Air and Space this Week

Item of the Week

Space Debris

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A few days ago, I was channel surfing and came across a travelogue showing a busy traffic circle in downtown Rome. Vehicles of all types were crowded in tightly. I wondered how so many could pass through such a small area without collision. Of course, traffic volume greatly impeded traffic flow, even without collisions, and, had a collision occurred, traffic flow would have greatly diminished, or ceased altogether.

I was reminded of part of my doctoral research, on the movement of surficial material by the wind on Venus, Earth, and Mars. As wind speed increases, sand-sized particles will begin being lifted off the surface, to sail with the wind in a hopping motion. Each time they hit the surface, the impact triggers the motion of other sand grains. Until the wind speed gets really high. Then there are so many sand grains in the wind that collisions become commonplace. The flow of sand, like Roman traffic, is impeded by other sand in motion getting in the way.

Later that day, with those mental images in mind, I saw the news item about the possible impact of two large pieces of Space debris. Concern ran high, because such a collision would spread a lot of smaller pieces of debris, shotgun-style, into an increasingly-crowded space where satellites in Low Earth Orbit (LEO) are congregated.

NASA and the public have been concerned about the hazards posed by the impact of celestial bodies, such as meteoroids, comets, and asteroids. Certainly, such impacts have played a profound role in the evolution of life on Earth; just ask the dinosaurs. Oh, you can't. Getting hit by a piece of re-entered Space debris now actually poses a greater risk (albeit tiny) to you than getting hit by a natural meteorite. Space debris is much too small to cause significant climate damage.

A much larger and potentially more-damaging danger is the impact of valuable spacecraft with Space debris, not naturally-occurring interplanetary material but rather the detritus of earlier Human Space utilization. NASA is concerned about that, too, as are the military and commercial users of LEO. Hollywood's concerned, too, as witnessed by the recent film, *Gravity*. This is an increasingly-important concern, especially as commercial operators are launching large constellations of communications satellites into LEO.

Scientists and engineers recognized the danger of micrometeoroid impact on spacecraft very early in the Space Age. For example, Fred Whipple, known for being the initial proponent of the now-accepted "dirty snowball" model of comets, envisioned the use of a thin aluminum outer skin for a spacecraft, one that did not add an unacceptable amount of weight, but thick

enough to stop or disperse impact damage caused by the potentially-numerous, but very small, naturally-occurring micrometeoroids. Whipple recognized the problem and a potential solution as early as 1947. Whipple's idea is still in use today; such an outer skin is now termed a "Whipple Shield" or "Whipple Bumper." [Insert your Charmin joke here.] A Whipple Shield was used on the *STARDUST* spacecraft, a mission designed to collect debris shed from Comet Wild 2, and such shielding is used on the *ISS* and other satellites, including military ones.

[Didja Know that Fred Whipple played an important role in the development of "chaff," aluminum strips dropped from aircraft to jam German radars in WWII?]

Concern regarding micrometeoroid impact, in both LEO and near the Moon, spurred NASA to fly experiment packages to assess the danger, on the *Saturn SA-8/Pegasus* spacecraft in 1965, *Lunar Orbiter 4* in 1967, and the *Long-Duration Exposure Facility*, flown from 1984-1990. This *LDEF* website also has info about microparticle impacts in general.

Micrometeoroids do pose a big hazard to operations in LEO. But Space debris has passed naturally-occurring impacts in terms of overall danger. The problem is two-fold. Orbital impacts are usually very high energy affairs, completely destroying the impacting craft. But such collisions don't simply punch a clean hole, they obliterate the spacecraft into a myriad of pieces, ***each of which*** become deadly projectiles capable of destroying another satellite.

If this reminds you of a nuclear fission chain reaction, it should. As LEO gets more and more crowded, it becomes more and more vulnerable to an impact cascade. One big collision could produce enough debris that many additional collisions would quickly result, making that much more debris, and so on, a particularly vicious vicious circle. Such an event could render LEO unusable, destroying a resource that many modern civilian and military organizations now rely upon.

Can you imagine a world without high-speed Internet connections, or one where all financial transactions have to be done with snail mail? Military services have analyzed the situation, and have recognized the peril. A rogue country, or terrorist organization, could detonate an explosive in LEO that would take down the whole system.

Sound farfetched?

At least one operational satellite has already been destroyed by collision with a piece of Space debris. On February 19, 2009, *Iridium 33*, a functioning spacecraft of the Iridium communication satellite constellation, collided with a retired Russian *Kosmos 2251*, destroying both, littering the LEO zone with dangerous debris. *Kosmos 2251* was one of the Strela ("Arrow") constellation of satellites, used for military messages, with an operational lifetime of a few months to a few years. (Ironically, *Iridium 33* was also launched from the Baikonur Cosmodrome in Kazakhstan, on September 14, 1997.)

The USA, Russia, and others have conducted tests on how LEO might be vulnerable or how it might be denied to al. On September 13, 1985, the US live-tested an anti-satellite weapon, exploding a still-operating solar observatory, *P78-1*, using an ASM-135 ASAT missile launched from an F-15. The test was successful, and the debris it generated increased the hazards in LEO

significantly. NASA had only a two-month warning of the test, but still managed to model the effects of the impact/explosion, which showed that the debris would have a decade(s)-long residence time in LEO, which would force NASA to enhance debris shielding on the *International Space Station*. Earlier, NASA had worked with the Air Force to plan a test that would not produce dangerous debris, but Congress was poised to restrict such testing, knowing the dangers. The Air Force bulled ahead anyway, before any such restrictions could be imposed, as they were the month following the test, after the Air Force had already launched two more test targets. NASA worked with DoD to monitor the debris, but most of it was a non-reflective material almost impossible to see.

The ASM-135 program was cancelled in 1988, after $5.3 billion had been expended. One of the missiles that had been built ended up on display at NASM, another is on display at the USAF Museum in Dayton.

Russia also has an ASAT program, but so far has done testing without destroying a live target. Their most recent test was on April 15, 2020.

China has been working on ASAT technology for decades, and they did conduct a live-fire test on January 11, 2007. A Chinese weather satellite was destroyed by a kinetic kill vehicle traveling in the opposite direction at 8 km/sec. One of their manned spacecraft released a micro-satellite in September, 2008, that flew near the *ISS*, demonstrating that they had the capability of shooting the *ISS* down.

India has also gotten into the act, destroying one of their LEO satellites with a kinetic kill vehicle on March 27, 2019. They did make an effort to cause the resulting debris to have orbits that would decay quickly, but there was a lot of debris.

Military testing is not the only culprit. Moribund satellites, boosters, and other Space gear pose a significant hazard, too. On numerous occasions, a Space Shuttle returned to Earth with noticeable impact damage to its windows; one was so impaired that it had to be replaced. Inspection showed that the impactor was a small fleck of paint, but it had enough kinetic energy to threaten the window….

One of the most dangerous potential sources of debris now aloft is ESA's bus-sized *Envisat*, originally designed to monitor Earth weather. It has been hit several times by small pieces of debris, causing it to shed fragments, but so far, it has not been hit by anything big enough to obliterate it, although there was at least one near-hit. In January, 2010, *Envisat* almost collided with a 1500 kg upper stage of a Chinese rocket. Envisat was still in operation at that time, and its controllers managed to dodge the collision using the satellite's thrusters. Dodging is not an option today, with *Envisat* completely inert. *Envisat* is big enough to be observed from your backyard easily; see the heavens-above website, put in your location, use the left-hand menu to select *Envisat*, and you'll see when and where it would be visible from your home.

The *ISS* orbits in the danger zone. NASA has had to maneuver the *ISS* about 40 times to avoid detected Space debris, a difficult and time-consuming task. One of the dodges kept the *ISS* from being hit by one of the pieces of debris from the Chinese ASAT test. The most recent was

September 22 of this year, when an unidentified piece of debris was not detected until collision was imminent. The three astronauts aboard had to button-up the *ISS* and retire to its Soyuz lifeboat, knowing full well that an object of the size and speed bearing down on them would annihilate the *ISS*. Read more about this frightening episode in the September 28 *New Yorker* magazine, or at: https://www.newyorker.com/magazine/2020/09/28/the-elusive-peril-of-space-junk.

The danger posed by Space debris in LEO, and the prospects for a runaway debris cascade, has been known for some time. In fact, a study by Donald Kessler back in 1978 outlined the parameters of the problem, and the likelihood that a impact debris cascade could render LEO unusable for decades, a situation that has come to be known as "The Kessler Syndrome;" see: http://www.spacesafetymagazine.com/space-debris/kessler-syndrome.

All is not lost (yet) however, there are some interesting ideas coming up about how the Space debris threat might be reduced, but efforts must be made now before a full-scale Kessler Syndrome develops. The U.S. had been a pioneer in the development of ideas to deal with Space debris, but NASA has recently cancelled our program in order to focus fully on a manned return to the Moon.

DOCENTS: Since the September 22 near-hit of the *ISS* has been in the news a lot of late, you will likely get questions about it, especially at the Udvar-Hazy Center, since it is actually open now and has an ASAT on display. I'd recommend the New Yorker and Space Safety Magazine articles to give you the background you need (if you don't already know this stuff) to answer any reasonable question posed.

For more info, see the above-mentioned resources and/or visit NASA's Orbital Debris Program Office: https://orbitaldebris.jsc.nasa.gov.

http://www.spacesafetymagazine.com/space-debris/kessler-syndrome

https://www.newyorker.com/magazine/2020/09/28/the-elusive-peril-of-space-junk

https://skyandtelescope.org/astronomy-news/distant-space-debris-threat-satellite

NOTE: I used to report Iridium Flare predictions in A+StW, based on data in the Heavens-Above website. Recall that such Flares are caused by sunlight glinting off one of the Iridium satellites, and could be as bright as magnitude -8. The Iridium satellites have been re-purposed, and no longer have tightly-controlled attitude, making prediction of Flares very difficult to the point that H-A stopped keeping track of them. However, Iridium satellites were not the only ones capable of causing a Flare. During the course of researching the Space debris topic, I ran across an interesting website I'd like to share with you. It's called "SATFLARE," and it tracks a lot of satellites, a lot of Space debris, and it does list Flare predictions. Check it out at: http://www.satflare.com/home.asp!

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