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European Satellite Burns Up for Science › ESA researchers pioneering re-entry science chase real-world data to the edge of space

BY LUCAS LAURSEN 10 SEP 2024

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On 8 September, the first of four satellites that make up ESA's Cluster mission reentered Earth's atmosphere over the South Pacific Ocean Uninhabited Area. DAVID DUCROSS/ESA

Just how hot was that salsa? A European Space Agency (ESA) aircraft embarked on a mission on Sunday, 8 September, to answer this very question. The agency's observational airplane—taking off from Easter Island, Chile—was geared up to collect data on a 24-year-old Earth observation satellite called Salsa as it burned up during atmospheric re-entry. The researchers wanted to know if Salsa would disintegrate completely or if it would instead take a long, slow tumble through the thickening air, with still unburnt pieces surviving the re-entry to splash into the ocean or make landfall somewhere.

As of press time, the team is still analyzing its images and streams of instrument output from Sunday's re-entry. But they do at least report success in gathering the data. "With the knowledge gained, ESA's Space Debris team hope to improve current prediction models," a Monday blog post from the researchers stated, "As well as learn more about how a satellite burns up."

ESA's mission was equipped with optical telescopes to track Salsa's path (or paths, if it broke up) and spectrographs, to characterize the temperatures at which it burned, and, possibly, which components burned when.

Re-Entry Science: Fact and Fiction

In a report to Congress this past fall, the U.S. Federal Aviation Administration warned satellite re-entry debris may make landfall on Earth more often as low-earth orbit satellite constellations today rapidly grow in size.

Most companies that launch and control satellites now rely on a relatively recent and rather thinly-veiled regulatory fiction: that we know where the craft are going to land long in advance of their re-entry. That is true enough for crewed spacecraft, which carry sufficient fuel and heat shields that allow for precise re-entry burns and predictable re-entry trajectories. Older satellites, such as Salsa, however, do not always still have both working communications and enough fuel to conduct a targeted re-entry burn. And even satellites launched under stricter, more recent rules—ones that might ensure sufficient re-entry fuel remaining in a mission—nevertheless could still surprise re-entry trackers. Oddly-shaped components on a satellite, for instance, can burn up unevenly and affect the satellite debris's trajectory as it hurtles through the upper atmosphere.

"Many of the requirements for durability in an unforgiving environment conflict with re-entry requirements," says space debris analyst Stijn Lemmens of the ESA's Space Debris Office, in Darmstadt, Germany. That is, durable equipment is less likely to break down predictably on re-entry. Yet the number of objects in orbit is growing fast, with lower orbits and shorter lifetimes meaning there is more need than ever for ensuring that remeaning there is more need than ever for ensuring that re-entering spacecraft won't harm anyone on Earth's surface. Indeed, ESA launched what they called a "Zero Debris Charter" in 2022 with the goal of getting space agencies and companies to design safe end-of-life plans for their spacecraft.

Researchers are using plasma wind tunnels to explore how spacecraft will disintegrate upon re-entry to arm future spacecraft designers with the information they need to design predictable breakups. Plasma wind tunnels replicate the conditions spacecraft encounter on re-entry—with speeds up to 12 times the speed of sound and temperatures in the several thousand degrees Kelvin range, all which causes the upper atmosphere to become increasingly electrically conductive.

NASA, ESA, and several private companies offer software that predicts space debris trajectories. And according to a March paper in the *Journal of Space Safety Engineering* that Lemmens co-authored, the science behind the software could still stand to be improved on. For example, the researchers note, engineers could design outer structures on satellites, such as solar panels, to break off early in the process to expose the core of the spacecraft to even heating, ensuring that most or all of it will be vaporized before it hits the Earth's surface.

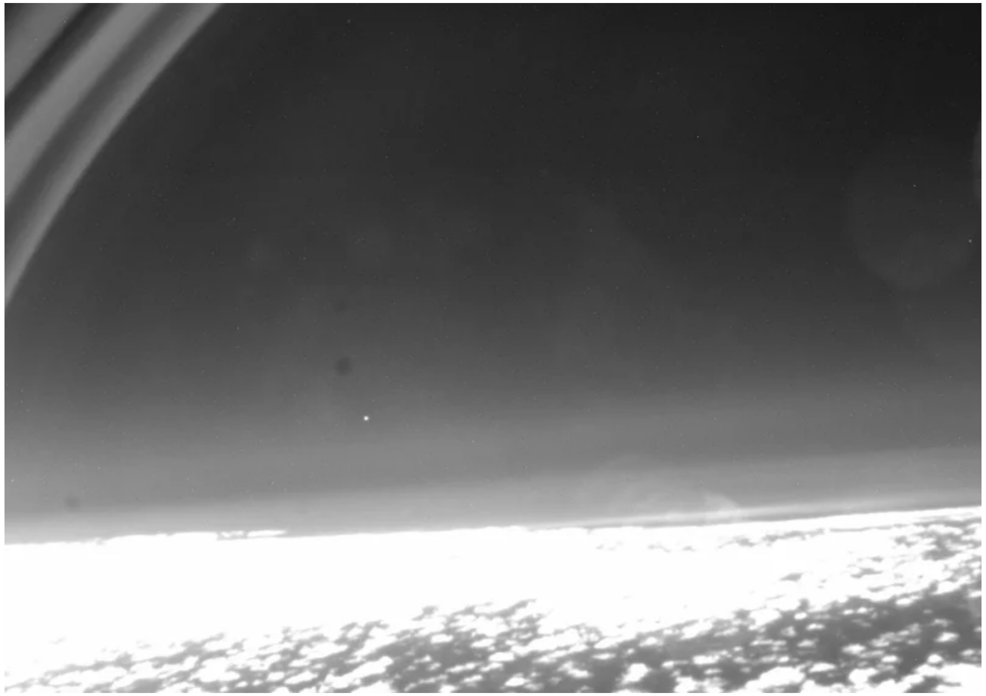
However, to arrive at conclusions as the above, more real-world data is still needed on how different materials—and differently

shaped materials—respond to re-entry conditions.

ROSIE to the Rescue

Enter the ROSIE mission, ESA's latest attempt to get a moving picture, albeit a brief one, lasting perhaps one minute, of how satellites re-enter the atmosphere. ROSIE used several types of cameras to watch Salsa, providing a stream of data that researchers will use to test their computer models for spacecraft breakups. Yet getting close enough to record useful data was no guarantee of success, given how the satellite could change its final trajectory in unpredictable ways. By Saturday, 7 Sept., ESA had narrowed the satellite's re-entry window to about four minutes, and Lemmens said before the mission. "We have about one minute to get it right."

Later, ESA managed to restore communications and conduct a de-orbiting burn that helped to narrow down the predicted re-entry window from about four minutes to about 8 seconds. As it turned out, the satellite re-entered close enough to its predicted path that the ROSIE observers obtained imagery of its burning up, albeit with the edge of a plane window intruding into the frame.



A European Space Agency satellite burned up as it re-entered the Earth's atmosphere on 8 September, and ESA scientists were on hand to study the re-entry in detail. RANJITH RAVICHANDRAN AND GERARD ARMSTRONG/ESA.

NASA and ESA have conducted re-entry observation missions starting in the 1970s, using a mix of visual, radar and spectroscopic tools. NASA also installed recorders in several space station cargo shuttles. However, many of those observations were focused on combat situations—such as ballistic missiles and decoys—or unusual spacecraft such as the Russian Mir space station that offer limited lessons for today's fast-growing constellation of low Earth orbit, short design life satellites.

Salsa's original remit was observing the Earth's magnetic field, but its more recent operators have demonstrated their ability to improvise new plans—including modifying its de-orbiting to accommodate the ROSIE mission. ESA researchers are also expected to repeat Sunday's observations with Salsa's three sister satellites—in 2025 and 2026. Of course, the best data is always from as close as possible to the source. That is why ESA is also preparing a satellite equipped with a hardened device like commercial aircraft's so-called black boxes, intended to record its own fiery demise. The agency plans to launch that mission, DRACO, in 2027.