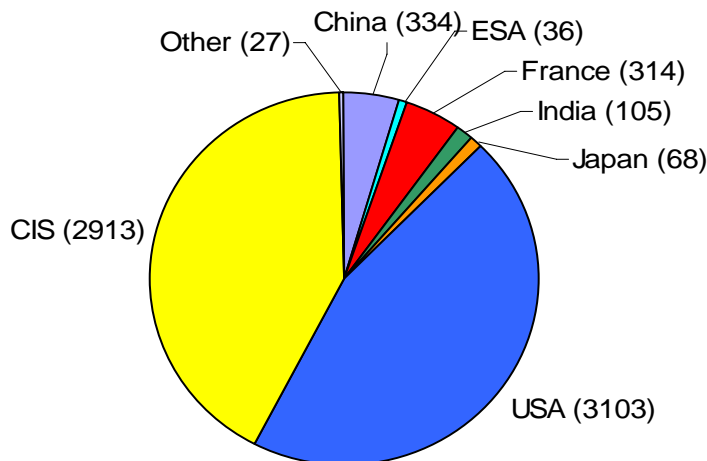


By October 2006, five cases of satellite fragmentation had been recorded for the year and one new accidental collision identified. On 14 February, a single fragment separated from US' Vanguard 3 satellite, possibly due to surface materials deterioration, or numerous micro-collisions. On 4 May, a 20-year old soviet rocket suddenly fragmented, possibly due to a residual propellant. Of the 50 new pieces of debris created by this fragmentation, more than

20 were expected to have re-entered the Earth's atmosphere by mid-August. Two Russian Proton motors broke-up in 2006, one on 10 June and the other during 1-2 September, bringing the total number of break-ups associated with this type of motor up to 35, since 1984. These two events produced more than 137 new pieces of tracked debris. On 8 August and 27 August, a two-step breakup of US H-2A second stage produced a total of 21 new pieces of debris, all of which are expected to re-enter in the near future. Another inconsequential fragmentation occurred in late August or early September, when a Russian Molniya upper stage broke up at low perigee, probably because of strain created by aerodynamic forces. Lastly, a debris-related disaster caused a Russian telecommunication satellite to shutdown on 29 March 2006. Although the impact caused the spacecraft to lose orientation and rotation, it was successfully move to a graveyard orbit.⁶

There were also various small debris-creating incidents in 2006. On 3 February 2006, a Russian space suit filled with trash was released from the International Space Station, and re-entered the Earth's atmosphere 216 days later. In July, a spatula was lost during a spacewalk, but was expected to have re-entered one month later. In September, several of bolts were lost during the installation of a module on the ISS, and will only re-enter the atmosphere after six months in orbit. Finally, Russian cosmonaut Mikhail Tyurin shot a 3 gram golf ball off the ISS on 22 November, as part of a publicity promotion for a golf company. The golf ball re-entered Earth's atmosphere 2 to 3 days later⁷. While most debris from these smaller incidents remain in orbit for short periods of time, they pose risks to space assets while in orbit, and upon their descent.

FIGURE 2: Total debris created by launching state since 1957⁸



2006: New policy to allow temporary increase of space junk in LEO

The jettisoning of a golf ball off the ISS coincided with a new policy proposal from NASA to intentionally toss unneeded gear off of the ISS, which will take effect if approved by the other international members of the ISS. According to this policy, objects would be pushed off of the rear of the ISS in such a way as to minimize the amount of time that it will spend in orbit and eliminating the possibility that released objects might collide with the station. Objects that could be released from the ISS are those that are unlikely to break up before re-entry, are therefore unlikely to create additional debris, and those that will probably not survive re-entry or cause damage on the ground. NASA has identified four types of objects

that do not meet these criteria, which will nonetheless qualify for jettisoning: those that would pose a danger to the ISS if kept onboard; those that would pose a danger to a space vehicle if it were to be sent back to Earth; items for which retrieval from the station is time consuming; and item designed to be jettisoned.⁹

2006: Pursuit of debris mitigation technologies continues

Advances were made in 2006 in the development of electromagnetic tethers that could be deployed after a satellite becomes non-operational. Space tethers are essentially cables made of conductive material and attached to a satellite with a electric current passed through it. The motion of the cable in the Earth's magnetic field provides propellant-free propulsion for orbital objects. When a satellite reaches the end of its operational lifetime a tether could be released to de-orbit the satellite, eventually causing it to burn up in the atmosphere if in LEO or to raise the orbit, if in GEO.¹⁰ The IADC has recently issued a final report assessing the potential benefits and risks of using such a mechanism as a debris mitigation technique, and has made various recommendations based on a 5 year-long study of the subject.¹¹ It concludes that while "electrodynamic tethers have strong potential to become effective mitigation measures...various problems are still to be solved before this technique can be practically adopted."¹²

To date no efficient technical means to remove existing space debris has formed. However a technology that may help to demonstrate ways forward is the Large Area Debris Collector (LAD-C) being designed by the US DOD which on 31 May 2006 held a Preliminary Design Review for the mission. The LAD-C is a 10 m² aerogel and acoustic sensor system that will be used on the International Space Station (ISS) to collect micro-meteoroids for post-flight analysis. It will record impact time, location and strength from acoustic techniques. The LAD-C will provide better understanding of the characteristics and possible sources of the LEO debris population. The LAD-C is currently scheduled for launch in 2008, and is expected to deploy for a one to two-year period, after which it will be returned to Earth.¹³

NASA announced on 1 October 2006 that it agreed to significantly extend the time-frame of the space elevator competition from one to five years, and increase the total prize purses to \$4-million. The second competition of the Elevator 2010 project was held in August 2006. It was designed to promote academic and industrial technological advances for the construction of a space elevator made with a thin ribbon extending into space, attached to a satellite orbiting in GEO. The elevator would be powered by solar panels, thereby eliminating the need for dangerous and polluting propellant-powered launches, as well as debris resulting from leftover launch vehicles and in-space explosions caused by residual propellants¹⁴.

2006: New research finds inevitable increase of space debris

New research by NASA scientists has shown that the orbital debris in LEO is bound to increase, even if countries put an immediate end to all new launches. The evolution of 10 cm or larger pieces of debris in LEO was projected over the next two hundred years with the assumption that no new debris producing launches or in-space debris disposal maneuvers were made. The study found that the debris population would remain stable over the next 50 years, but would begin to increase beyond 2055. Collisions would have a predominant debris creating effect but other causes would include atmospheric drag and solar radiation. The study foresees a threefold increase in the number of medium to large size debris within the

next 200 years, causing a 10-fold increase in collision probabilities. These numbers are an underestimate of what will occur in reality, since debris-producing launches will continue.¹⁵

Finally, no technically means to efficiently remove debris has yet to be developed.

Net assessment:

Developments in space debris had a mixed impact on space security in 2006. On the one hand, developments in debris mitigation technology such as space tethers and the space elevator could potentially have a positive effect on space security by reducing the amount of space debris, ensuring that satellites remain in their allocated positions, and limiting the number of inactive satellites in orbit that could pose threats to operational spacecraft. On the other hand, the sufficiency and cost-effectiveness of these mitigation technologies have yet to be proven, while the rate of space debris production is increasing, and will continue to increase. Failure to develop such technologies will endanger space security in the long term.

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

2006: Space debris mitigation guidelines drafted at UN COPUOS

The Space Debris Working Group of the Scientific and Technical Subcommittee of COPUOS has drafted space debris mitigation guidelines consistent with those of the IADC. COPUOS's draft document entitled "UN COPUOS STSC Space Debris Mitigation Guidelines" presents general recommendations in the form of seven guidelines to be implemented through national legislation and protocols (see Figure 3).

Figure 3: UN COPUOS STSC Space Debris Mitigation Guidelines¹⁶

UN COPUOS STSC Space Debris Mitigation Guidelines
1. Limit debris released during normal operations
2. Minimize the potential for break-ups during operational phases
3. Limit the probability of accidental collision in orbit
4. Avoid intentional destruction and other harmful activities
5. Minimize potential for post-mission break-ups resulting from stored energy
6. Limit the long-term presence of spacecraft and launch vehicle orbital stages in the low-Earth orbit (LEO) region after the end of their mission
7. Limit the long-term interference of spacecraft and launch vehicle orbital stages with the geosynchronous Earth orbit (GEO) region after the end of their mission

2006: Debris mitigation a priority for US National Space Policy

In 2006 the US updated its National Space Policy for the first time since 1996. This new policy recognizes the risk posed by space debris, and affirms that the US will "seek to minimize the creation of orbital debris by government and non-government operations in space." To this end, departments and agencies must continue to follow US's Orbital Debris Mitigation Standard Practices cost-effectively, licensing procedures followed by the Secretaries of Commerce and Transportation must "continue to address orbital debris issues," and the US "shall take a leadership role" to promote the adoption of debris

mitigation policies and practices on an international level. Apart from a reference to the government's new Standard Practices, this policy closely resembles the previous one. Cost-effective mitigation is the approach favored by the US to deal with the orbital debris problem. There is no reference in this policy to any obligations upon departments and agencies to develop remediation techniques.¹⁷

Net assessment:

The adoption of debris mitigation guidelines by COPUOS bodes well for space security although at present these guidelines remain voluntary and do not encompass any implementation, verification, or compliance measures. Although debris mitigation procedures are on the verge of being accepted on a world-wide scale, these policies will be insufficient to combat the growing debris problem in the long-run without additional efforts to remove debris, given natural increases in space debris.

TREND 1.3: Growing demand for radio frequency spectrum

2006: Significant decrease in radio frequency interference cases reported

According to the Satellite Users Interference Reduction Group, there were only 180 satellite radio frequency interference incidents reported in 2006 representing 7.6 times fewer incidents than the 1,374 incidents report in 2005. Of these events, 17 percent were caused by equipment malfunction and 19 percent by human error, while the causes of almost 40 percent of incidents were unknown. Adjacent satellites were responsible for almost 4 percent of the incidents. None of the interferences reported were caused deliberately. Less than 1 percent of the interference occurrences were caused by terrestrial services and another 14 percent occurred during cross-polarization – when satellite dishes are being aligned to receive signals from the satellite. Almost 70 percent of the incidents occurred in the Atlantic region.¹⁸

2006: US Strategic Command treats interference as attack

US STRATCOM announced that it is now treating all satellite disturbances as if they were an attack on US satellites, instead of making the conventional assumption that these abnormalities are due to the space environment or system failure. Officials say that the change in policy is meant to increase response time in case of an actual attack, and to allow operators to practice response procedures.¹⁹

2006: Growing bandwidth demand may increase pressure on frequency slots

The dramatic increase in military satellite telecommunications usage in terms of bandwidth (see Space Support for Terrestrial Military Operations) as well as the trend towards digital media may increase pressure on frequency slots if it is not met with an equivalent growth technical means to increase in bandwidth per frequency and orbital slot allocation.

In June 2006, 101 states signed an international treaty in Geneva agreeing to replace traditional analytical radio and TV broadcasts with digital ones by 2015. This agreement will promote global connectivity and provide remote communities with modern communication technologies. Implementation of this treaty is also likely to significantly increase bandwidth demand world-wide and to ensure the continued growth and the satellite industry.²⁰

The US military is currently working on various projects that could help to solve problems related to bandwidth scarcity. Boeing and Northrop Grumman successfully carried out tests in 2006 on new military satellite systems: the Wideband Gapfiller Satellite (WGS), the Advance Extremely High Frequency (AEHF) system. Both of these systems are expected to considerably increase bandwidth availability for the US military: One WGS should provide ten times the capacity of one of the existing satellites. Recent reports indicate the launching of the first WGS in 2007 and the first AEHF in 2008,²¹ but both projects have experienced significant delays.

The next evolutionary step in US telecommunication technology is the Transformational Satellite Communication System (TSAT), which is expected to be online by 2014. The program continues to suffer from delays and budget cuts, however (see Space Support for Terrestrial Military Operations). MiRaytheon and Harris are both working on prototypes of a US Navy Multiband Terminal (NMT), that will double the data transmission rate for the US Navy, and “will set the architecture for the core community” of the TSAT. Both firms announced major developments last year, in the building of the NMT system.²²

2006: European efforts to harmonize radio frequency utilization

Following a 2005 European Commission (EC) report on the need to coordinate European spectrum policy, plans were announced in 2006 to harmonize its regulatory framework for satellite communications, allowing for better allocation of the frequency spectrum for all users. To promote its satellite communication sector, the EU is funding a newly inaugurated industry-led platform called the Integral Satcom Initiative (ISI), which will address a variety of satellite communications issues, including the promotion of a harmonized European regulatory framework.²³

Net assessment:

Growing demand for radio frequency allocation continued to challenge the sustainability of broader access to and use of space in 2006, however continuing regional efforts to harmonize the allocation of radio frequencies promised to help manage the demand on this limited resource. Although radio frequency competition and interference continued to pose a challenge to space security in 2006, the significantly lower number of incidents suggests success in international efforts to manage this security challenge.

TREND 1.4: Growing demand for orbital slot allocations

2006: Increasing number of states acquiring satellites

More states accessed space in 2006. Kazakhstan launched its first satellite, a telecommunications satellite KazSat-1 with the assistance of the Russian company Khrunichev.²⁴ Arianespace has agreed to launch Vietnam’s first satellite by 2008. The satellite, VINASAT-1, is a telecommunication satellite that will be built by Lockheed Martin.²⁵ Vietnam has until the second quarter of 2008 to put a satellite into GEO before it loses rights to the orbital slot it reserved several years ago with the ITU.²⁶

2006: Competition and cooperation in the allocation and use of orbital slots

Further consolidation of the telecommunication industry in 2006 may lead to better management and more efficient use of the frequency spectrum and orbital slots in the future.

The two top satellite operators, Intelsat and PanAmSat, merged in 2006 after obtaining approval from US Regulatory Authorities. The new Intelsat is now the largest satellite operator in the world followed by SES, which merged this year with New Skies Satellites and signed a partnership agreement with Eutelsat in October 2006 (see Commercial Space). This joint venture will operate using the S-band to provide video, radio and data services to mobile equipment.²⁷ French telecommunication company Alcatel bought American communications network developer and US military contractor Lucent in 2006.²⁸ It is now moving forward with consolidation with Thales.²⁹

The FCC granted EchoStar's application to operate in the 86.5° W.L. orbital location against Telesat's claim that granting such a request would affect satellite service to 1.5 million Canadian consumers. The FCC found that granting EchoStar's application was in the public interest, but subjected such approval to EchoStar's submission of a detailed orbital debris mitigation plan, and to various interference limits until operations were coordinated with adjacent satellites.³⁰

Net assessment:

Developments in 2006, including competition for GEO slots, demonstrated the governance challenges associated with secure and sustainable access to and use of space. It also illustrated one of the central dilemmas of space security. While the increasing number of states seeking to acquire satellites may allow greater access and use of space for some, the corresponding strain on the availability of orbital slots and the frequency spectrum may reduce the sustainability of space use, particularly in an absence of international cooperation. International cooperation for space resource allocation was enhanced in 2006, however, and continuing international mergers of telecommunication companies may unexpectedly provide further cooperation and coordination.

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

2006: Expansion of US space surveillance and space situational awareness capabilities

The US continued to pursue the world's most robust space surveillance system in 2006. The US Air Force (USAF) announced that two of its three Space Fence systems, a very high frequency radar surveillance system, will be deployed internationally. The USAF will post a contract notice in 2007 requesting bids to expand the system and to upgrade its radar bandwidth, though initial operations are not expected to begin before 2013 or 2014³¹.

Progress on the development of the Space-Based Surveillance System (SBSS) continued throughout 2006, with the completion of a key risk reduction step for the SBSS Pathfinder satellite, now planned for launch in December 2008. The supplier of the charge coupled device (CCD), the fundamental optical data acquisition element to be placed in the satellite, has successfully completed environmental and life testing as part of a rigorous risk reduction program implemented by the Boeing team responsible for building the SBSS system. The Pathfinder satellite will track manmade objects in space, and will be used primarily to monitor communications, intelligence, surveillance, and reconnaissance technology in space,

but will also be employed by the US DOD to detect and track orbital debris, thereby greatly increasing the SSN's capabilities.³²

2006: Russia plans to expand its space surveillance capabilities

Though little information is available on Russia's Space Surveillance System, in November 2006 Russia's Space Forces announced plans to expand the detection range of the Okno space-monitoring center. The tracking precision and servicing period will also be enhanced, through the modernization of the electronic equipment. The complex is presently able to detect objects at altitudes ranging from 2,000 to 40,000 kilometers.³³

2006: European actors continue to develop independent space surveillance capabilities

European states continue to develop independent space surveillance capabilities, but there is still not an integrated European network. Nonetheless, the ESA has defined space surveillance as one of three main security priorities.³⁴

France's GRAVES space surveillance radar is now fully operational as of 22 December 2005. The system is capable of monitoring space objects, including orbital debris. This radar is also able to observe satellites up to 1,000 kilometers in altitude and follow more than a quarter of all satellites, particularly those that France considers "the most threatening" and those for which the US does not publish orbital information³⁵. France has cited the necessity of developing this system to decrease reliance on US surveillance information, and to ensure the availability of data in the event of a data distribution blackout.³⁶ France is now able to maintain a satellite database of approximately 2,000 space objects.

The UK's British National Space Centre (BNSC) is working towards establishing a new space surveillance system to map large areas of the sky in a short time span. This method is different from the conventional, time consuming method of detecting individual space objects, and would provide a more efficient and appropriate means of tracking space objects in today's crowded skies. Through this project, the BNSC also intends to update its re-entry prediction capabilities³⁷.

Net assessment

The international improvement of space surveillance and space situational awareness capabilities in 2006 may have a positive effect on space security by providing improved and redundant tracking of space objects. However, the development of space situational awareness and the continued drive for *independent* space tracking systems indicate broader mistrust, and the technology holds dual-use potential for space negotiation purposes.

ENDNOTES

¹ Large and medium sized objects refer to objects over 10 centimeters in diameter. NASA Orbital Debris Program Office, 10(1) Orbital Debris Quarterly News (January 2006) at 7, online: Orbital Debris Quarterly News < <http://orbitaldebris.jsc.nasa.gov/newsletter/newsletter.html> > (date accessed: 8 February 2007).

² The number of objects being tracked is only a representation of what sensors are online and their capability. With improvements to tracking capabilities, the database will increase even if the amount of debris is going down. The amount of debris that can cause damage to space assets could easily exceed 200,000 objects.

³ Comparison of “Orbital Box Score” data from NASA Orbital Debris Program Office, 10(1) Orbital Debris Quarterly News (January 2006) at 7 to 10(4) Orbital Debris Quarterly News (October 2006) at 9, online: Orbital Debris Quarterly News < <http://orbitaldebris.jsc.nasa.gov/newsletter/newsletter.html> > (date accessed: 8 February 2007).

⁴ At present the CIS includes Azerbaijan, Armenia, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russia, Tajikistan, Turkmenistan, Uzbekistan, and Ukraine.

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⁸ Orbital Debris Quarterly News (January 2007) at 9, online: Orbital Debris Quarterly News < <http://orbitaldebris.jsc.nasa.gov/newsletter/newsletter.html> > (date accessed: 8 February 2007).

⁹ Kelly Young, “Astronauts to Pitch Unwanted Gear off Space Station”, NewScientist.com (10 November 2006), online: New Scientist Space <<http://space.newscientist.com/article/dn10512-astronauts-to-pitch-unwanted>> (date accessed: 8 February 2007); “The New Jettison Policy for the International Space Station” 10(3) Orbital Debris Quarterly News (July 2006) at 6, online: Orbital Debris Quarterly News < <http://orbitaldebris.jsc.nasa.gov/newsletter/newsletter.html> > (date accessed: 8 February 2007).

¹⁰ NASA, “Space Transportation with a Twist”, online: NASA <http://www.nasa.gov/vision/universe/roboticexplorers/tethered_spacecraft.html> (date accessed: 8 February 2007).

¹¹ “Progress in Space Tether Sever Modeling,” 9(4) Orbital Debris Quarterly News (October 2005) at 4, online: Orbital Debris Quarterly News <<http://orbitaldebris.jsc.nasa.gov/newsletter/newsletter.html>> (date accessed: 8 February 2007); Carmen Pardini, Toshiya Hanada, Paula H. Krisko, “Benefits and Risks of Using Electrodynamic Tethers to De-Orbit Spacecraft”, IAC-06-B6.2.10, online: Inter-Agency Space Debris Coordination Committee < http://www.iadc-online.org/index.cgi?item=docs_pub > (date accessed: 8 February 2007).

¹² Carmen Pardini, Toshiya Hanada, Paula H. Krisko, “Benefits and Risks of Using Electrodynamic Tethers to De-Orbit Spacecraft”, IAC-06-B6.2.10, online: Inter-Agency Space Debris Coordination Committee < http://www.iadc-online.org/index.cgi?item=docs_pub > (date accessed: 8 February 2007).

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¹⁹ “STRATCOM Treating all Satellite Disturbances as Attacks for Practice” 12(22) *Inside Missile Defense* (25 October 2006).

²⁰ Virgil Labador, “Top Stories of 2006” 4(8) *Satmagazine.com* (December 2006) at 20.

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²² Caitlin Harrington and Tony Skinner, “Next-Generation Satellites Move into Next Phase” *Jane’s Defense Weekly* (16 August 2006) at 28; Mark A. Kellner, “Raytheon, Harris Claim Milestones in U.S. Navy SATCOM Program” *DefenseNews.com* (13 November 2006) at 18, online: *DefenseNews.com* <<http://www.defensenews.com/story.php?F=2343775&C=navwar>> (date accessed: 8 February 2007).

²³ “Integral Satcom Initiative Holds Launch Meeting”, *European Commission Space News and Features* (16 February 2006), online: European Commission <http://ec.europa.eu/comm/space/news/article_3847_en.html> (date accessed: 8 February 2007).

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²⁶ Pham Le, “Satellite Project Picks up Speed” *Saigon Times Weekly* (12 November 2005).

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