The next frontier in space is closer than you think – welcome to the world of very low Earth orbit satellites

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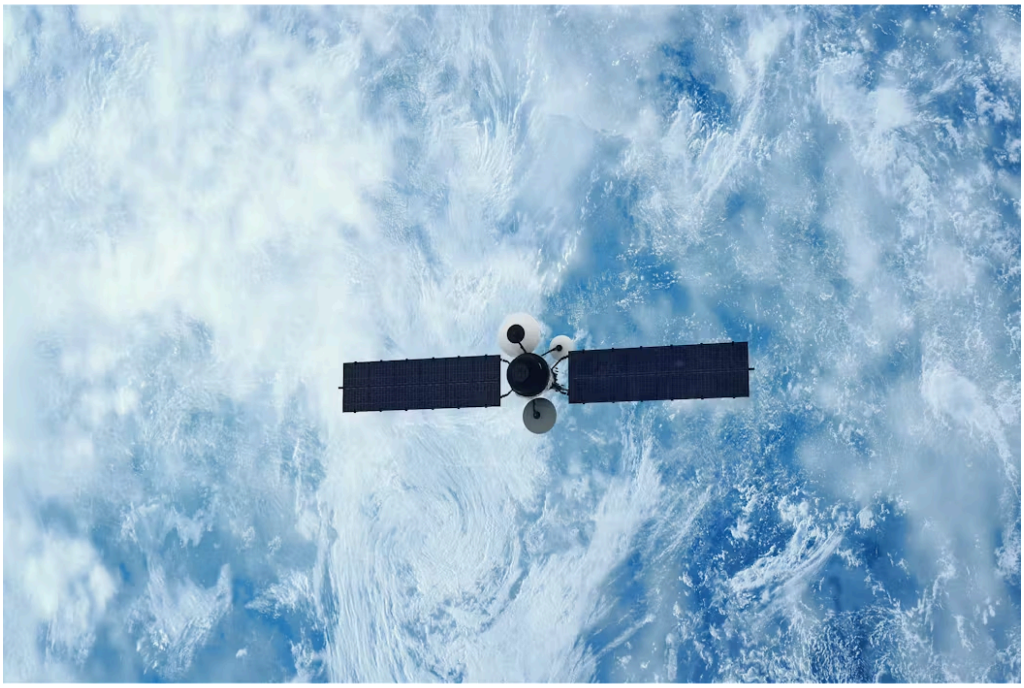

The closer a satellite – like this telecommunications one – orbits to Earth, the more atmospheric drag it faces.

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There are about 15,000 satellites orbiting the Earth. Most of them, like the International Space Station and the Hubble Telescope, reside in low Earth orbit, or LEO, which tops out at about 1,200 miles (2,000 kilometers) above the Earth's surface.

But as more and more satellites are launched into LEO – SpaceX's Starlink internet constellation alone will eventually send many thousands more there – the region's getting a bit crowded.

Which is why it's fortunate there's another orbit, even closer to Earth, that promises to help alleviate the crowding. It's called VLEO, or very low Earth orbit, and is only 60 to 250 miles (100 to 400 kilometers) above the Earth's surface.

As an engineer and professor who is developing technologies to extend the human presence beyond Earth, I can tell you that satellites in very low Earth orbit, or VLEO, offer advantages over higher altitude satellites. Among other benefits, VLEO satellites can provide higher-resolution images, faster communications and better atmospheric science. Full disclosure: I'm also a co-founder and co-owner of Victoria Defense, which seeks to commercialize VLEO and other space directed-energy technologies.

Advantages of VLEO

The images from very low Earth orbit satellites are sharper because they simply see Earth more clearly than satellites that are higher up, sort of like how getting closer to a painting helps you see it better. This translates to higher resolution pictures for agriculture, climate science, disaster response and military surveillance purposes.

End-to-end communication is faster, which is ideal for real-time communications, like phone and internet service. Although the signals still travel the same speed, they don't have as far to go, so latency decreases and conversations happen more smoothly.

Much weather forecasting relies on images of clouds above the Earth, so taking those pictures closer means higher resolution and more data to forecast with.

Because of these benefits, government agencies and industry are working to develop very low Earth orbit satellites.

The holdup: Atmospheric drag

You may be wondering why this region of space, so far, has been avoided for sustained satellite operations. It's for one major reason: atmospheric drag.

Space is often thought of as a vacuum. So where exactly does space actually start? Although about 62 miles up (100 kilometers) – known as the the von Kármán line – is widely considered the starting point, there's no hard transition where space suddenly begins. Instead, as you move away from Earth, the atmosphere thins out.

In and below very low Earth orbit, the Earth's atmosphere is still thick enough to slow down satellites, causing those at the lowest altitudes to deorbit in weeks or even days, essentially burning up as they fall back to Earth. To counteract this atmospheric drag and to stay in orbit, the satellite must constantly propel itself forward – like how riding a bike into the wind requires continuous pedaling.

For in-space propulsion, satellites use various types of thrusters, which provide the push needed to keep from slowing down. But in VLEO, thrusters need to be on all, or nearly all, of the time. As such, conventional thrusters would quickly run out of fuel.

Fortunately, the Earth's atmosphere in VLEO is still thick enough that atmosphere itself can be used as a fuel.

Innovative thruster technologies

That's where my research comes in. At Penn State, in collaboration with Georgia Tech and funded by the U.S. Department of Defense, our team is developing a new propulsion system designed to work at 43 to 55 miles up (70 to 90 kilometers). Technically, these altitudes are even below very low Earth orbit – making the challenge to overcome drag even more difficult.

Our approach collects the atmosphere using a scoop, like opening your mouth wide as you pedal a bike, then uses high-power microwaves to heat the collected atmosphere. The heated gas is then expelled through a nozzle, which pushes the satellite forward. Our team calls this concept the air-breathing microwave plasma thruster. We've been able to demonstrate a prototype thruster in the lab inside a vacuum chamber that simulates the atmospheric pressure found at 50 miles (80 km) high.

This approach is relatively simple, but it holds potential, especially at lower altitudes where the atmosphere is thicker. Higher up, where the atmosphere is thinner, spacecraft could use different types of VLEO thrusters that others are developing to cover large altitude ranges.

Our team isn't the only one working on thruster technology. Just one example: The U.S. Department of Defense has partnered with defense contractor Red Wire to develop Otter, a VLEO satellite with its version of atmosphere-breathing thruster technology.

Another option to keep a satellite in VLEO, which leverages a technology I've worked on throughout my career, is to tie a lower-orbiting satellite to a higher-orbiting satellite with a long tether. Although NASA has never flown such a system, the proposed follow-on mission to the tether satellite system missions flown in the 1990s was to drop a satellite into much lower orbit from the space shuttle, connected with a very long tether. We are currently revisiting that system to see whether it could work for VLEO in a modified form.

Other complications

Overcoming drag, though the most difficult, is not the only challenge. Very low Earth orbit satellites are exposed to very high levels of atomic oxygen, which is a highly reactive form of oxygen that quickly corrodes most substances, even plastics.

The satellite's materials also must withstand extremely high temperatures, above 2,732 degrees Fahrenheit (1,500 degrees Celsius), because friction heats it up as it moves through the atmosphere, a phenomenon that occurs when all spacecraft reenter the atmosphere from orbit.

The potential of these satellites is driving research and investment, and proposed missions have become reality. Juniper research estimates that $220 billion will be invested in just the next three years. Soon, your internet, weather forecasts and security could be even better, fed by VLEO satellites.

Sven Bilén founder and co-owner of Victoria Defense, which seeks to commercialize VLEO and other space technologies. He receives funding from DARPA and NASA related to VLEO technologies.