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INITIAL ANALYSIS OF SPACE DEBRIS HAZARD

Space debris is currently an extremely serious problem for any operations in space, including navigation, communications, surveillance and researches. The constantly increasing amount of debris in space near Earth may render it unavailable for generations. The problem of space debris is analyzed.

Introduction

Ever since the launch of Sputnik, mankind has been propelling objects into Earth's orbit and it's starting to add up. We're not only talking about rocket ships, but hundreds - even thousands - of satellites.

The improved tracking abilities allowed us to "see" the debris and gave the idea of its actual number. More than 21,000 orbital debris larger than 10 cm are [illegible]

exceeds 100 million.

Space debris as it is

There are a lot of different names to call this notion: space debris, orbital debris, space junk, space waste. But what does it actually mean? Orbital debris are all man-made objects in orbit about the Earth which no longer serve a useful purpose.

Space debris encompasses derelict spacecraft and upper stages of launch vehicles, carriers for multiple payloads, debris intentionally released during spacecraft separation from its launch vehicle or during mission operations, debris created as a result of spacecraft or upper stage explosions or collisions, solid rocket motor effluents, and tiny flecks of paint released by thermal stress or small particle impacts.

The higher the altitude, the longer the orbital debris will typically remain in Earth orbit. Debris left in orbits below 600 km normally fall back to Earth within several years. At altitudes of 800 km, the time for orbital decay is often measured in decades. Above 1,000 km, orbital debris will normally continue circling the Earth for a century or more.

In low Earth orbit (below 2,000 km), orbital debris circle the Earth at speeds of 7 to 8 km/s. However, the average impact speed of orbital debris with another space object will be approximately 10 km/s. Consequently, collisions with even a small piece of debris will involve considerable energy [1].

Most orbital debris reside within 2,000 km of the Earth's surface. Within this volume, the amount of debris varies significantly with altitude. The greatest concentrations of debris are found near 750-800 km. The dispersion of space junk can be seen on fig 1.

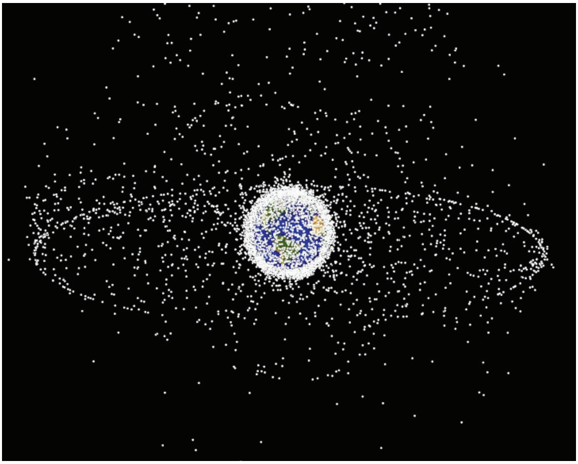

Fig. 1. Space debris populations seen from outside geosynchronous orbit

Why do we fear space debris

The hazard to space operations from debris is a function of the nature of those operations and the orbital region in which they take place. The orbital region is important because the debris flux encountered by a spacecraft varies greatly with orbital altitude and, to a lesser extent, orbital inclination. The nature of the operations is a factor because the same piece of debris that could cause serious damage to one type of spacecraft might do little harm to a spacecraft with a different configuration or orbital attitude.

Operational spacecraft are struck by very small debris (and micrometeoroids) routinely with little or no effect. Debris shields can also protect spacecraft components from particles as large as 1 cm in diameter. The probability of two large objects (> 10 cm in diameter) accidentally colliding is very low. The worst such incident occurred on 10 February 2009 when an operational U.S. Iridium satellite and a derelict Russian Cosmos satellite collided.

Kessler syndrome

The Kessler Syndrome, proposed in 1978 by a former scientist from NASA, Donald J. Kessler, is a scenario in which the density of objects in Low Earth Orbit (LEO) is high enough that a single collision between two objects could cause a cascade – each collision generating space debris which increases the likelihood of further collisions. Which means that there's nowadays so much junk in space that one collision could result in a multitude of others. That in turn could lead to debris being knocked off course and that could be directed to earth.

Every satellite, space probe, and manned mission has the potential to create or become space debris. As the number of satellites in orbit around the earth grows and old satellites become obsolete, the risk of a cascading Kessler syndrome becomes ever greater [3].

Protection against space debris

Orbital debris protection involves conducting hypervelocity impact measurements to assess the risk presented by orbital debris to operating spacecraft and developing new materials and new designs to provide better protection from the environment with less weight penalty. The data from this work provides the link between the environment defined by the models and the risk presented by that environment to operating spacecraft and provides recommendations on design and operations procedures to reduce the risk as required.

Spacecraft shielding is designed to withstand a majority of the micrometeoroid and orbital debris (MMOD) particles that can impact a spacecraft, thus reducing the likelihood of serious damage to the vehicle and/or crew. Shielding is one part of an overall strategy to reduce impact risk that can also include collision warning and avoidance. Although it is not possible to eliminate all impact risk, shields are designed to meet or exceed probability-based protection limits.

Spacecraft shielding for Earth-orbiting satellites must protect against both the natural meteoroid and human made orbital debris which have very different velocity regimes. Orbital debris impact velocities in LEO have an average velocity of about 11 km/sec, concentrating an enormous amount of kinetic energy at the point of impact. Meteoroids have even higher velocities, averaging about 20 km/s and reaching velocities as high as 70 km/s.

One way to shield against MMOD impacts is to increase the thickness of the spacecraft wall so that the wall remains intact after the impact. However, this significantly increases the weight of the spacecraft which must be launched into space. A smarter method is to use the “Whipple Shield” concept.

In the 1940s, Fred Whipple proposed a meteoroid shield for spacecraft, called the Whipple shield in recognition of his contribution. The Whipple shield consists of a thin, aluminum “sacrificial” wall mounted at a distance from a rear wall. The function of the first sheet or “BUMPER” is to break up the projectile into a cloud of material containing both projectile and BUMPER debris. This cloud expands while moving across the standoff, resulting in the impactor momentum being distributed over a wide area of the rear wall. It can be seen on fig 2. The back sheet must be thick enough to withstand the blast loading from the debris cloud and any solid fragments that remain. For most conditions, a Whipple shield results in a significant weight reduction over a single plate, which must be strong enough to receive the projectile kinetic energy in a localized area.

Collision avoidance is an important, but limited, tool for protecting spacecraft in orbit. In 2009, the US Space Surveillance Network was tracking ~19,000 objects larger than 5-10 cm in diameter. Of those objects, less than 5% are operational satellites capable of maneuvering. In addition, maneuverable spacecraft can only avoid the other 19,000 tracked objects, a small fraction of the estimated 500,000 hazardous orbital debris larger than 1 cm.

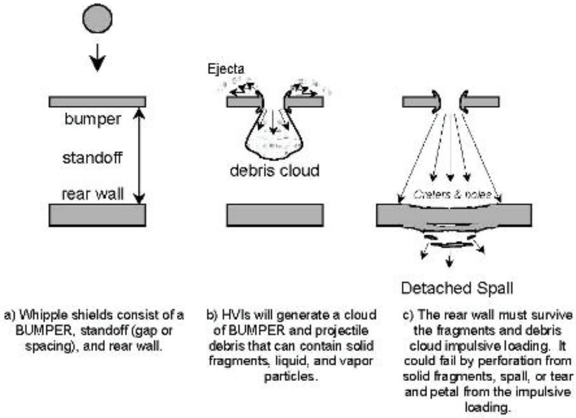

Fig. 2 Whipple shield scheme

Regardless of the limitations, many high value satellites choose to perform conjunction analyses and, if necessary, to execute collision avoidance maneuvers. The NASA Johnson Space Center developed and has been using collision avoidance procedures for many years to support Space Shuttle missions and the International Space Station. Later, the NASA Goddard Space Flight Center developed a conjunction assessment and collision avoidance process for robotic spacecraft, e.g., NASA's Earth Observation System (EOS) in low Earth orbit and the Tracking and Data Relay Satellite System (TDRSS) in geosynchronous orbit.

Conclusion

Space debris has become an essential and serious problem for the development of current space programs and if left as it is will soon make the space inaccessible, destroying a lot of things, which have become common nowadays, including satellite internet, satellite navigation and communication, which are available for civil users.

A way to destroy or recycle this debris is required, but nowadays there are no realistic approaches to it. Therefore it is an actual scientific task to resolve the space debris problem.

References

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