Why do Satellites Fail?

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The large meteoroid that struck Russia last week is just one of the factors in space that cause satellites to fail. Sigrid Close, a Stanford Assistant Professor of Aeronautics and Astronautics, is proving that the effects of "space dust" are a more likely cause.

New research by Stanford [1] Aeronautics and Astronautics assistant professor Sigrid Close [2] suggests she's on track to solve a mystery that has long bedeviled space exploration: Why do satellites fail?

In the popular imagination, satellites are imperiled by impacts from 'space junk' – particles of man-made debris the size of a pea (or greater) that litter the Earth's upper atmosphere – or by large meteoroids like the one that exploded spectacularly [3] over Chelyabinsk, Russia last week.

But although such impacts are a serious concern, most satellites that have 'died' in space haven't been knocked out by them. Something else has killed them.

The likely culprit, it turns out, is material so tiny its nickname is 'space dust.'

These natural, micro-meteoroids are not directly causing satellites harm. When they hit an object in space, however, they are travelling so fast that they turn into a quasi-neutral gas of ions and electrons known as plasma. That plasma, Close theorizes, has the potential to create a radio signal that can damage, and even completely shut down, the satellites they hit. The signal is an electromagnetic pulse, or EMP – similar in concept but not in size to what is generated by nuclear detonations. (Tellingly, a massive EMP knocked out cell phones when the Chelyabinsk meteoroid hit."

"Spacecraft transmit a radio signal, so they can receive one that might potentially disable them," Close notes. "So our question was: do these plasmas emit radio signals, and if so, at what frequencies and with what power?"

Now, through experiments she's led at the Max Planck Institute for Nuclear Physics [4] in Germany, Close has proof that particles that mimic space dust can indeed cause trouble.

“We shot femtogram (10-15)-sized dust particles at targets resembling satellites at speeds of 60 kilometers per second,” she explains. “We found that when these particles hit, they create a plasma or quasi-neutral gas of ions and electrons, and that plasma can then emit in the radio frequency range.”

Next Up: Experiments in Space

These plasma-induced bursts of energy could explain mysteries like the European Space Agency’s loss of its Olympus [5] communication satellite in 1993, Close believes.

“Olympus failed during the peak of a meteor shower, but they never detected a momentum transfer, which means whatever hit it wasn’t big enough to be detected mechanically,” she recalls. “And yet this multi-million dollar spacecraft was effectively taken out.”

Many other satellites have also failed electronically rather than mechanically. If Close is right, her experiments point to design modifications that might lessen the damage that space dust inflicts. How the satellite is oriented in space, whether it is being heated or cooled at the time and whether it is positively or negatively charged, all appear to make a difference to whether a plasma-induced radio signal actually causes damage.

“Spacecraft are being hit all the time by these particles,” notes Close. “So we feel like we found a smoking gun here in the sense of explaining why this doesn't always happen. And once we know what's going on, there are solutions we could implement to save billions and billions of dollars."

Her next step will be to show that these effects also occur in space. To that end Close is working with Dr. James Smith and Dr. Henry Garrett of NASA’s Jet Propulsion Laboratory [6] to design an experiment that could be anchored to the International Space Station.

“The idea is to try and get hit as much as possible!” Close jokes.

Meteors Not Missiles

Close’s interest in astronautics began with a childhood love of shooting stars. By the time she was born, however, these weren’t just objects of wonder.

“Larger meteoroids look remarkably like missiles when they come into the atmosphere,” she says. “That’s why scientists started looking at them more carefully back in the 1960s, because it was hard to tell the difference between a big rock entering our atmosphere versus someone trying to shoot us.”

Space agencies’ focus has since switched to the threat posed by meteoroids themselves.

A second research project of Close’s, for which she’s received an NSF CAREER

Award for outstanding young teacher-scholars, uses ground-based radar to spot meteoroid-created atmospheric plasmas. By mapping the location, size and density of these plasmas, she's able to deduce the size and locations of the particles causing them – and thus better understand the scope of what's hitting Earth, how fast it's coming at us and where in the universe it actually originates.

In a related investigation, Close and three colleagues in her department are working on an international research effort to model how space debris of all kinds gets produced and then changes over time. The project is funded by the Center of Excellence for Commercial Space Transportation at the U.S. Federal Aviation Administration , which, as space flight becomes more commercialized, could take on a responsibility for safety similar to the one it holds for regular commercial flight today.

Close has also received NSF and U.S. Navy funding to research the connection between meteoroids, plasma and lightning to understand how meteoroids and other phenomena that create atmospheric plasmas might cause interruptions to satellite communications, and then to help ameliorate these interruptions. Another, newer project, tackles the problem of the communications blackouts that bedevil spacecraft when they re-enter the Earth's atmosphere at hypersonic speeds.

Near-Earth Expertise

Beyond her research around meteoroids, Close is the Americas leader of QB50 [7] – a multi-national project to build a network of 50 small satellites to better understand the ionosphere, which lies some 300 km above the Earth's surface. Separately, she's exploring how to make electric plasma propulsion rockets more efficient for space travel.

Her lab is also researching black box technology for spacecraft. "We don't have an all-inclusive set of sensors on spacecraft that looks at everything that the space environment can do to them," she explains. She hopes the data from those boxes could be used to avoid these problems.

"If we're going to eventually send people to Mars, we need to learn about these phenomena, and no one has really been looking at them comprehensively until now."

A Passion for Science Education

Close herself once dreamed of being an astronaut. Now the mother of two young girls, she is not so eager to fly into space. But she remains passionate about sharing her enthusiasm for space science at the university level and beyond.

To that end Close regularly helps out with NASA outreach events and was one of the four main hosts for National Geographic's Known Universe TV series.

Next up, she's slated to host a multi-part series produced by Worldview Pictures about unresolved mysteries in astronomy and astronautics. The working title suits a researcher dedicated to solving the astronautic mysteries that nature throws at us—Sigrid Close: Space Investigator.

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For more information visit engineering.stanford.edu [1].

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