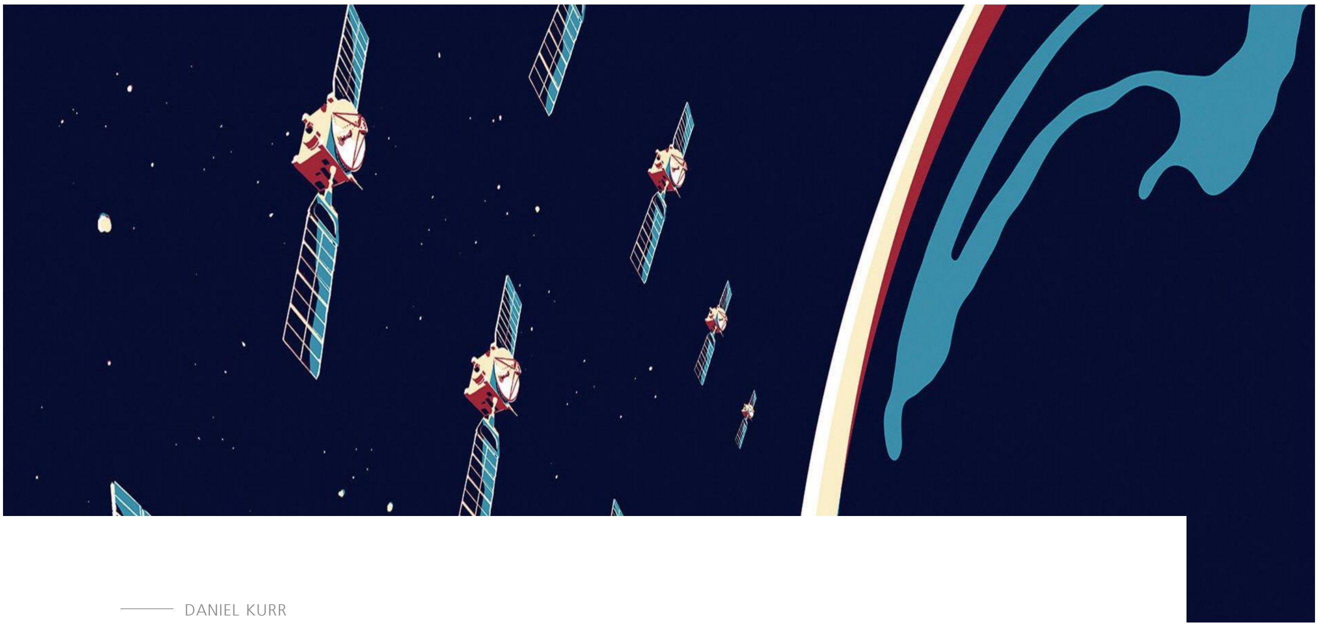


DANIEL KURR

Our swarm in space - how laser is revolutionizing space

The era of low Earth orbit satellites has begun. Their advance into space relies on cutting-edge laser technology — not only for construction and communication, but also for some high-tech orbital traffic enforcement.

Viewed from the moon, our home planet looks like a giant blue ball with patches of color and white stripes. But thanks to billionaires Elon Musk and Jeff Bezos, it could soon look more like a bees' nest! SpaceX and Amazon are aiming to put huge numbers of satellites into low Earth orbit (LEO), meaning that our planet will be surrounded not by insects, but by swarms of satellites the size of washing machines. The hope is that these satellites will provide answers to pressing questions on issues such as arable soil health. They should also help us to improve traffic planning and find ways of processing increasing quantities of data.

The prospects for LEO technology look good, and with experts expecting it to become a multi-billion-dollar market, the future looks bright for business. One glance at the figures shows just how confident satellite builders are about the future of the market. Bezos's company Amazon has sought approval to launch 3,236 satellites as part of "Project Kuiper". But the most ambitious plans of all are currently those being pursued by SpaceX: Musk's company intends to launch an incredible 42,000 satellites into space to create a global communications network – at least if it can figure out how to significantly reduce the cost of producing and operating them at scale.

Race through space

This is no easy task, because the closer an object orbits the Earth, the higher its speed must be to counteract Earth's gravity. Conventional communications satellites fly some 36,000 kilometers up at a speed of about 11,000 kilometers per hour, which allows them to match the Earth's rotation as they travel. In contrast, LEO satellites travel at an altitude of just 500 to 2,000 kilometers and fly at a speed of around 27,000 kilometers an hour, faster than the Earth's rotation. They therefore orbit the Earth every 90 to 120 minutes, which is why each satellite can only communicate with a ground station for a few minutes at a time. SpaceX therefore needs a lot of satellites to ensure that when one satellite goes out of range of the ground station, the next one can take over, much like an orbital relay race!

This is the only way to maintain a continuous connection. Achieving this goal is vital not just for Netflix viewers on Earth, but also for SpaceX: should a satellite collide with a piece of space junk and shatter into pieces, the resulting debris would immediately endanger all the other LEOs in the same orbit. That’s why it’s so important to have real-time information on what the satellite swarm is doing.

But why would companies go to all this trouble in the first place? Why not simply aim for the higher altitude regions like before? The answer is simple: closer proximity to the Earth offers the huge advantage of fast data transmission speeds. The time required for data to travel from its source to its destination and back – known as latency – is far shorter for LEO satellites than for those in more distant orbits. Systems in conventional orbits have a median latency of up to 600 milliseconds. SpaceX is aiming for 20 milliseconds and is eventually hoping for half that. Because signals propagate faster in orbit than through fiber optic cables, LEO satellites have the potential to compete with, and possibly even surpass, ground-based networks.

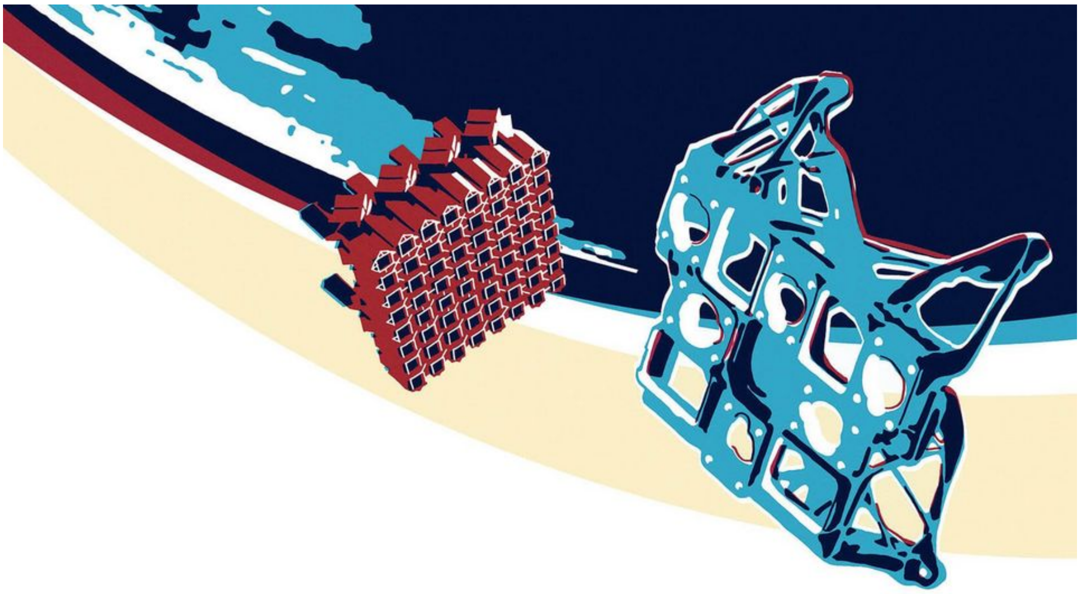
Infrastructure with lasers

One thing is already clear: LEO satellites have a key part to play in future broadband communications. Their deployment will create new infrastructure in space – and laser technology will play a major role in their construction and operation. The choice of the laser is a logical result of satellite builders’ preferences for high-tech materials, which engineers typically like to machine with lasers. Now, laser specialists have introduced a further innovation of metal 3D printing for components such as antennas.

3D printing

Sending chunks of data through the ether requires special antennas that look very different to those we may have seen in the past. The lower section contains a specially shaped waveguide as a filter. These structures are designed to amplify electromagnetic waves or attenuate them in certain frequency ranges. The upper, wider part is the output to which the data is transferred. Phase shifting allows the antenna to point its data in a specific direction without having to rotate. The fabrication of these antennas is a masterclass in precision engineering. Many of their structural components cannot be produced by conventional means such as turning, milling, casting and bending, so additive manufacturing is often the best option. 3D printers can cater to even the most complex and contorted shapes, so they are the perfect choice for building the antennas’ curved cavities with their extremely thin walls and stabilizing ribs. These geometries have a major impact on the frequency at which the antennas are used. The higher the frequency, the higher the data throughput and the smaller the components ultimately have to be. The tiny laser spots used by modern additive manufacturing systems cater to the most delicate of wall thicknesses; depending on the geometry, these can be as thin as 100 microns. 3D printers can distribute material with pinpoint accuracy, allowing the geometry to fully reflect the distribution of forces in the structure. This means engineers can use 3D printing to faithfully recreate any idea in metal form – in high volumes, and with maximum precision.

Another area where 3D printers come into their own is in the fabrication of satellite brackets to support the antennas and other components. Brackets are used in multiple places on a satellite, but these vital parts take up space and add to the overall weight. This is another area where 3D printing can help. Engineers can now minimize the amount of material in each bracket by printing them in shapes that are based on precise calculations of force distribution, just like with the antennas. Bracket weight can be reduced by up to 55 percent – a big saving for a component that is used numerous times in each satellite!



3D printing will finally allow us to see satellite components at their best: highly reduced, purely functional forms that weigh next to nothing.

A place in space

TRUMPF, the European Space Agency (ESA) and other project partners are also investigating the possibility of laser printing coils that align themselves to the Earth's magnetic field and help position the satellite – key components that are barely larger than a two-euro coin. The ESA is already using 3D-printed thrusters to correctly align satellites in space, each one kitted out with special channels for cooling and for carrying fuel. These internal channels were almost impossible to build before the invention of additive manufacturing, but now the 3D printer simply forms the cooling channels during the build process, looping them through the walls to achieve optimum fuel distribution. Once again, this 3D printing solution also helps to reduce weight. Weight savings are always a powerful argument in any new laser application – and for LEO satellite builders, every gram counts. From an economic perspective, it’s fairly simple: every kilo launched into space costs money. On that basis, laser technology can potentially save between 10,000 and 20,000 euros per satellite. Considering how many satellites are in play, this leaves companies with millions of extra euros.

Space junk

One of the downsides of LEO satellites is their relatively short operating life of five to seven years. Their close proximity to Earth subjects them to tremendous atmospheric friction and rapid aging. Using remote control, they are eventually brought into a controlled descent and allowed to burn up in the atmosphere. Sometimes, however, satellites suffer a collision or failure and end up as space debris. Near-Earth orbit already resembles a gigantic junkyard, including 3,000 non-functional satellites, 34,000 individual parts that are ten centimeters or larger, and 128 million parts smaller than a millimeter. Crashes are inevitable when so much stuff is whizzing around.

The Institute of Technical Physics in Stuttgart, part of the German Aerospace Center (DLR), is turning to lasers to help tackle the problem of space pollution head-on. Their plan is to use “laser nudging” to prevent collisions, in other words using light pressure delivered by lasers on the ground to nudge debris in orbit. All that is required is a gentle push, because nudging benefits from the fact that even the smallest deviation can lead to large changes in orbit due to the high speeds and enormous distances covered by orbital debris. A gentle nudge with a very small amount of energy is all it would take to direct space junk back towards Earth, allowing it to burn up in the atmosphere.

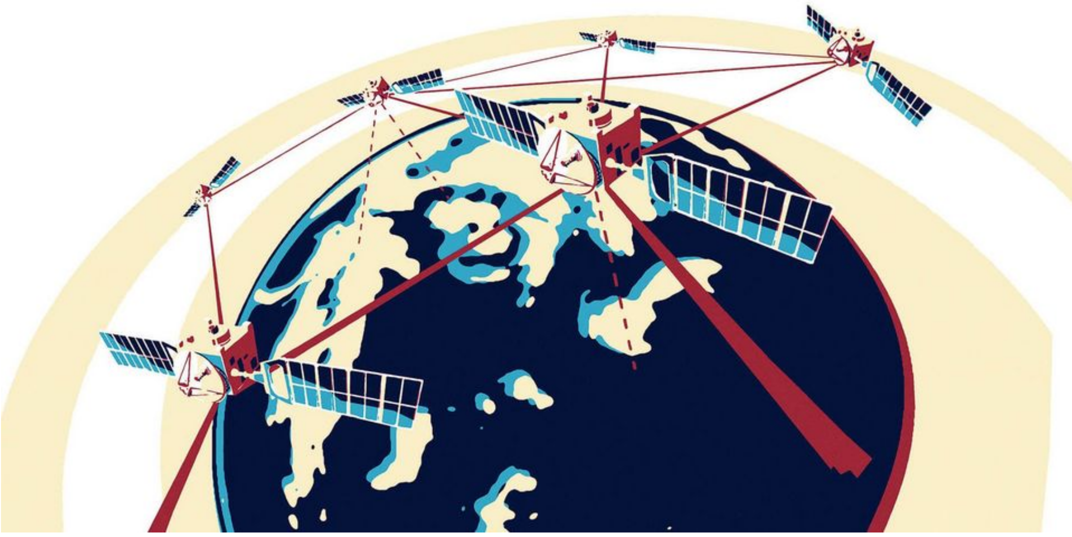
The DLR aims to use lasers to nudge space debris into a crash and burn trajectory.

Making debris visible by day

But the first step is to track down the debris and identify its current course. Fortunately, there is also a laser-based application designed to do just that. ESA researchers have succeeded in using a special combination of telescopes, detectors, lasers and light filters at specific wavelengths to increase the contrast of orbiting objects in the daytime sky, making them easier to see. "This new technology will enable us to track objects that were previously invisible against the blue sky – and that means we'll be able to work with laser ranging all day long to help prevent collisions." says Tim Flohrer, head of ESA's Space Debris Office.

Communication

Laser beams are also set to become an essential tool for a completely different aspect of the new LEO satellites, namely that of data transmission. Traditional geostationary satellites stay in the same position relative to Earth and communicate with ground stations by radio. In contrast, LEO satellites race around the Earth at incredible speed and must communicate by radio not only with the Earth, but also with their fellow satellites in space. This is the only way in which companies can guarantee permanent network coverage. Here, too, lasers could come to the fore in the future, because additional intersatellite radio links will make communication even more dependent on large antennas and energy-hungry amplifiers. An optical solution therefore offers clear benefits. Whenever a fellow satellite races through the search algorithm's field of view, the LEO satellite will simply fire an information-packed laser beam at it – sharpshooting in space over distances of 5,000 kilometers! Researchers at the German Aerospace Center near Munich have successfully used a laser beam to transmit data at 1.7 terabits a second, almost fifty times higher than the amount of data that can be sent by radio.



Laser communication between satellites– amazing sharpshooting skills in space!

New Laser era

SpaceX has already successfully sent 1,500 satellites into orbit. Apps such as Star Walk 2 offer a fun way to search for satellites in the sky and watch the swarm increase in size from one week to the next. With our smartphones in our hands and the LEO swarm overhead, there’s no doubt that we have entered a new era. The age of mass satellite communication is upon us□–□and so, too, is the era of laser technology.

DANIEL KURR
TRUMPF □□ □□□□□□