Space tractor beams may not be the stuff of sci-fi for long

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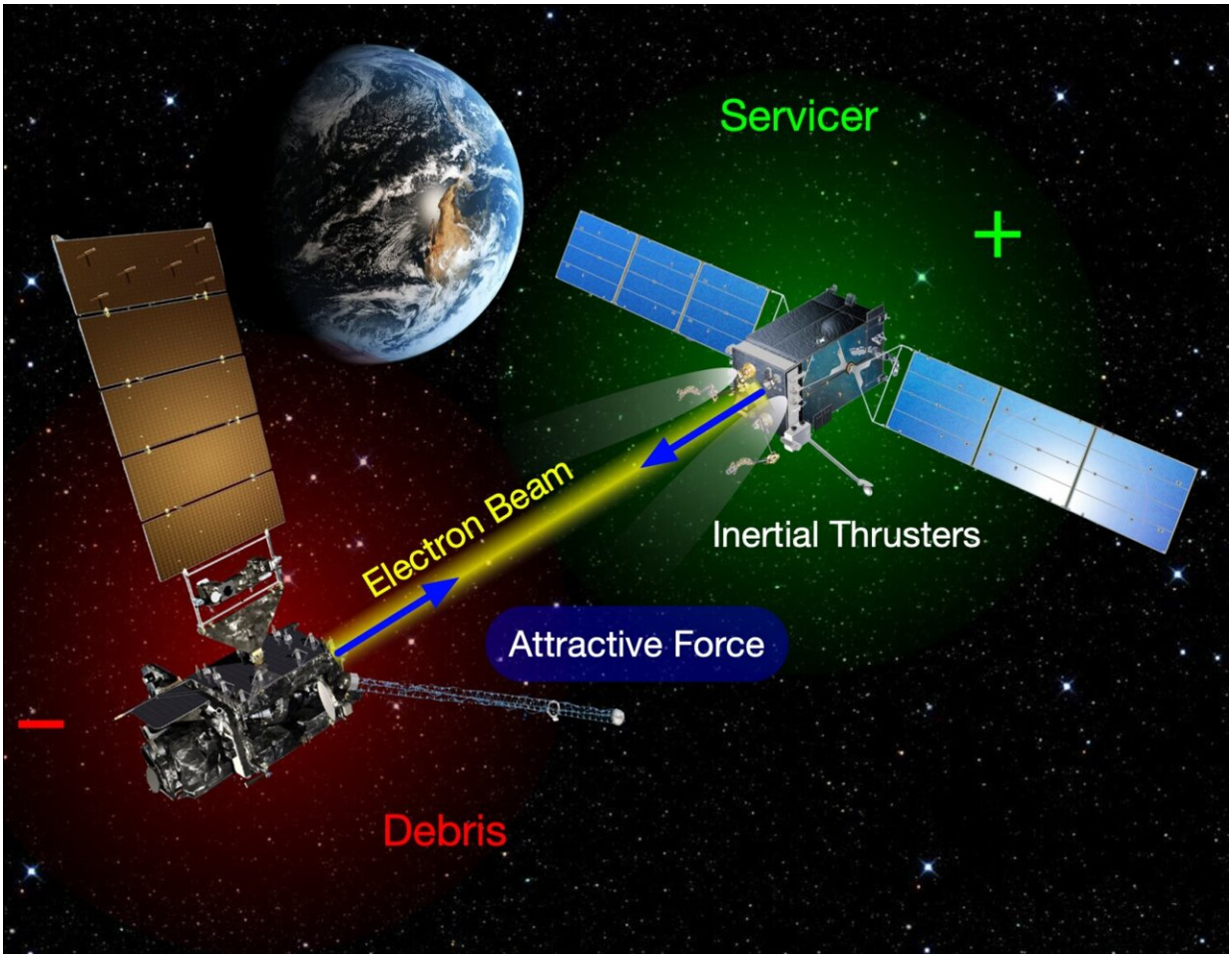

Graphic illustrating how a servicer spacecraft could remove debris from orbit using electrostatic forces. Credit: Schaub Lab

On Feb. 10, 2009, disaster struck hundreds of miles above the Siberian Peninsula. That evening, a defunct Russian satellite orbiting Earth crashed into a communications satellite called Iridium 33 moving at a speed of thousands of miles per hour. Both spacecraft erupted into a rain of shrapnel, sending more than 1,800 chunks of debris spiraling around the globe.

No other spacecraft (or humans) were harmed, but for many aerospace engineers, the event was a sign of things to come. Space, it seemed, was getting crowded.

NASA estimates that about 23,000 chunks of debris the size of a softball or larger currently swirl through space. All that junk means that another collision like the one that destroyed Iridium 33 becomes increasingly likely every year—only this time, the fallout could be much worse.

"The problem with space debris is that once you have a collision, you're creating even more space debris," said Julian Hammerl, a doctoral student in aerospace engineering sciences at CU Boulder. "You have an increased likelihood of causing another collision, which will create even more debris. There's a cascade effect."

Hammerl and a team led by Professor Hanspeter Schaub have a plan for stopping those cascades before they start. The researchers are drawing on one of the oldest tropes in science fiction: tractor beams like the ones the Starship Enterprise uses to safely move asteroids out of the way.

Imagine this: In the not-so-distant future, a fleet of small spacecraft could whiz around Earth, rendezvousing with dead hunks of metal in geosynchronous orbit around the planet. Then, using devices called "electron beams," these space dumpster trucks would slowly haul that debris to safety without ever having to touch it—all by tapping into the same kind of physics that make your socks stick to your pants in the

dryer.

"We're creating an attractive or repulsive electrostatic force," said Schaub, chair of the Ann and H.J. Smead Department of Aerospace Engineering Sciences. "It's similar to the tractor beam you see in Star Trek, although not nearly as powerful."

First, Schaub and his colleagues must solve a series of challenges, which they've described in numerous recent studies. The researchers, for example, are employing a new facility to replicate the surprisingly complex environment around Earth. They're also setting their sights on how tractor beams might someday remove debris from the region of space between Earth and the moon.

"Touching things in space is very dangerous. Objects are moving very fast and often unpredictably," said Kaylee Champion, a doctoral student working with Schaub. "This could open up a lot of safer avenues for servicing spacecraft."

Space in a can

Champion and her fellow researchers are exploring those avenues now from a lab with a view of the Flatirons on the university's East Campus.

A handful of students cluster around a cylinder about the size of a whiskey barrel. It's made of a thick layer of stainless steel with several, porthole-like windows for peeking inside. This vacuum chamber, called the Electrostatic Charging Laboratory for Interactions between Plasma and Spacecraft (ECLIPS), is open at its base now. But with a buzz of a motor, the cylinder slowly lowers down until it clamps shut.

Soon, a pump will begin depressurizing the chamber. In about a day, no air will remain inside—a small pocket of space right in the middle of

Boulder. Schaub and his team designed the chamber themselves, and it's unlike any other research facility in the country.

This space-in-miniature takes center stage in the group's experiments with electrostatic tractors. Inside, the group can replicate the environment around Earth, which isn't empty but, instead, awash in a thin gas of free electrons and charged atoms called plasma. The group can even simulate debris in this chamber using cubes or more complex shapes made of metal.

Today, the researchers are trying to mimic conditions in what Schaub called an "expensive patch of real estate" in space.

Earth's geosynchronous orbit, or "GEO," begins about 22,000 miles from the planet's surface, a far trek from the low-Earth orbit, or "LEO," where Iridium 33 met its demise. There, you can find some of the most expensive satellites ever built—military and telecommunications spacecraft that reach the size of school buses and weigh well over a ton.

"GEO is like the Bel Air of space," Schaub said.

It's also getting crowded. Engineers estimate that there are about 180 potential geosynchronous orbital parking spots where satellites can squeeze into. All of them have been claimed or are already occupied.

Tractor beams, Schaub said, may be able to safely move old spacecraft out of the way, making room for the next generation of satellites.

Virtual tethers

For Hammerl, the research project is one he couldn't have dreamed of when he was a young student in his home city of Vienna, Austria. Hammerl studied mechanical engineering as an undergraduate, but he

moved to Boulder for graduate school to pursue his passion for space exploration. (Austria doesn't have its own space program.)

When he arrived, he had no idea just how complex this seemingly empty expanse could be.

In a simple sense, he explained, the team's concept for an "electrostatic tractor" works a bit like rubbing a balloon on your head to make your hair stand on end. First, a servicing ship would approach a derelict satellite from a distance of about 15 to 25 meters (49 to 89 feet), then zap it with a beam of electrons. Those electrons would give the space debris a negative charge, while making the servicer more positive.

Like the adage says, opposites attract.

"With that attractive force, you can essentially tug away the debris without ever touching it," Hammerl said. "It acts like what we call a virtual tether."

It seems to work, too. Based on experiments in ECLIPS and computer models, the researchers calculate that an electrostatic tug could pull a satellite weighing several tons about 200 miles in two to three months. That's a sluggish pace, but good enough to remove what are essentially glorified paperweights from precious orbital slots.

Scientists have proposed other strategies for removing debris from orbit, such as grabbing wayward satellites using harpoons. But all of those approaches require coming into direct contact with junk.

In practice, however, actually using a tractor beam in space is rife with complications.

For a start, decommissioned satellites don't usually sit still and can even

tumble wildly through space. In studies, Schaub and his students have shown that if you hit these chunks of metal with a rhythmic pulse of electrons, rather than a steady beam, you can potentially slow down their rotation—making the satellites safe to tug away or even get close to for making repairs.

Far from home

The team has also begun to think about a region of space where few pieces of debris reside today but is about to get a lot busier: "cislunar" space, or the zone between Earth and its moon. Here, conditions can get really wild.

Champion explained the sun ejects a near-constant stream of plasma, referred to as the solar wind. Outside of Earth's protective magnetic field, that plasma environment can become unpredictable. Vehicles soaring through can disturb the flow of plasma and generate a wake of ions behind them, almost like a sailboat skimming through water. Those wakes could, in turn, affect the performance of an electrostatic tractor.

"That's what makes this technology so challenging," Champion said. "You have completely different plasma environments in low-Earth orbit, versus geosynchronous orbit versus around the moon. You have to deal with that."

To do just that, Champion and her fellow lab members have augmented ECLIPS with an "ion gun," a device that can create fast-moving currents of argon ions inside the chamber.

She hopes her work could one day help NASA's efforts through its Artemis Program to send humans back to the moon—and, from there, to even farther beyond.

"Once we put people back on the moon, that's a steppingstone to traveling to Mars," Champion said.

Schaub noted space tractor beams might not be the stuff of science fiction for long. With the right funding, he predicts that his team would be ready to launch a prototype electrostatic tractor into space in just five to 10 years.

"The exciting thing about this technology is that the same servicing craft could move two or three or even dozens of objects during its lifetime. That brings your cost way down," Schaub said. "No one wants to spend a billion dollars to move trash."

Provided by University of Colorado at Boulder

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