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TAMING DEAD SATELLITES

Europe's Envisat is one of the large defunct spacecraft in low-Earth orbit that the Airbus Detumbler could prepare for deorbiting. Contact with the satellite, shown here in an illustration, was lost in 2012 shortly after the 10th anniversary of its launch. European Space Agency

Space is not the calm place it might seem. Once a satellite dies, various phenomena can cause it to tumble, making it hard to grab and remove from orbit. An experimental device in orbit now could solve the problem. Paul Marks spoke to its designers.

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From harpoons and deployable nets to the grasping robot arms of space tugs, there's no shortage of ways in which spaceflight engineers believe a dead satellite can be captured for subsequent deorbiting.

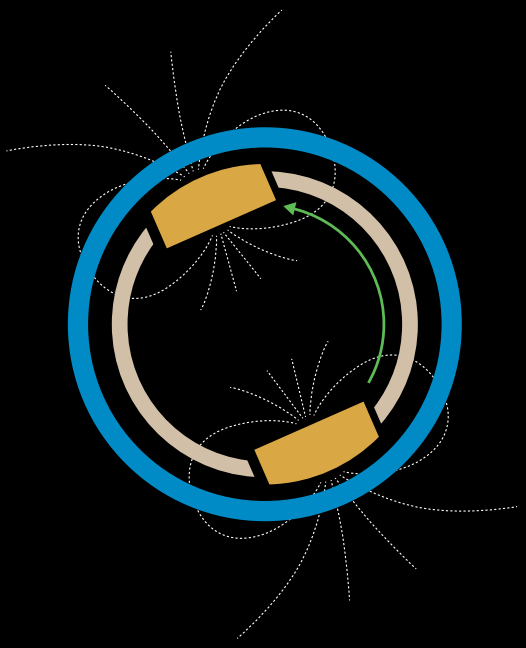
But such capture techniques can all be thwarted by one debilitating problem: A dead spacecraft lacks the propulsion and power it needs for attitude control and so can easily start tumbling. The spinning spacecraft is hard to grapple, and its angular momentum can break grippers or tear harpoon tethers and nets, in turn risking damage to the chaser vehicle and creating more space debris.

But with constellations of hundreds of thousands of internet-delivery satellites set to swell the population in low-Earth orbit over the next decade — Starlink, OneWeb and Amazon's Kuiper are just the start of what's becoming a gold rush — finding a way to detumble and deorbit the defunct ones has become a priority for the industry.

The numbers tell the story: In October, researchers at the University of British Columbia established that at least 1 million LEO satellites in some 300 constellations were registered with the International Telecommunication Union between 2017 and the end of 2022 for future launch — a potential 115-fold increase over today's orbital population. "The addition of hundreds of thousands of new satellites would greatly increase the complexity of operations and the risk of on-orbit collisions," the UBC team warned in the journal Science.

"This thing needs to be cheap and small if we're going to put it on every spacecraft in a massive constellation."

— Kristen Lagadec, Airbus Defence and Space



The Detumbler in action

HOUSING Made of aluminum, it doubles as the device's stator, or stationary part, and is affixed to the satellite.

ROTOR This aluminum wheel is free to turn.

MAGNETS Made of samarium-cobalt, these make the rotor turn to stay aligned with Earth's magnetic field.

A Detumbler could be robotically attached to a satellite at the end of its design life, or it could be affixed to a satellite before launch. The magnetic force it continually imparts is weak enough that during the satellite's life it would not interfere with station keeping maneuvers. But should the satellite die and start tumbling, the force would be strong enough to gradually slow that tumbling. As the rotor turns close to the housing, eddy currents are generated in the housing, and these currents generate a magnetic force in the opposite direction of the tumbling. The device does not need a source of electricity, since it relies on the electromagnetic properties of the materials.

But all may not be lost. A new gadget is in development that could stop defunct satellites from tumbling. Its inventors are confident enough to call it "a breakthrough for space sustainability."

The technology is the work of engineers Kristen Lagadec, Cyrille Tourneur, Laurent Boyer and Baptiste Brault of Airbus Defence and Space in Toulouse, France. Working with research partners at the French space agency CNES, the Airbus team has invented a lightweight electromagnetic device that could offer an inexpensive way to detumble defunct spacecraft.

Called — you guessed it — the "Detumbler," the gadget would be bolted to a satellite before launch but would only kick into action if the spacecraft were to start tumbling after it dies. The device itself is an unassuming aluminum can, 4 centimeters deep and 5 centimeters in diameter, that contains an aluminum rotor with two magnets, one on either side. The following may sound unlikely for such a diminutive device, but due to the particular principle of electromagnetism that the Detumbler's action is based on, its designers believe it will dampen the spin of any defunct satellite of up to 1.5 metric tons (1,500 kilograms), Lagadec says.

The choice of the Detumbler's operating principle was led by two major factors. First, says Lagadec, "This thing needs to be cheap and small if we're going to put it on every spacecraft in a massive constellation." Second, it had to work without being electrically powered or otherwise fueled, as most end-of-life satellites are "passivated" — that is, their batteries are discharged and all their propellant is vented to prevent explosive fragmentations and risky excursions from the orbital path. To meet these demanding conditions, Lagadec and colleagues decided to harness a principle of electromagnetism, described by Lenz's law, that is exploited in the contactless induction brakes used in some trains and trucks in place of friction-based brake pads.

In such brakes, a conducting disc is attached to a wheel axle and rotates between two electromagnets. When the driver brakes, those magnets are energized to apply a magnetic field across the conducting disc. But electric "eddy" currents generated in the conductor create a magnetic field in opposition to the applied one, producing a braking force that slows the vehicle without any contact between the disk and electromagnets.

Trucks and trains are not a perfect analog, though, for the way the Detumbler harnesses Lenz's law. "That's a very, very large-scale version of our technology. Ours only dissipates tiny picowatts of power. The Detumbler is a hybrid between [the braking mechanism] and a compass," Lagadec says.

Specifically, the Detumbler is fixed to the satellite so that in normal operation, the two magnets fixed to either side of its free-turning rotor wheel (see diagram) cause it to align with the local true north of the Earth's magnetic field, just like a compass. But, after the satellite is decommissioned, if solar radiation pressure, a propulsion failure or a debris strike has set it tumbling, the rotor will start to rotate to stay fixed on true north, and its magnets will induce eddies in the aluminum housing, the stationary part, or stator, of this electric machine. These eddies create an opposing magnetic force that dampens the motion. Over time, those tiny torques add up, combining to stop the tumble of a 1.5-ton satellite over something like 300 days.

"We hope to be able to detumble a relatively large spacecraft in significantly less than a year," says Lagadec. "Anything that can reduce or completely suppress tumbling would be a very, very welcome addition to a spacecraft in the eventuality that it might have to be actively removed if it cannot deorbit on its own at the end of its mission."

They might soon know if their idea has merit. The first test Detumbler is on orbit now after being launched on the SpaceX Transporter-9 ride-sharing mission in November. Bolted to an 8-unit cubesat called Exo-0 — owned by Exotrail and built by EnduroSat — the Detumbler was awaiting being spun up for tests as of mid-December.

Airbus is not yet revealing the Detumbler's projected price, but Lagadec says that "the target is that it should be negligible with respect to the price of any other satellite avionics equipment." Although the potential market size makes constellations the device's primary target, he adds that Airbus will "probably be working on a version for larger spacecraft" that might also be attachable to existing space junk.

And that brings a fascinating possibility into play: the detumbling of some of the most dangerous debris, like the European Space Agency's 8.2-ton Earth observation satellite, Envisat, which died suddenly on orbit in 2012. Ever since, Envisat has been tumbling at 770 kilometers, threatening havoc in LEO if it were to collide with other objects or break up. Damping it would likely require a number of larger Detumblers, plus an accurate way to attach them to Envisat, says Lagadec.

But freeing LEO from being haunted by such threats would be worth it, he says. "It would be like applying a tranquilizer dart to an animal: We could then wait for the beast to settle down and then grab it." ★