Oribiting Debris: A Space Environmental Problem

INTRODUCTION

Debris, left in a multitude of orbits about Earth as the result of the exploration and use of the space environment, poses a growing hazard to future space operations. Unless nations reduce the amount of orbital debris they produce each year, future space activities could suffer loss of capability, loss of income, and even loss of life as a result of collisions between spacecraft and debris.

Because of their concerns about the safety of spaceflight, the Senate Committee on Commerce, Science, and Transportation, and the House Committee on Science, Space, and Technology requested an assessment of the future hazard from orbital debris,[1] and an examination of strategies for reducing that threat. This background paper derives primarily from a workshop on orbital debris held at OTA on September 25, 1989. In preparing this paper, OTA also received assistance from other contributors. OTA gathered information from many other sources, including the 1989 U.S. *Report on Orbital Debris*[2] prepared by the Interagency Group (Space), the 1988 European Space Agency (ESA) Report, *Space Debris*,[3] and a workshop convened jointly by OTA and the U.S. Space Foundation in April 1989.[4]

Since the launch of Sputnik 1 by the Soviet Union in 1957, nations and organizations involved in the exploration and exploitation of space have completed over 3,200 launches, which have placed more than 3,800 payloads into orbit around the Earth. About 6,500 artificial objects orbiting Earth, weighing about 2 million kilograms in sum, are now cataloged by the Space Surveillance Network (SSN), operated by the U.S. Space Command (USSPACECOM).[5] However, only 6 percent of the cataloged objects in Earth orbit are functional satellites;[6] the rest fall into the category of "orbital" or "space" debris[7] (figure 1). Moreover, analysts believe that the total orbital debris population is much greater, because orbital debris includes a wide variety of *artificial* objects (table 1), which range in size from a millimeter or smaller to the full bulk of a deactivated satellite or spent rocket stage.

Orbital debris travels in the full range of orbits used by Earth-orbiting satellites (box l). Unlike natural meteoroids, which pass through near-Earth space in a matter of a few minutes as the Earth sweeps through space, orbital debris, depending on its altitude, may continue to orbit Earth for periods as long as centuries.[8] It moves in many different orbits

[1] The House Committee on Science, Space, and Technology held a hearingon July 13, 1988 on the subject of orbital debris. Witnesses included representatives from NASA, DOD, the Department of State, and the Department of Transportation, as well as legal and technical experts from the private sector. Witnesses expressed concern about the potential hazards from orbital debris and the need for technical and policy mechanisms to address those hazards.

[2] National Security Council, *Report on Orbital Debris,* Interagency Group (Space), February 1989.

[3] European Space Agency, *Space Debris* (Paris: European Space Agency, November 1988).

[4] U.S. Congress Office of Technology Assessment and U.S. Space Foundation, Joint Workshop on Space Debris and Its Policy Implications, Proceed*ings of the Fifth National Space Symposium* (Colorado Springs, CO: U.S. Space Foundation, 1989), pp. 1-24.

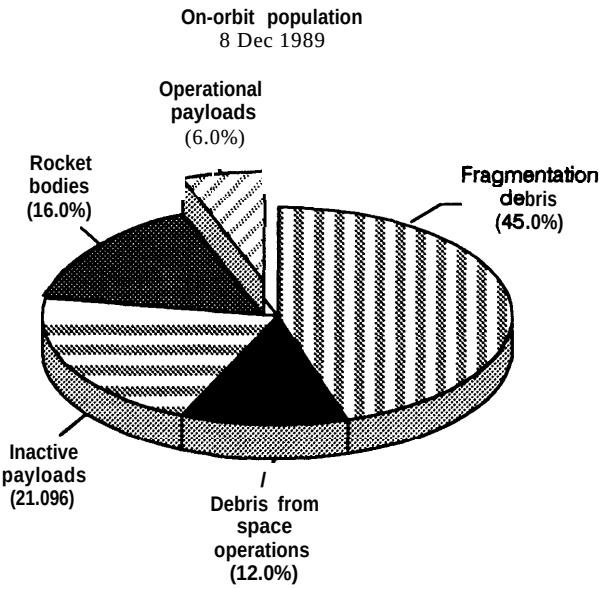
[5] The SSN was earlier operated by the North American Aerospace Defense Command (NORAD). However, in 1988, responsibility for surveillance passed from NORAD to USSPACECOM.

[6] Nicholas L. Johnson and David J. Nauer, *History of On-Orbit Satellite Fragmentations, 4th* ed. (Colorado Springs, CO: Teledyne Brown Engineering, January 1990), NASA Contract NAS 918209.

[7] Both terms are in common use. The term orbital debris will be used throughout this background paper to assist in distinguishing between artifical objects in space, which orbit Earth, and cosmic dust, meteoroids, and other natural objects, which pass by or strike Earth as it travels through the interplanetary medium.

[8] Much debris, however, falls back into the atmosphere within months or years.

Figure 1 -Cataloged On-Orbit Population



SOURCE: Nicholas L Johnson and Davld J. Nauer, *History of On-Orbit Satellite Fragmentatons,* 4th ed. (Colorado Springs: Teledyne Brown Engineering, January 1990), NASA Contract, NAS 18209,

Table 1 -Elements of Orbital Debris

● deactivated Spacecraft
● *spent* rocket stages
● fragments of rockets and spacecraft and their instruments
● paint flakes
● engine exhaust particles
● spacecraft rocket separation devices
● spacecraft coverings
● spent Soviet reactors

SOURCE: Office of Technology Assessment, 1990

Box 1 -Some Categories of Earth Orbits

- ***Low-Earth-Orbit(LEO)-any*** orbit below about 2,000 kilometers (1,250 miles) above Earth's surface,* which correspmds to an orbital period of 127 minutes, or less. Space Station Freedom will reside in LEO at altitudes between 300 and 500 kilometers.
- ***Medium-Earth-Orbit*** (MEO)-orbits between LEO and GSO.
- ***Geosynchrynous Orbit*** (GSO)-orbits at an average altitude of 35,787 kilometers (22,365 miles) in which a satellite has a 24-hr period.
- Geostationary Earth ***Orbit (GEO)-a*** special case of GSO in which a satellite orbits above Earth's Equator at an angular rotation speed equal to the rotation of Earth. It thus appears to remain stationary with respect to a point on the Equator. Positions along the GEO are highly sought for communications satellites because the geostationary vantage point allows one satellite continuous coverage of a large portion of Earth. In addition, GEO satellites can be repositioned along the orbit to change their coverage at reasonable cost.
- ***Supersynchronous Orbit-an*** orbit with a longer period, and greater average altitude than GSO.
- Sun Synchronous Orbit-an orbit synchronized with the sun in such a way that it passes over the Equator the same time each day. Such orbits are therefore highly important for remote sensing satellites that must view Earth's surface at the same time of day on each pass in order to maintain consistent data sets.

* the boundary between LEO and higher orbits is not well defined.

and directions, at velocities ranging from 4 kilometers per second to over 7 kilometers per second, and constitutes a potential hazard to working spacecraft (table 2). In the near-vacuum of outer space, no forces act to slow debris down. Even very small objects, if they have high velocities relative to the objects they hit, may do considerable damage. For example, in 1983, a tiny titanium oxide paint chip, estimated to have been about 0.2 millimeter in diameter, collided with the Shuttle orbiter *Challenger*[9] at very high velocity and damaged a window. Although the damage posed no immediate danger, the window was weakened beyond the allowable safety limits for reflight and was replaced before the orbiter's next launch.

Cataloged objects, some weighing up to several tons, reenter the atmosphere at a rate of two to three per day. Over the past 30 years, some 14,000 trackable objects have fallen to

[9]Nicholas L. Johnson and Darren S. McKnight, *Artificial* Space *Debris* (Malabar, FL: Orbit Books, 1987), p. 4.