Space Junk Grows with Weapons Tests

Tens of thousands of marble-sized bits of trash orbit Earth, each one potentially lethal; new weapons tests promise more of the same

By destroying a live satellite in a weapons test this September, the U.S. Air Force became a willful polluter of space, adding 100 bits of debris to the junk in orbit above Earth (*Science*, 4 October, p. 44). It also added slightly to the chances of a collision between orbiting trash and a working satellite, a growing hazard for all users of space, including the military.

America has often dumped trash in space by accident and indifference, but until recently it did not compound this record with intention. Unlike Russia, it did not smash its own spacecraft in antisatellite (ASAT) tests. Now that has changed. The growing burden of trash will accelerate a phenomenon that may begin forming a man-made meteoroid belt in 10 years, according to researchers at the National Aeronautics and Space Administration (NASA).

At present, more than 5600 man-made objects are tracked in orbit around Earth. Of these, about 72 percent are classed as debris (a category that does not include dead satellites), and of this debris, about 57 percent belongs to the United States. It includes spent rocket stages, ejected satellite shrouds, clamps, exploded fuel tanks, insulation, and odds and ends left by astronauts. The Soviets' share of the debris is about 40 percent. It includes the same kind of junk, but also the finely shattered (and less visible) remains of nine antisatellite explosions from a series of ASAT tests begun in 1968. The last 3 percent of debris was contributed by Britain, the European Space Agency, France, West Germany, India, Japan, and the People's Republic of China.

In addition to these relatively large objects, there are reckoned to be tens of thousands of pieces of untracked debris the size of marbles, and literally billions of paint flakes orbiting Earth. There are also transient bits of frozen sewage from the shuttle.

The ill effects of this junkpile will take time to be noticed. The people who will be affected directly are those who travel in or send equipment to outer space. For them, the debris will add to a growing possibility of a high-speed collision. Even a tiny 0.5-mm metal chip, encountered at the average collision speed in space of 10 kilometers a second, can puncture a space suit, if it hits at the right point, and kill an astronaut. Objects 1 to 10 millimeters across can damage a spacecraft.

This presents obvious risks for the shuttle, especially for the crew members when they are on extra-vehicular tasks. It poses greater risks for the space station and its planned industrial lab to be built in the 1990's. They will be larger than anything launched before, making them more likely to be hit. Trash also creates some unusual hazards for the President's Strategic Defense Initiative, which aims to fill near-Earth space with weapons in the 1990's. Some of the weapons will be "salvage-fused," meaning they will be set to explode if tampered with. The Defense Initiative will add to the problem most significantly just by increasing the number of machines in low orbit.

Any increase in the number of large space objects will raise the risk of collision, NASA astrophysicist Donald Kessler has written. There is already a great deal of trash in space; putting up large targets for it to collide with will produce more. Trash will engender trash. Once a critical density is reached, the pollution will grow at an exponential rate. Natural asteroid belts may have been formed by the same kind of grinding in space, Kessler says. By his calculation, exponential growth of debris could begin dramatically within a century. Some satellites may have been hit by trash already. In 10 years, an artificial asteroid belt may begin to encircle Earth.

Space trash has been growing in the last two decades at varying rates, influenced by the level of solar activity. (During the cyclical period of storms and sunspots from 1979 to 1981, solar pressure drove many objects down to destruction in the atmosphere, including Skylab.) The best way to describe the situation, according to Kessler, is to say the net balance of junk in space is growing by 300 to 500 objects per year, at a time when new launches are running at 100 per year.

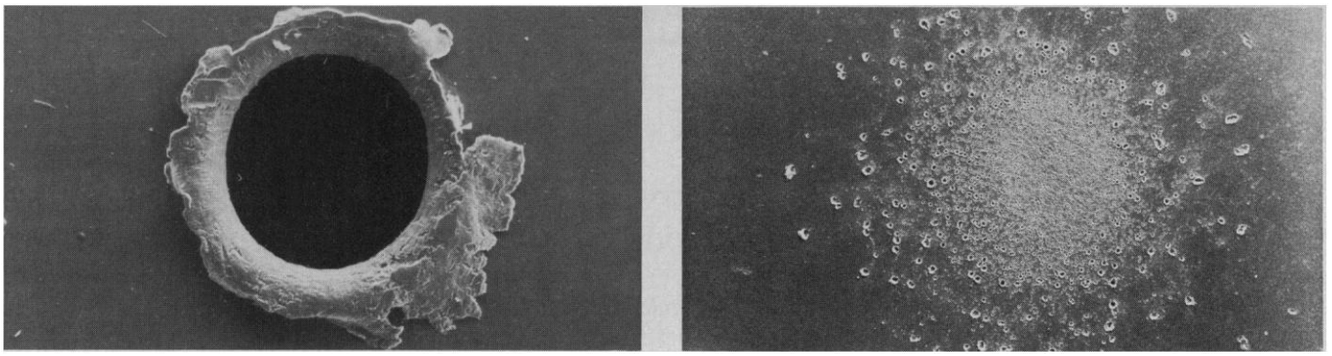
Most users of space see this as a minor problem because "there's a lot of room out there," as one insurance broker put it. Furthermore, junk is concentrated at low altitudes (600 to 1100 km high), not out in the precious geosynchronous orbit (35,800 km) where communications satellites operate. The closer the trash is to Earth, the sooner it will fall back and burn in the atmosphere. So the hazard seems "negligible," in the term used by Gerald Frick of Marsh and McLennan, a satellite insurance broker. It appears to be a mess that will clean itself up.

The notion of space as self-cleaning is misleading, according to Kessler. It understates the time it takes gravity to pull debris out of orbit. A small, marble-like object released in a circular orbit at 500 kilometers would stay aloft for about a year. But if it were released at 800 kilometers, it would stay up for 30 years. And at 1200 kilometers it would remain in space 300 years. Man-made junk has been dumped in this densely polluted area in such quantities, Kessler says, that it is becoming more abundant than natural meteoroids.

No wilderness tract on Earth is as wild as the void where satellites travel, and none shows human intrusions so readily. Space is not protected by environmental laws. Thus, a single event such as the U.S. ASAT test on 13 September can have a great impact. At 4:42 p.m. EDT, a U.S. missile hit an old Air Force satellite called P78–1, on a low polar orbit about 530 kilometers high.

The large pieces are tracked by the radars and cameras of the North American Aerospace Defense Command (NORAD), which can see objects the size of a baseball (10 centimeters across) at distances beyond 500 kilometers. Shattering a satellite generates many more unseen than visible pieces. Those from P78–1 have now joined the estimated 40,000 bits of untracked, marble-sized debris already aloft.

What are the chances that some of this litter could damage a live satellite? Kessler, who directs a 10-year study of debris for NASA in preparation for the space station, says the risk is small but real. His summary of a 1982 workshop at NASA states: "All modelers concluded that the probability that a large structure (approximately 100 meters in diameter) would collide with a currently tracked object in low-Earth orbit is already significant—approximately 0.1 in a 10-year period." If small, untracked objects are considered, the risk grows three to five times larger. The shuttle faces only one chance in a million, per mission, of being hit by a major object because it has smaller dimensions, stays aloft for short periods, and hugs low altitudes where debris quickly falls to Earth.



Insulation on the Solar Max satellite had 160 small craters caused by flying paint chips. Photo shows a 0.6-mm hole (left) in the outer insulation caused by one small chip, followed by ejecta (right) spattered behind the hole. [*Photo courtesy of NASA*]

Many experts, including Kessler, think there is evidence of damage being done right now. They cite examples such as the following:

- In April 1984, the shuttle crew brought back to Earth some malfunctioning electronics boxes on the Solar Max satellite. NASA found the outer surfaces peppered with around 160 small holes created by flying paint chips.
- On its seventh mission in July 1983, the shuttle orbiter Challenger was hit by something that chipped a window. NASA concluded that the damage was done by a tiny (0.2 mm) flake of white paint, possibly the kind used on U.S. Delta rockets. (It was not clearly of Russian origin, as NASA administrator James Beggs once suggested.)
- In July 1981, the Soviet navigation satellite Kosmos 1275 broke up over Alaska in a pattern suggesting it had been hit by debris.
- The Soviet surveillance satellite Kosmos 954, with a nuclear reactor aboard, suddenly depressurized and fell to Earth over northern Canada in January 1978, also in a way that suggested a collision had occurred.
- The European Earth observation satellite, GEOS-2, suffered injury to its solar panels in 1978, apparently when hit by debris.
- PAGEOS, a U.S. balloon satellite, probably was struck by untracked debris and damaged in high orbit in July 1975.

The visible bits of debris are few enough at present that they can be tracked and avoided. Some communications satellites have to make dodging maneuvers on occasion, coming within kilometers of other satellites. And when the shuttle is traveling in space, NORAD uses much of its computer power to scan the shuttle's route for hours in advance, preparing for evasive action if necessary. Kessler says that, according to statistical probabilities, the shuttle should pass within 25 kilometers of a visible object at least once a day.

While big and dangerous objects can be dodged, there is no way to avoid the less-threatening small forms of trash such as paint. Kessler estimates that there are now 10 to 100 billion paint flakes in orbit. It's not clear how they came to be there, but NASA scientists think they may have broken loose from orbiting rocket hulls when the bonding agent in the paint was corroded by atomic oxygen or ultraviolet light.

In addition, NASA has found that second-stage rockets, when fired in deep space to put satellites in exact orbit, emit a particulate exhaust of aluminum oxide (Al_2O_3). When the windows of the Skylab command module were examined, half the pit marks were found to contain this compound. Kessler reports that firing one solid rocket motor in high orbit produces for 2 weeks afterward a cloud of tiny particles that outnumber natural objects of the same size. In fact, this pollution has frustrated several studies of tiny meteoroids, for the data were drowned out by the artificial "noise." This form of debris, although it may be short-lived, can damage optical instruments.

Some remedial suggestions, such as sending up a flying garbage truck, seem impractical. Others make sense intuitively, but may be more risky than doing nothing. For example, at the recent meeting in Geneva of the World Administrative Radio Conference for geostationary orbit matters, Britain urged members to create a standard method for disposal of used satellites. The plan was to have everyone boost old units out of geosynchronous orbit into a higher "junkpile orbit." But the U.S. delegate, Dean Olmstead, insisted that it was too early to adopt such a position, for the risk associated with restarting old spacecraft motors may be greater than leaving the satellites where they are. He persuaded the group to study the issue rather than make recommendations.

The cheapest and simplest way to deal with trash is to take some preventive steps. One successful example of this is the U.S. program of burning to depletion all the fuel that remains in Delta second-stage rockets. A study made by John Gabbard, a former NORAD employee, showed that 15 percent of all the debris in space had been caused by the breakup of these used and abandoned Delta second stages. Fuel tanks appeared to be corroding, leading to the mixing of fuel and spontaneous explosion. At Kessler's urging, NASA investigated and confirmed the problem, and then asked the controlling company to bleed the fuel out of Deltas still in orbit. Since that program began in 1981, there have been no more explosions.

Scientists at various institutions have tried to interest the space-using nations in adopting a formal policy on debris. The American Institute of Aeronautics and Astronautics issued a position paper in July 1981 calling for international action to curb space trashing. In discussing ASAT tests, it said, "Even if such actions are essential to national security, they should be carried out with a clear understanding of the consequences." The AIAA recommended that ASAT test fallout be studied intensively. "In the long term," the paper noted, "the issue must be faced cooperatively by all space users, and international agreements should be drawn up to ban or restrict to low orbit the explosion of satellites."

In the past, NASA officials have tried to interest Soviet space authorities in ideas such as this, with absolutely no success. Now that U.S. ASAT tests have begun, it will be more difficult. And while American military authorities may be sympathetic to NASA's case, they have other, higher priorities at the moment. Responding to questions about the Strategic Defense Initiative, Col. George Hess made only one comment: "The problem created by natural and man-made debris . . . is not trivial." He added that it would be dealt with by contractors who are designing military spacecraft.

Thus it seems possible that the space pollution will grow steadily. It may even accelerate in the 1990's, if the plans for arming outer space are carried to fruition. And the predicted man-made asteroid belt may start to appear within a generation.—**ELIOT MARSHALL**