Current Status of International Efforts to Mitigate Space Debris
Josh Levinger

Introduction

Douglas Adams reminds us that “space is big… vastly, hugely, mind-bogglingly big.”[1] But although the universe may seem boundless, our planetary orbit is also fragile. It is an environment devoid of most of the self-regulating phenomena we take for granted on Earth. Once something is in orbit, it will remain there until it collides with something else, or the faintest wisps of atmosphere eventually drag it down.

Orbital debris, though small, can possess incredible amounts of energy. At typical impact speeds of 9,700 m/s [2], a one gram object has the same kinetic energy as a bowling ball traveling at 114 m/s, or over 250 miles per hour. That energy is more than sufficient to severely damage a satellite or manned spacecraft, destroying millions of dollars of hardware, or putting lives in danger. Because space is so large, the odds of impact are low, but are steadily rising with each launch. As with many environmental problems, early prevention will be far cheaper than a later cleanup.

History

From the beginning of the space age, international agreements have been forged to regulate activities and safeguard space for all mankind. The Outer Space Treaty of 1967 requires signatories to “pursue studies of outer space, including the Moon and other celestial bodies, and conduct exploration of them so as to avoid their avoid harmful contamination and also adverse changes in the environment of the Earth resulting from the introduction of extraterrestrial matter and, where necessary, shall adopt appropriate measures for this purpose.” While not specifically mentioning debris, this does form the basis for further international efforts.

The U.S. Space Command currently tracks 13,000 objects in orbit over 10 cm in size, of which 93 percent is debris.[3] There are an estimated 330 million objects larger than 1 mm.[4] While every space launch creates some debris, there have been several notable events that produced large quantities of debris. The French Ariane booster has suffered third stage breakups four times over the life of the program.[5] Countermeasures were initiated in 1993, and no Ariane vehicle launched since then has experienced on-orbit fragmentation.

In the 1960s, American scientists were interested in creating a system to relay radio signals without satellites, in the event of a nuclear conflict. To this end, they launched 480 million copper filaments to a 3700 km orbit as part of Project West Ford in 1963.[6] The chosen orbit was designed to resonate, so local gravitational anomalies would accumulate, leading to a shorter orbital lifetime. Initial projections were that the belt of filaments would reenter within three years due to solar radiation pressure.[7] However, due to a last minute change in the launch schedule and problems with the dispersal device, clumps of filaments formed which can still be observed.[8] These 40,000 clusters with an estimated 750,000 needles have a higher area to mass ratio than predicted, and so solar pressure will be insufficient to cause reentry for many

years.[4] However, because of the height of their orbit, these clusters do not pose a significant threat to other satellites.

In addition to notable creations of space debris, there have also been several documented cases of debris impacts. The Space Shuttle routinely is impacted by microdebris, and has more than 80 windows replaced.[9] The International Space Station maneuvered around the remainder of a Pegasus rocket in 1999.[10] In July 1996, a French microsatellite was hit by debris from an Ariane upper stage, destroying the stabilization boom.[11] Because both the source and target of the collision were launched by the same nation, the question of liability was resolved domestically. When an international collision happens, which it assuredly will, space law may see its first major challenge.[12]

IADC Guidelines

The Inter-Agency Debris Coordination Commission (IADC) is an international forum for governmental space agencies to set joint policy. Mitigation Guidelines were proposed in October 2002, and were introduced at the UN Committee on the Peaceful Uses of Outer Space (COPUOS) in 2003. The guidelines were developed by consensus, and require that members adhere to the following:

- Limit debris released during normal operations
- Minimize the potential for on-orbit breakups by
  - Releasing stored energy (flywheels, propellants, batteries) after mission end
  - Performing failure analysis during operation
  - Avoiding intentional destruction
- Disposing of satellites after mission end by
  - Boosting to a graveyard orbit ~235 km above GEO, or
  - Placing into an orbit which will cause reentry within 25 years

These guidelines are less stringent than those required by NASA and other space agencies, but still represent a major step toward solving the problem of debris. Long term modeling of the space debris population shows that without any regulation, there could be 18,000 objects larger than 10 cm by 2100. With the IADC guidelines in place, there could be as few as 9,000.[13] While this is still above the current figure, it is far preferable to the reference scenario, especially with the increased traffic expected by that date.

Opposition

While the IADC guidelines were developed by consensus, and all the members of that group sit on COPUOS, the regulations have not been enshrined into international law. India and China oppose the guidelines due to their perceived cost, and want them implemented on voluntary basis. Private statements indicate their belief that mitigation guidelines amount to “imperialism” because the United States and Russia were not so careful in the early days of their space programs.

Statements by the Indian and Chinese representatives to COPUOS demonstrate their intransigence.

> "We look forward to finalize and adopt the Space Debris Mitigation Guidelines to be implemented by the Member States on a voluntary basis through their national mechanisms. The Indian delegation considers that the Guidelines will lead to effective preservation of the outer space environment so that all developing countries would be able to explore outer space in future without any constraints."
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> B. N. Suresh to COPUOS, June 8, 2004

> "The Chinese delegation is of the view that, since space debris mitigation requires necessary technology and financial support, whereas space-faring countries are different in their levels of development. Therefore, IADC Space Debris Mitigation Guidelines is a document of a guiding nature which is to be followed by all space agencies in a voluntary manner. In order to create a safe space environment for human peaceful activities in outer space, the China National Space Administration has voluntarily referred to the Space Debris Mitigation Guidelines in defining its space debris mitigation provisions for the national space activities of its space industry.
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> The Chinese delegation believes that, despite the fact that some countries, particularly developing countries, are not technically or financially capable or not fully capable of carrying out space debris mitigation work. However, space debris would create a threat or danger to human activities in outer space."
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> X. Liu to COPUOS, June 8, 2004

Despite their opposition to regulation, India claims to meet these requirements on their GSLV and PSLV launch vehicles.[14] However, the breakup of a PSLV third stage in December 2001, creating 326 trackable pieces of debris, was judged due to a lack of passivation of propellants after orbital delivery.[15]

Similarly, China experienced the failure of Long-March 4 third stage 2000, creating 316 pieces of debris. This was the second breakup in four missions, and occurred after China pledged to adopt countermeasures and attempted passivation.[16]

Another possible source of opposition to debris mitigation guidelines is the U.S. military. Ongoing plans for Kinetic Energy interceptors or ASAT weapons might cause the U.S. to violate more formal international rules.[17] An influential conservative working group, funded by the Heritage Foundation, strongly opposes expanding the international legal framework in space, on the grounds that it will unreasonably constrict American efforts to develop missile defense.[18] While many see these views as outlandish, several members of the group still hold considerable influence in Washington.

The argument that the mitigation guidelines will impose significant cost deserves further scrutiny. Performing failure analysis during design and operation is little more

than good engineering practice, and is something that a responsible satellite operator should do regardless of regulation. The passivation of propellants and other stored energy at mission end incurs no cost, assuming that the mission is truly over. However, due to the high cost of launch, operators often try to prolong the mission in order to turn an appreciable profit. Some satellites near their end of life may be resold to another operator, a transaction which passivation would prevent. These are legitimate concerns, but a good satellite design should allow enough control for passivation after all conceivable operations are complete.

Boosting to a graveyard orbit does incur cost. The fuel and opportunity cost to boost a 1,000 kg satellite from GEO up 235 km could mean $7 million in lost amortization.[19] While this sum is significant, it is not insurmountable. A quote from Edmonton Journal speculates that boosting would cost “hundreds of millions of dollars”[20] in lost revenue, but has no technical basis. The cost of boosting might represent three percent of the total cost of the satellite. Because industry profit margins are between zero and five percent[21], the cost could be reimbursed to satellite operators through tax breaks, insurance, or other incentive mechanisms. The future usefulness of the space environment for commercial, military, and exploration missions would be worth the short term cost of disposal.

Prospects

Although the passage of the IADC guidelines failed at the last several COPUOS meetings, the question remains on the agenda for future conferences. However, the 2006 report of the Scientific and Technical Subcommittee indicated that any future regulations would be voluntary, so as not to impose a significant cost on developing space powers and commercial operators.[22] Because COPUOS functions by consensus, a more formal adoption of guidelines must address Chinese and Indian concerns.

A set of guidelines based on the IADC work, but less technical and more high level, are set to be introduced in the 2007 session of the General Assembly. However, these guidelines are also voluntary, and will only set the basis for national regulations. They also recognize that exceptions may be justified, and explicitly states that it is not binding under international law.[23]

Binding, legally enforceable guidelines are necessary to genuinely start to solve the problem of space debris. Because major space powers already follow these guidelines, the only holdouts are those who wish the guidelines voluntary. Unfortunately, it may take another collision, perhaps with the loss of equipment or life, for serious measures to be accepted by all parties. Until then, the space debris threat will continue to grow.

[1] Douglas Adams, *The Hitchhiker's Guide to the Galaxy*, Pan Books, 1979.
[2] A. Rossi and P. Farinella, "Collision rates and impact velocities for bodies in low Earth orbit", *ESA Journal*, Vol. 16, No. 3, 1992.
[3] Nicholas Johnson, "Monitoring and Controlling Debris in Space," *Scientific American,* Vol, 279, No. 2. August 1998, p 62-67.
[4] Carsten Wiedemann, "Space Debris," Institute for Aerospace Systems, December 2, 2005. http://www.ilr.ing.tu-bs.de/forschung/raumfahrt/spacedebris/en/index.html.
[5] NASA JSC, *History of On-Orbit Satellite Fragmentations*, 13th edition, March 2004, 1991-015C, p 300.
[6] Donald Martin, "Experimental Satellites," *Communication Satellites*, 4th ed, Aerospace Press, 2000. http://www.aero.org/publications/martin/martin-4.html.
[7] John Findlay, "West Ford and the Scientists," *Proceedings of the IEEE*, May 1964, p 455-460.
[8] Richard Goldstein *et al*, "Radar Observations of Space Debris," *Planetary Space Science*, Vol. 46, No. 8, 1998, pp. 1007-1013.
[9] Maia Weinstock, "Orbiting Space Junk Continues to Threaten International Space Station," *Space.com*, September 5, 2000, http://www.space.com/scienceastronomy/planetearth/space_junk_000901.html.
[10] Kenneth Silber, "Space Station Dodges Debris," *Space.com*, October 26, 1999, http://www.space.com/news/spacestation/iss_debris_991026.html.
[11] Surrey Satellite Technology Ltd, "Space Debris Collides with CERISE Microsatellite," August 15, 1996, http://www.ee.surrey.ac.uk/SSC/CSER/UOSAT/press/cerisepr1.html.
[12] Leonard David, "Tossed in Space," *Foreign Policy,* May/June 2003, p 68.
[13] Alessandro Rossi, "Population models of space debris," *Proceedings IAU Colloquim*, No. 197, 2005.
[14] A.S. Ganeshan, "International Meet on Space Debris", *Space India*, January-March 2003, http://www.isro.org/newsletters/spaceindia/janmar2003/webpgs/pg08.htm.
[15] *History of On-Orbit Satellite Fragmentations,* 2001-049D, p 366.
[16] *History of On-Orbit Satellite Fragmentations,* 1999-057C, p 362.
[17] Taylor Dinnerman, "Space Debris: Not Just an American Problem?," TheSpaceReview.com, November 29, 2004. http://www.thespacereview.com/article/279/1.
[18] Robert Pfaltzgraff *et al*, "Independent Working Group on Missile Defense, the Space Relationship and the Twenty-First Century." 2007.
[19] C. Wiedemann, H. Krag, J. Bendisch, H. Sdunnus, "Analysing costs of space debris mitigation methods," *Advances in Space Research*, Vol. 34, p. 1241-1245, 2004.
[20] Andrew Revkin, "Highway patrol: Outer Limits: The final frontier is becoming cluttered with garbage and satellites. Scientists are trying to set some ground rules for controlling pollution and traffic in space," *Edmonton Journal*, source New York Times, March 2 2003, D9.
[21] Peter Selding, "Buyers, Insurers Want Satellite Makers to Take on More Financial Risk," *Space.com*, April 18, 2005, http://www.space.com/spacenews/archive05/Risk_041805.html.
[22] Report of the Scientific and Technical Subcommittee, COPUOS, 43rd Session, March 16, 2006, A/AC.105/869, page 20.
[23] Progress Report of the Working Group on Space Debris, COPUOS, 43rd Session, February 28, 2006, A/AC.105/C.1/L.284.