Space needs better 'parking spots' to stay usable, and an engineer is finding them

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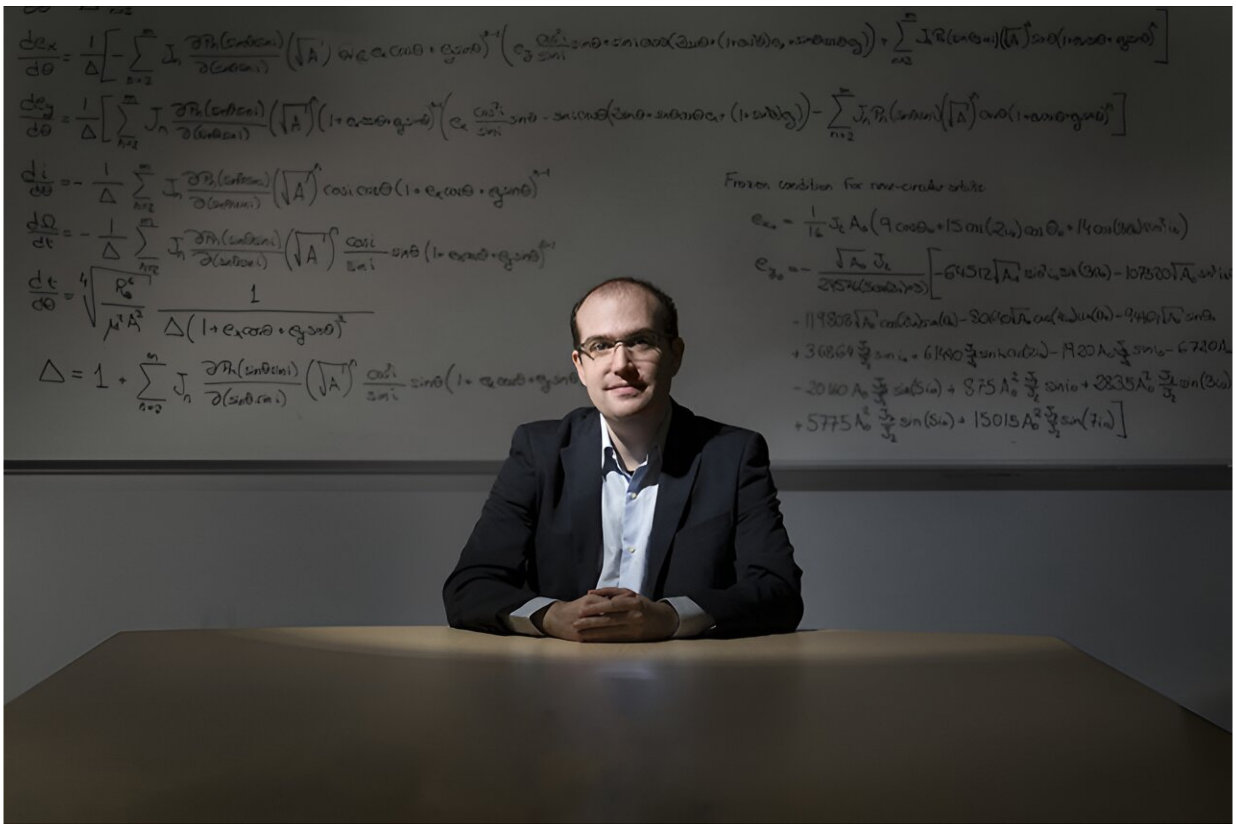

"Space is a common resource for humanity," says David Arnas, a Purdue professor whose research is pointing out more sustainable ways to organize satellites in space. Credit: Purdue University photo/John Underwood

Any mission headed to space needs a "parking spot" at its destination. But these parking spots, regions located on orbits, are quickly becoming occupied or more vulnerable to collisions.

Most objects launching to space are satellites, which can travel faster than 4 miles per second in the regions where they park. About 10 times the number of satellites currently in space are expected to launch by 2030. Simultaneously, satellite constellations are increasing in number and size. These are groups of satellites working together as a system, such as for enabling GPS, observation of Earth, internet access and other types of communications.

"With this density of satellites, something is going to fail and cause a collision. It's just a matter of probability," said David Arnas, an assistant professor of aeronautics and astronautics in Purdue University's College of Engineering. "Satellite constellations are getting so big and numerous that it's becoming impossible to accurately track them all and ensure their long-term safety even through computational means."

Arnas and his graduate students are investigating how orbits could be used to design better parking spots for satellites both in areas closer to Earth, where many of these available locations have already been taken, and in other parts of space that will soon see an increase in satellite population, such as the large area between Earth and the moon called the cislunar region. His research group also is coming up with new methods for feasibly analyzing satellite constellations as they increase in size.

Arnas' goal is to make space more equitable. Putting spacecraft in designated parking spots instead of just anywhere could reduce the likelihood of space becoming too cluttered for missions to safely take place.

"Space is a common resource of humanity, just like water and air. Even if it seems very vast, it is still limited. It is our responsibility to ensure that future generations will also have fair access to it," he said.

Helping satellite constellations get bigger more safely

No matter whether satellite constellations are located closer to Earth or eventually near the moon, space debris is an unavoidable issue.

Within just one month, pieces of debris from a satellite explosion or collision in low Earth orbit can cover the whole Earth. This debris could stick around for anywhere from a few years to several hundred years, depending on the altitude. If low Earth orbit becomes more crowded, satellites will have few places where they can quickly get out of the way of debris before getting hit.

This presents a mess of a math problem. But Arnas and his students are identifying how to organize large satellite constellations so that it's feasible to predict how they should reconfigure when a massive debris cloud is headed their way.

"If we have a lot of satellites in an area where there's been a fragmentation event, we will have to move these satellites. This means that we have to optimize not only the final positions of the satellites, but also the maneuvers that each satellite would have to perform in a very short period of time. And right now, that's not possible to do if several large constellations are involved," he said.

"However, if you have a general structure, a distribution containing all satellites in the region, it's not only possible, but something that we can do even with pen and paper. We can foresee the possibilities of reconfiguration and react very quickly if something unexpected happens."

Arnas has made findings about how to estimate orbital capacity, reduce the risk of collisions within satellite constellations, and design satellite orbits that are more resilient to disturbances. One method he developed would help to calculate the minimum distance that satellites should maintain from each other so that no matter what happens in a particular orbit, each satellite would be far enough away to avoid a collision. He's also proposed a new way to analyze large satellite constellations in subsets so that they are easier to study.

Currently, there are few policies regulating where satellites can be put in space. Through the tools he's creating, Arnas hopes to help inform decision-makers on what the consequences could be for launching a new satellite or establishing a new constellation.

"I want to give policymakers a way to know how approving a mission is going to affect the future capacity and sustainability of the space sector," he said.

Making travel between Earth and the moon more fuel-efficient

The increase in space missions and satellite density doesn't just affect spacecraft orbiting close to Earth.

Dozens of missions may be traveling through the cislunar region over the next few years, but it's hard to chart the trajectories spacecraft should take for each individual mission. Solar radiation and the combined gravitational pull of the Earth, moon and other planets have a large effect on orbits and how they're used.

To help solve this issue, Arnas' research group is exploring how so-called resonant orbits could be used to design these trajectories and help spacecraft save fuel when traveling the 238,900 miles from Earth to the moon.

Arnas and Purdue graduate student Andrew Binder are building on an idea NASA explored in the past to propel satellites from low Earth orbit without expending fuel by using very long cable structures called "tethers." Applying this idea to the cislunar region, Arnas and Binder envision building a reusable infrastructure in space based on a pair of tethers that could "catch and throw" satellites between Earth and the moon. One tether would be in orbit around Earth and the other would orbit the moon. The tethers would provide the necessary impulse for satellites to cross cislunar space so that they won't have to use up fuel to perform that trip.

Although their findings are preliminary, Arnas and Binder are developing more complex models of this tether system that they hope could help lead to a more streamlined way to travel through cislunar space.

"If missions to the moon and back are going to become more common, then it could be very useful to have an infrastructure already built in orbit to transition payloads in the cislunar system," Arnas said.

Provided by Purdue University