Powering cube satellites

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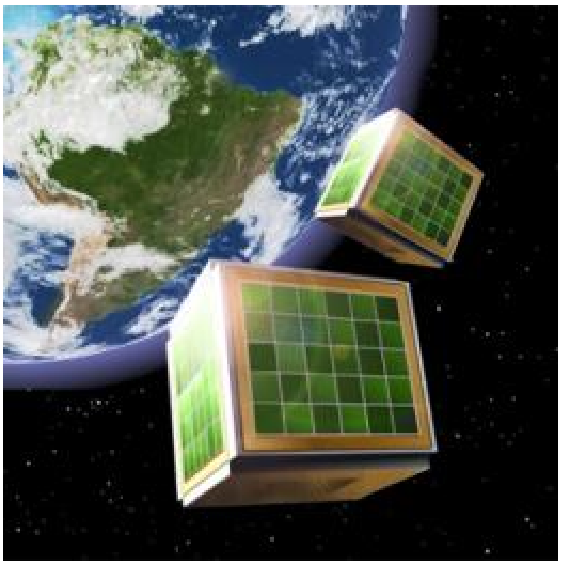

MIT reseachers' new thrusters could increase the number of CubeSats in orbit and expand the tasks they are able to complete. Graphic: Christine Daniloff

Right now, 10 to 15 Rubik's Cube-sized satellites are orbiting high above Earth. Known as cube satellites, or "CubeSats," the devices help researchers conduct simple space observations and measure characteristics of Earth’s atmosphere. One advantage is that they are relatively cheap to deploy: While launching a rocket may cost between $50 million and $300 million, a CubeSat can “piggyback” onto a large rocket platform at an additional cost of as little as $40,000. But their small size also means they lack on-board propulsion systems, which is why they generally remain locked to a particular orbit.

That could soon change, however. Paulo Lozano, the H.N. Slater Assistant Professor of Aeronautics and Astronautics at MIT, is designing a tiny propulsion system that could allow the satellites, which weigh about a kilogram and are used for tasks that don't require precise orbit control, to travel great distances and perform more serious tasks, such as searching for planets outside our solar system. The technology, which is based on the process of extracting and accelerating charged ions, or atoms that have gained or lost an electron, could make CubeSats much more useful for organizations or countries that until now have had limited access to space.

For decades, the only way to get objects into space from Earth — and then propel them through space — was to use chemical propulsion systems. But the systems require a lot of propellant, or fuel, and haven't been miniaturized to the scale appropriate for a CubeSat. By changing the design from chemical to electric, and to one that relies on a simple power supply, Lozano has created a system that produces more efficient thrust — the force created when mass is accelerated in a certain direction — than that produced by a chemical-based system, which produces a low thrust per gram of propellant. About the size of a computer chip, the mini-thruster design also overcomes the size constraints of chemical propulsion and other forms of electric propulsion because it does not require a bulky chamber to burn (chemical) or extract ions from (electric) the propellant. Although other electric propulsion systems have been developed, Lozano's is considered superior because it uses only one power supply.

With funding from the Air Force Office of Scientific Research, Lozano has been developing the technology to make the mini-thruster. The Air Force and other government agencies are interested in using CubeSats that can move between different orbits in space, and more specifically, that have the propulsion required to reenter Earth's atmosphere and destroy themselves at the end of their mission (thereby keeping them from becoming "space junk"). The thruster design requires that the total volume of the propulsion system be less than 10 percent of the CubeSat.

"The goal is to have a space engine that leaves plenty of room for the payload, or cargo, of the CubeSat," Lozano said. Certain missions require chemical propulsion, such as a trip to the moon, because in order to land on the moon's surface, the amount of force from the engine must be at least equal to the weight of the lander, a value that Lozano said is generally "way too high" for electric propulsion engines. But chemical-based systems are severely limited by the fact that the vehicle mass must be made mostly of propellant, which leaves little room for the payload. Quite often the propellant must also be stored in a pressurized container with thick walls and pipes, further limiting the payload size. Although other electric propulsion systems exist, they require a pressurized container to store the propellant.

Vadim Khayms, a systems engineer at Lockheed Martin, explained that most electric propulsion systems haven't been scaled to operate at very low power levels and are typically suitable for larger satellites that have more power available and require more thrust. He is not aware of another electric propulsion system designed for CubeSats. "You probably couldn't use any other existing electric propulsion [systems] on these very small satellites," Khayms said of Lozano's design.

How the power system works

Lozano's design relies on electrospraying, a physics process that uses electricity to extract positive and negative ions from a liquid salt that is created in a laboratory and serves as the system's propellant. The liquid contains no solvent, such as water, and can be charged electrically with no heat involved. Whereas other electric propulsion systems charge the ions in a chamber on the satellite, the ionic liquid in Lozano's design has already been charged on the ground, which is why his system doesn't need a chamber.

Electricity is then converted from the main power source of the CubeSat, typically batteries or a solar panel, and applied to a tiny structure roughly the size of a postage stamp. This thin panel is made of about 1,000 porous metal structures that resemble needles and have several grams of the ionic liquid on them. By applying voltage to the needles, an electric field is created that extracts the ions from the liquid, accelerates them at very high speeds and forces them to fly away. This process creates an ionic force strong enough to produce thrust.

Whereas chemical rockets waste too much propellant to reach a net change in spacecraft velocity, electric thrusters can do exactly the same mission using just a small fraction of the propellant. The only difference is one of time: Although electric propulsion is very fuel efficient, it is slower due to power limitations.

"Eventually, you'll run out of propellant, but that is the benefit of electric propulsion because it accelerates so fast that you don't need a lot of it," he said. "No other electric propulsion system would be so compact and efficient at the same time."

Because the mini-thrusters are scalable, thousands of them could be built into long, thin panels to produce thrust for a much larger spacecraft that requires low, but steady, acceleration. "There's no impediment to making a whole table of them similar to a solar panel," Lozano said. "This gives you a lot more flexibility in what you can do."

Lozano predicts that CubeSats using this technology will become a reality in less than three years. He plans to have a prototype of the mini-thruster in four to five months and hopes to begin testing it to measure performance metrics such as the velocity of the ions and their energy to figure out the force produced by the engine. Knowing this, researchers can estimate its efficiency. After Lozano delivers a prototype this year, his team will look for additional support to turn the design into a flight version.

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