Rapid Space Debris Cleanup

Problem Statement

On November 15, 2021, Russia tested an antisatellite weapon on their defunct 2,000 kilogram Cosmos-1408 satellite. Its orbit, at 485 kilometers, it passed near the International Space Station's orbit. The resulting debris cloud, consisting of hundreds of thousands of pieces of debris, all but a few thousand too small to be individually tracked, threatened the ISS enough that all crew aboard, including two Russian cosmonauts, had to take shelter.

The use of anti-satellite weaponry has been an unspoken (or under spoken) fear for the United States space community. Unfortunately, these fears have proven to be well-founded. The cost of doing business in Low Earth Orbit has just become more expensive and dangerous because of Russia's belligerence. Private sector entrepreneurs putting their capital to work in LEO are now that much more apprehensive. However, industry can also help assuage that concern by developing effective countermeasures.

International condemnation of Russia's move was both swift and pointless. That Russia's military would put their own citizens in harm's way suggests that incidents like this are likely to happen again. Moreover, elements of the Chinese military have demonstrated similar disregard for international norms, and in some cases their own citizens.

These types of dangerous and reckless actions require us to quickly implement a solution to this problem. These clouds of debris contain too many pieces for solutions that deal with one piece at a time to be practical, at least by themselves. Less than one percent of the debris is large enough to be individually tracked. If there were merely one hundred thousand pieces, taking out one piece an hour would take more than a decade to clean up – and there are multiple hundreds of thousands.

Fortunately, pieces too small to be tracked are individually lightweight. The problem is akin to sweeping up a floating cloud – granted, a cloud consisting of pieces moving very quickly. Most of these small pieces should come out of orbit within a year or so, though it would be preferable to remove them faster.

As of November 9, 2021, according to the European Space Agency, there were about 36,500 pieces of space debris larger than 10 centimeters across, 1 million pieces between 1 and 10 centimeters across, and more than 300 million pieces smaller than 1 centimeter across. Assuming the November 15 incident's debris is similarly distributed, there are only a few dozen pieces larger than 10 centimeters across.

Industry Response

The mass distribution suggests a two-tier response. Spacecraft that can dock with and deorbit large intact objects in space are different from spacecraft meant to sweep up large numbers of small particles. This analysis does not address all space debris, but rather an immediate response to specific debris-generating events when most of the resulting fragments are still close together.

CubeCab is developing a rapid-response launch capability for small payloads: 5 kg to 400 km Sun-Synchronous Orbit, or slightly higher for more equatorial orbits such as Cosmos-1408's. CubeCab's Cab-3A is an air launched, all solid fuel rocket that can be readied and launched in one business day in an emergency. CubeCab argues the sudden existence of a cloud of debris threatening the ISS counts as an emergency sufficient for the Federal Aviation Administration to waive the usual paperwork requirements and grant emergency launch authorization, if there was something to launch that could effectively respond to such a situation. Thus, we propose a solution: a series of 3U CubeSats, each about 5 kg, launched with a one business day turnaround directly to the new debris' location.

First, we would target two or three small radar satellites, with propulsion to maneuver on orbit. While a CubeSat is nowhere near as large as the most famous ground radar dishes, a CubeSat can make up for this by getting much closer: between the Cab-3A launch (to an orbit matching the destroyed object's) and an initial approach by the satellites (matching velocity with the core of the debris cloud), getting to within 1 kilometer is readily possible, and approach to within hundreds or even tens of meters of the near edge of the debris cloud is feasible (the main danger being getting too close, but the satellite will detect the closest objects as it approaches). These radar satellites are simple and low-cost enough that they could be built ahead of time and stored against need.

Once these satellites are in place and giving better tracking data than ground-based radars (which have difficulty tracking objects less than one centimeter across), two more types of satellites can be launched. Both are likewise CubeSats with propulsion, manually guided from the ground. Both can be assembled from commodity components, not necessarily specific to space, which are likely to be in supply within the United States. Assembly would begin while the radar satellites are being launched, and they can be ready for launch within a few days.

One type of satellite addresses the few dozen large pieces. It has a camera to visually acquire the pieces, a small gripper to attach to them, and extra fuel to substantially change the pieces' orbits so they will reenter the Earth's atmosphere. The large pieces may also be moved through denser parts of the debris field, to transfer their momentum to smaller pieces (preferably at angles that adjust the smaller pieces' orbits to pass through denser parts of the atmosphere) to assist in deorbiting. Once a piece is on a deorbit trajectory, the satellite can let go and find another.

The other type of satellite can be summarized as "space bulldozer." Its main feature is a thin, lightweight but structurally strong panel that unfolds to cover a large area. This satellite drives the panel through the cloud, picking up small pieces and clearing out a volume of space. Multiple satellites can sweep away most to all of the debris cloud, making multiple passes if they do not collect enough debris at first. These satellites risk breaking up if they run into larger pieces of debris, thus the need for the gripper satellite. It is best to use this type of satellite soon after the incident, while the smaller debris is still concentrated near the orbital slot where the debris generating incident occurred.

Conclusion

More incidents like this are going to happen. Industry, working with government, can and should develop appropriate countermeasures. Rapid response satellites are a newly available capability, which can neutralize the impact and safeguard American assets in orbit.

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