

SCIENTIFIC AMERICAN

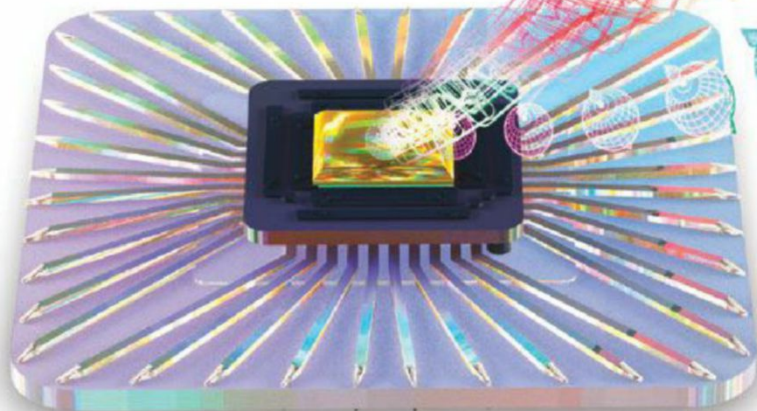
A New Race
to the Moon

Lost Roads of the
Roman Empire

The Scariest
Problem
in Math

The **QUANTUM** Revolution

Can the next big thing in computing
live up to the hype?





Light trails from satellites in low-Earth orbit fill the sky in this composite long-exposure photograph, which was captured over a 30-minute period.

Unchecked Megaconstellations

Satellite swarms could destroy our view of the heavens and seriously damage our planet BY PHIL PLAIT

REMEMBER THE FIRST TIME I SAW A SATELLITE. I was a teenager, standing in my mildly light-polluted suburban yard and doing my usual stargazing. The satellite was a faint “star” moving slowly and smoothly across the sky, and as I watched it I felt a mix of awe and wonder that such a thing could be seen—and that humans could put an object into orbit at all.

That was a lifetime ago, and I now look back on that evening with more discomfiture than nostalgia; my adolescent naivete feels almost embarrassing.

That’s because these days, seeing one of those celestial travelers fills me with dread. We are firmly in the era of the satellite constellation—groups of dozens of similar satellites—and are currently entering the era of the megaconstellation, wherein groups of thousands of satellites swarm the skies. The clusters of satellites started small, but like a viral outbreak, they grew almost without us noticing—and now we’re dealing with a pandemic.

I wrote about this problem for *Scientific American* in May 2023. At the time, there were 7,500 active satellites orbiting Earth; about 4,000 of them were SpaceX Starlink satellites

that provided Internet service. In the three years or so since then, the number of Starlink satellites in orbit has surpassed 10,000. Today there are more Starlink satellites up there than the sum total of all other operational satellites.

This ratio will almost certainly get more skewed toward Starlink, too; back in 2019, when the first Starlink satellites were launched, SpaceX filed proposals with the Federal Communications Commission for up to 30,000 additional satellites.

Does that sound bad? Well, there may come a day, all too soon, when we’re nostalgic for that small a number of satellites cluttering the sky. On January 30, 2026, SpaceX applied for permission to launch as many as one million more satellites.

Yes, one million.

SpaceX’s plan is for this sprawling megaconstellation to become a distributed network operating as an orbital data center, similar to ground-based data centers that provide the information-processing backbone of the Internet. In this case, instead of having equipment capable of all that processing power stored in massive warehouses, each satellite in orbit would do a small part of the number crunching and then beam the final results back to the ground.

In principle, such plans could ease the insatiable power demands and environmental effects of ground-based centers. In 2023 data centers in the U.S. alone consumed a staggering 176 million megawatt-hours of energy—a little more than 4 percent of the nation’s annual electricity usage and enough to power 16 million homes for a year. Many of these centers are powered by fossil fuels, which add greenhouse gases that worsen global warming into the atmosphere. These centers also need to be cooled, and that process typ-

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Alan Dyer/WPIcs/Alamy

ically requires vast amounts of water. And as the use of computationally intensive artificial intelligence soars, so, too, will the appetite for ever more power—and the potential for ever greater environmental harm.

Exporting most of that “compute” to orbit, SpaceX claims, is the way to break this vicious cycle. And there is some truth to that: The satellites will be solar-powered, easing the electricity demand on Earth. They won’t need water to cool their hot chips and will instead rely on large radiators to vent heat—a slower, less efficient method but the best one available in the near vacuum of space. Currently in-use Starlink satellites cool themselves this way, and the heat load for a satellite used to process data would be roughly the same as for one used to provide access to the Internet, so this problem isn’t the showstopper many people assume it to be.

So if you don’t look too deep, large-scale orbital data centers might make sense. Scratching the surface of this idea, however, shows just how colossally terrible it is.

First, those satellites need to get to space. As astrophysicist Jonathan McDowell, my friend and colleague, points out, SpaceX claims that its Starship rocket will (once it passes testing) be able to take 150 metric tons to low-Earth orbit, but there are good reasons to think the real operational capacity will be more like 100 metric tons. Assuming that low-Earth orbit is in fact where all the satellites will go (although many will undoubtedly need to fly higher) and that each satellite weighs two metric tons, Starship can launch around 50 of them at a time—so creating this megaconstellation even under optimized conditions would require some 20,000 Starship launches.

It gets worse: These satellites will fail after a few years and will need to be replaced. In the end, upkeep for this notional million-satellite megaconstellation could take on the order of 10 Starship launches per day—forever.

The environmental consequences

wouldn’t be trivial. A single Starship launch emits the equivalent of 76,000 metric tons of carbon dioxide, for example—leaving aside issues of noise pollution and potential damage to nearby habitats. Twenty thousand launches would have an immense effect, including more damage to our critical ozone layer. The fiery atmospheric reentries of satellites would be a source of pollution, too, dumping significant amounts of vaporized metal and plastic into our planet’s fragile upper atmosphere. At least one Starlink satellite is already burning up in this way every day, based on when these satellites started entering orbit and their planned replacement cycles—and orbital data centers could make this reentry rate skyrocket.

As if these things weren’t enough, the proliferation of megaconstellations also carries risks for the orbital environment itself. The volume of satellites

In three years the number of Starlink satellites in orbit has gone from about 4,000 to more than 10,000.

already overhead is huge, but the numbers of proposed satellites are so vast that space-traffic management to avoid collisions would become an even more massive task. A single collision in orbit can become catastrophic: These satellites are moving at speeds many times faster than a rifle bullet, and a direct hit from one creates a cloud of shrapnel. That debris spreads, hitting other satellites and creating even more debris, resulting in a violent cascade called the Kessler syndrome. Triggering this sequence of events is already a real concern, despite orbital decay naturally “cleaning” low-Earth orbit over time. Increasing the numbers of satellites by several thousandfold could make this threat apocalyptically worse.

And as an astronomer, I can’t help but worry over the effect on my beloved

field. A study published last December in *Nature* showed that if there were roughly half a million satellites in orbit, at least one would contaminate essentially every observation taken by the Hubble Space Telescope. Ground-based telescopes are already being severely affected. Vaporized debris from reentries will also add to sky glow, making it more difficult to see faint cosmic objects. Even simple stargazing from your backyard would be hindered. In a very real sense, by launching so many satellites, we risk losing the sky.

Keep in mind that SpaceX is not the only satellite maker crowding the sky. China has filed to launch 200,000 satellites for its own network. Other countries and companies will no doubt follow suit; Amazon and Blue Origin already plan on launching thousands of satellites each. Even more concerning is a new company called Reflect Orbital that wants to launch thousands of giant

space mirrors into orbit to provide “sunlight on demand” anywhere on Earth. The beams would be far brighter than the full moon and, even if carefully pointed, would scatter in the atmosphere to be very bright off-beam, disrupting wildlife and effectively destroying the sky’s remaining natural beauty by erasing the stars from our sight. These mirrors are a truly terrible idea.

That’s the common theme here, in fact. Even if we ignore the deeply disturbing environmental and light pollution from all these launches and reentries, there is another consequence. Our night sky—and it is ours—is a natural wonder, a cosmic park we need to preserve, not commodify with a laissez-faire attitude. This careless exploitation of the heavens above is a real danger to us all. ●