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Space jam

More and more satellites are being crammed into Earth orbit, raising collision risks and spoiling our view of the heavens. Can we avert disaster, wonders **Robin George Andrews**

DEEPOL BY PLAINPICTURE/PAUL ZIZKA / TOP:SHUTTERSTOCK/PHONLAMAI PHOTO

Straight lines across the sky like these are caused by the light reflected from satellites as they move

ON 11 July 1979, shards of a space station fell to Earth. Skylab, the first US outpost in space, was supposed to plunge into the ocean 1300 kilometres off South Africa, but it took longer to disintegrate than predicted.

The 77-tonne behemoth overshot its target and exploded 16 kilometres above the Indian Ocean, sending debris into the water and across a 150-kilometre stretch of Western Australia. Thankfully, nobody was injured. But the incident served as a stark reminder that what we launch into space doesn't simply disappear.

Today, there are thousands of satellites in orbit, and the number is growing fast. The concern isn't only that one of these will land on someone's head. Certainly, our rush to fill space above Earth has significantly upped the odds of cataclysmic collisions in orbit that might rain stuff down on us. But space debris – defunct satellites, bits of rockets and fragments scattered by crashes – is only half of the problem. Satellites are unintentional mirrors, reflecting sunlight and obscuring our view of the stars. They are even making it harder to see threats coming our planet's way from outer space.

Many insist that when it comes to such problems, we are approaching a tipping point. "If something doesn't happen, we stand to lose the skies in three years," says Aparna Venkatesan, a cosmologist at the University of San Francisco, California. "The skies will change forever."

The pressure is on for something to change. There is no shortage of people seeking answers, but the big question is: can they be found and applied before it is too late?

We have been littering space for decades. In 1979, when Skylab plunged to Earth, it was one of just over 300 satellites in orbit. In mid 2019, there were roughly 2000 active satellites orbiting Earth. Today, there are more than twice as many as that – not forgetting all the retired satellites still up there.

The US government estimates that there are 23,000 pieces of debris larger than 10 centimetres in diameter in Earth's orbit, and more than half a million pieces smaller than that. Although you might think of it floating around gently, space debris is often moving at speeds in excess of 28,000 kilometres per hour. Moreover, it is hard to track. Whereas active satellites reveal their positions via on-board GPS, dead ones and all other debris can only be tracked by ground-based radar. The smaller stuff is sometimes invisible to such systems.

All of which means there will inevitably be collisions, which can be dangerous for active satellites and increase the chances of bits of debris falling to Earth and causing damage. In 2009, a derelict Russian military satellite slammed into an active one operated by Iridium Satellite LLC, a private US company. Both satellites were destroyed, causing some issues with Iridium's communications service and creating 1800 fragments.

Collisions could be avoided. The Space Surveillance Network, part of a branch of the US military called the Space Force, uses a global array of telescopes and radar systems to track objects and assess the likelihood of two crashing. If one or both are active satellites, another part of the Space Force lets the operators know so that action can be taken, usually by commanding the craft to fire thrusters.

But as low Earth orbit – between 160 and 1000 kilometres up – gets more crowded, this gets trickier. A major collision, perhaps one that will take out some vital satellite infrastructure, is already inevitable. But it could be much worse than that. If you have ever watched the 2013 film *Gravity*, then you have seen the so-called Kessler syndrome in action. This occurs when, beyond a critical threshold of objects in orbit, one collision's spray of debris causes many more collisions, creating an unstoppable cascade.

The problem is that these cascades unfold ›

SHUTTERSTOCK/YURIJ OMELCHENKO, JU JAE-YOUNG

very slowly and it could be centuries before major collisions are happening constantly, says Hugh Lewis, a space debris expert at the University of Southampton, UK. "We're looking out for some sign that this collision cascade has started," he says. "I think that all the evidence points to the fact that it already has. And it probably started decades ago."

If low Earth orbit gets crammed with satellites, and collisions turn that orbital highway into a shooting gallery, "then we've got the issue of trying to get through all this stuff to go to the moon", says John Crassidis, a space debris expert at the University of Buffalo. "Our astronauts are going to be in danger of being hit by this stuff."

One saving grace so far has been that space junk often gets dragged into the lower atmosphere and burns up. Unfortunately, as we have recently discovered, climate change means the rate at which this happens may decline, making orbital overcrowding worse.

In the upper atmosphere, the sun's extreme ultraviolet radiation splits molecular oxygen into two oxygen atoms that collide with carbon dioxide molecules, releasing infrared energy. Adding more carbon dioxide to the upper atmosphere increases this effect. As more infrared energy is released, it escapes into space and so the upper atmosphere cools. In this more frigid environment, the particles lose energy and the upper atmosphere contracts.

This phenomenon was predicted in 1989, and has been observed for some time. But Lewis and his colleagues recently realised it is influencing the lifetime of space junk. When falling orbital debris meets atmospheric particles, the object experiences drag. This causes the size of its orbit to shrink, bringing it closer to the denser, lower atmosphere in which it will eventually be incinerated. The climate change-induced contraction of the upper atmosphere will reduce the drag that debris experiences as it spirals toward us. This means it will stay in orbit for longer.

A recent paper, co-authored by Lewis, found that objects in low Earth orbit will stay up there for 30 per cent longer even if we restrict carbon dioxide emissions to successfully keep the global average temperature rise to 1.5°C this century. On current mitigation pledges, way more CO_2 is heading skyward and we are on track for 2.7°C of warming. This means the time junk stays up there will probably be even longer.

Out of space

As if all that doesn't sound bad enough, we have also found a different way to clutter space – one that has arguably more profound consequences for people back on Earth.

About a third of all the active satellites in space today belong to an internet-providing swarm named Starlink, owned and operated by SpaceX. Having multiple small satellites acting together or sharing orbital planes, known as constellations, isn't a new concept. But the sheer number of Starlink satellites led to a new word, the "megaconstellation".

The rationale for constellations that can cover a large proportion of Earth's surface might seem laudable. The European Union's Copernicus programme, for example, provides free information on marine pollution, deforestation, the movements of refugees, air quality and ice cap melting. California-based

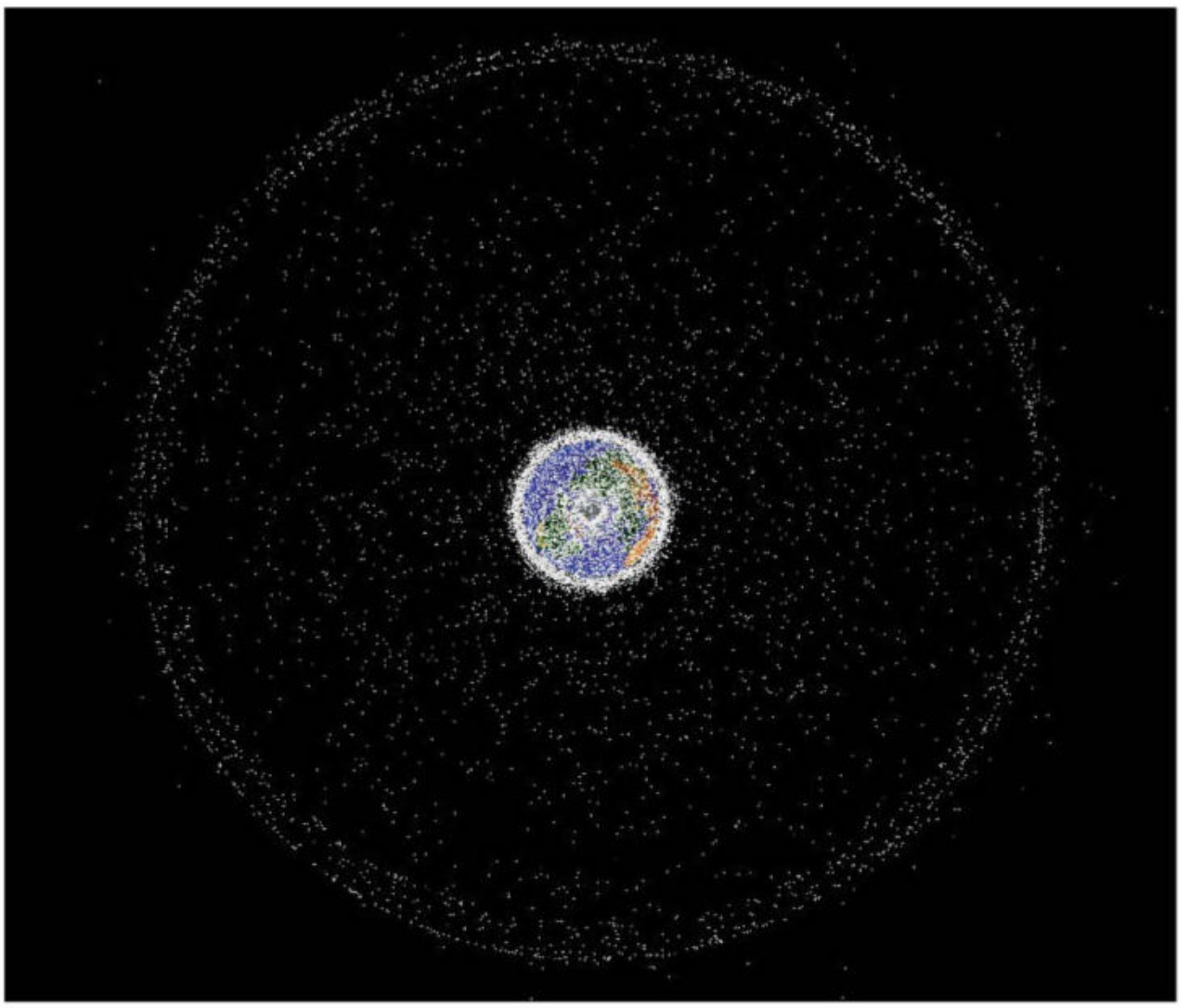
Asteroid watch

There are an estimated 25,000 asteroids 140 metres across or larger near Earth. But around 17,000 of them are missing. "We don't know where they are," says Megan Bruck Syal, a planetary defence researcher at the Lawrence Livermore National Laboratory in California. That is based on sound estimates of the number of such objects. The small ones could wipe out a city; the biggest would wipe out all life on the planet. It is vital they are found.

Astronomers are on the case. To look for potentially hazardous near-Earth objects (NEOs), telescopes are pointed toward the vicinity of the sun not long after sunset or a little before sunrise. During that time, telescopes are pointing in the direction that Earth is moving. That way, you can spot NEOs crossing in front of the planet's orbital path without being blinded by the sun.

Thanks to their positioning in the night sky, that's precisely when satellite constellations like those made by SpaceX are extremely well lit by the sun. City-killing asteroids are already hard to spot as it is. Now, says Syal, we may not be able to see them "because of this extra light pollution". This leads to an absurd possible future in which we miss an Earth-bound space rock because a private company wanted to sell internet access.

"You don't want to miss the one that's going to kill us all," says McDowell. "That would be embarrassing."



NASA ODPO

Space derbis around Earth based on NASA data, as shown looking down on the north pole

company Planet offers similar services. Both aid an array of experts, from academics to emergency managers.

Starlink satellites are one way to get internet access to many remote communities that don't have it. "There's a lot of people in Northern Canada, particularly First Nations, who don't have good internet," says Sam Lawler, an astronomer at the University of Regina in Canada. "Starlink is going to be a huge, huge advantage for them."

The problem is megaconstellation satellites are so bright and so numerous that they threaten to diminish our view of the night sky. "These satellites, on average, are about a billion times brighter than the faintest things astronomers can see," says Connie Walker, an astronomer at NOIRLab, an umbrella organisation for several US-funded observatories.

Simulations show that with 65,000 satellites in the sky – a possible near-future scenario – this kind of light pollution would affect the entire planet. "The stars will still be there, but you'll be looking at them through a grid of moving satellites," says Lawler. Even in once-shadowed parts of the world, the Milky Way and meteor showers could eventually be washed out. Satellites could even obscure our efforts to watch out for incoming asteroids that could kill all life on the planet (see "Asteroid watch", page 44).

"Our astronauts are going to be in danger of being hit by this stuff"

The rush to space also has uncomfortable parallels with centuries of colonisation, where those with the least power suffered the most. Many Indigenous communities still use the night sky for traditions that are now under threat, such as for telling the time, for precipitating sociocultural or religious events and for wayfinding at sea. Even the potential benefits won't reach everyone, as costs are too high for many internet-starved nations. "We shouldn't have to choose between having astronomy and having the internet," says Lawler. Starlink didn't respond to a request for comment.

So how did we end up here, and what can we do about the growing downsides? The UN's Outer Space Treaty, humanity's first attempt at legislating for activity in orbit and beyond, says space is an open realm that anyone can use. But the treaty, which took force in 1967, didn't foresee the rise of private space companies or their constellations. Neither did individual nations. There are no internationally binding laws that apply to the operation of constellations. As long as satellites are doing what they are supposed to, governments can't interfere.

People are taking matters into their own hands. Various groups are experimenting with contraptions that remove debris from orbit. RemoveDEBRIS, a project led by researchers at the University of Surrey, UK, has successfully trialled the capture of debris using spacecraft armed with nets and harpoons. In August 2021, Japanese firm Astroscale managed to recapture a small satellite it launched into space using another craft armed with magnets.

None of these prototypes are trying to capture real debris yet. If they did, they might be pulled along by the momentum of such objects and become another sizable piece of space junk, says Crassidis. Moving between orbital altitudes to capture lots of debris would also require more fuel than these ›

TOP: SHUTTERSTOCK/AAPSKY RIGHT: SHUTTERSTOCK/INGO BARTUSSEK

Satellite trails like these, captured during a meteor shower in Germany, are now a common feature in images of the night sky

"People are trying to survive, and so the skies aren't on their mind"

missions are currently capable of carrying.

Most experts agree that space junk must be regulated on an international level. One option is for different altitude ranges to belong exclusively to different nations and private companies, which would cut down on collisions in the first place. But, politically, an international body that deals with this is difficult to envisage at present.

The future impact of megaconstellations appears just as disheartening. Scientists have held two conferences discussing their impact on astronomy over the past two years, with no agreement on what is best to do. One thing is certain: megaconstellations are here to stay. "We have to accept that the landscape is changing," says Jeffrey Hall, director of Lowell Observatory in Flagstaff, Arizona.

Software may eventually be capable of partially filtering out bright Starlink trails from telescope views, but this won't be a panacea. Eventually, some astronomy done on Earth will move into space, out of the way. But doing that for all observations would be prohibitively expensive. It would also be bad for science "because for the same amount of money, we won't be able to afford nearly as many telescopes", says Jonathan McDowell, an astronomer at the Center for Astrophysics in Cambridge, Massachusetts.

Slow it down

Starlink has worked on dimming its constellation by painting the craft black and, during later launches, by adding a sun-blocking visor. But "there's no way the companies can make the satellites faint enough to be invisible to research telescopes", says Hall. And even if dimming efforts continue to bear fruit, the staggering number of satellites will always present a problem.

Some think confrontation may be a better option. "We're not going to stop them, but we need to slow them down until we regroup grassroots community advocacy, in my opinion, that can partner with professional societies," says Venkatesan. "And we slow them down through lawsuits."

One legal challenge already in the works – based on an argument put forward by attorney Ramon Ryan – involves a law that requires agencies to assess if their future actions are going to cause environmental harm. Minor actions are exempt from this law. The Federal Communications Commission (FCC) – which approves the deployment of US-based commercial satellites – has applied this exception to almost everything it does. This means Starlink launches are exempt, while satellites launched by NASA – another federal agency – do require an environmental review.

Viasat, a Starlink competitor based in California, has launched a court action to try to halt the approval of 3000 Starlink satellites until after an environmental review is conducted. The case is currently working its way through the US Court of Appeals.

Optimistically, the US may one day adopt strict legal mandates on megaconstellations and space junk. But who is to say that China – gearing up for its own megaconstellation – will follow suit? And for the countries that do choose to legislate such actions in space, will the voices of their Indigenous peoples be heeded? History suggests not, but New Zealand provides a hopeful note in this regard. Every branch of the New Zealand government – including its space agency – has to consult the Indigenous Māori communities before doing anything.

The sky can be saved, but the solutions aren't simple. They involve everyone, from all walks of life, and the hourglass is nearly empty. As the covid-19 pandemic has shown us, when a global crisis emerges, "it's much harder to take action later—and much more expensive", says Lewis. "You have to act when it looks like everything is fine."

Venkatesan worries that a confluence of multiple crises – the pandemic, climate change, racial inequality, gender disparities, erosion of democracy – may hobble efforts to salvage the starry night. "People are trying to survive, and so the skies are not on their mind," she says. "Who wants to read about another crisis?" ▮

Robin George Andrews is a freelance writer based in London, UK. For details on his latest book, see page 35