A few Links and Resources on Space

● **HERE The New Space Race Is Causing New Pollution Problems,** ***The New York Times, Jan 2024***
Earth's stratosphere has never seen the amounts of emissions and waste from rockets and satellites that a booming space economy will leave behind.

●**BBC Inside Science – How Green is Space Science? – 26 Sept 2024**
The images beamed back to Earth of the first civilian spacewalk have prompted a very pertinent question from one Inside Science listener: What effect is space travel having on our climate? We're used to delving into the carbon footprint of Earth-bound travel – so this week we're going to explore the impact of the rapidly growing space industry on our climate. How does a rocket launch compare to a flight taking off? Do we even know the true cost yet – and if it's significant, what might the solution be?
https://www.bbc.co.uk/sounds/play/m00237zq

● **Space is Full of Junk. Here's How to Clean It Up…, from Be Smart, PBS, 15 February 2024 (on CAHIER DE PREPA)**
https://www.youtube.com/watch?v=uJcXCdbm77g&ab_channel=BeSmart

● **How giant lasers could get rid of space trash – VOX – February 29 2024**
https://www.youtube.com/watch?v=VQKpMmBDtZo&ab_channel=Vox

● **Can man land, and live, on Mars?**
Our new podcast series explores the mission to the red planet
The Financial Times, October 2025
https://www.ft.com/content/6c3c0272-74c1-4efd-afc5-d6b90f13d8fd?shareType=nongift

The New Space Race

Document 1 - Who owns the Moon? A new space race means it could be up for grabs

BBC News, 9 June 2024
Rebecca Morelle, Science editor You can listen to Rebecca Morelle read her article HERE

We're in the midst of a Moon rush. A growing number of countries and companies have the lunar surface in their sights in a race for resources and space dominance. So are we ready for this new era of lunar exploration?

This week, images were beamed back to Earth of China's flag unfurled on the Moon. It's the country's fourth landing there - and the first ever mission to return samples from the Moon's far side. In the past 12 months, India and Japan have also set down spacecraft on the lunar surface. In February, US firm Intuitive Machines became the first private company to put a lander on the Moon, and there are plenty more set to follow.

Meanwhile, Nasa wants to send humans back to the Moon, with its Artemis astronauts aiming for a 2026 landing. China says it will send humans to the Moon by 2030. And instead of fleeting visits, the plan is to build permanent bases.

But in an age of renewed great-power politics, this new space race could lead to tensions on Earth being exported to the lunar surface.

"Our relationship with the Moon is going to fundamentally change very soon," warns Justin Holcomb, a geologist from the University of Kansas. The rapidity of space exploration is now "outpacing our laws", he says.

A UN agreement from 1967 says no nation can own the Moon. Instead, the fantastically named Outer Space Treaty says it belongs to everyone, and that any exploration has to be carried out for the benefit of all humankind and in the interests of all nations.

While it sounds very peaceful and collaborative - and it is - the driving force behind the Outer Space Treaty wasn't cooperation, but the politics of the Cold War.

As tensions grew between the US and Soviet Union after World War Two, the fear was that space could become a military battleground, so the key part of the treaty was that no nuclear weapons could be sent into space. More than 100 nations signed up.

But this new space age looks different to the one back then.

One major change is that modern-day Moon missions are not just the projects of nations - companies are competing, too.

In January, a US commercial mission called Peregrine announced it was taking human ashes, DNA samples and a sports drink, complete with branding, to the Moon. A fuel

leak meant it never made it there, but it sparked debate about how delivering this eclectic inventory fitted in with the treaty's principle that exploration should benefit all humanity.

"We're starting to just send stuff up there just because we can. There's no sort of rhyme or reason anymore," says Michelle Hanlon, a space lawyer and founder of For All Moonkind, an organisation that seeks to protect the Apollo landing sites. "Our Moon is within reach and now we're starting to abuse it," she says.

But even if lunar private enterprise is on the increase, nation states still ultimately remain the key players in all this, Sa'id Mosteshar, director of the London Institute of Space Policy and Law, says any company needs to be authorised to go into space by a state, which will be limited by the international treaties.

There's still a great deal of prestige to be had by joining the elite club of Moon landers. After their successful missions, India and Japan could very much claim to be global space players.

And a nation with a successful space industry can bring a big boost to the economy through jobs, innovation.

But the Moon race offers an even bigger prize: its resources.

While the lunar terrain looks rather barren, it contains minerals, including rare earths, metals like iron and titanium - and helium too, which is used in everything from superconductors to medical equipment.

Estimates for the value of all this vary wildly, from billions to quadrillions. So it's easy to see why some see the Moon as a place to make lots of money. However, it's also important to note that this would be a very long-term investment - and the tech needed to extract and return these lunar resources is a some way off.

In 1979, an international treaty declared that no state or organisation could claim to own the resources there. But it wasn't popular - only 17 countries are party to it, and this does not include any countries who've been to the Moon, including the US.

In fact, the US passed a law in 2015 allowing its citizens and industries to extract, use and sell any space material.

"This caused tremendous consternation amongst the international community," Michelle Hanlon told me. "But slowly, others followed suit with similar national laws." These included Luxembourg, the UAE, Japan and India.

The resource that could be most in demand is a surprising one: water.

"When the first Moon rocks brought back by the Apollo astronauts were analysed, they were thought to be completely dry," explains Sara Russell, professor of planetary sciences at the Natural History Museum. "But then a kind of revolution happened about 10 years ago, and we found out that they've got little traces of water in them trapped in phosphate crystals."

And at the Moon's poles, she says, there's even more - reserves of water ice are frozen inside permanently shadowed craters.

Future visitors could use the water for drinking, it could be used to generate oxygen and astronauts could even use it to make rocket fuel, by splitting it into hydrogen and oxygen, allowing them to travel from the Moon to Mars and beyond.

The US is now attempting to establish a new set of guiding principles around lunar exploration - and lunar exploitation. The so-called Artemis Accords state that extracting and using resources on the Moon should be done in a way complies with the Treaty for Outer Space, although it says some new rules might be needed.

More than 40 countries have so far signed up to these non-binding agreements, but China is notably absent from the list. And some argue that new rules for lunar exploration shouldn't be led by an individual nation.

"This really ought to be done through the United Nations because it affects all countries," Sa'id Mosteshar tells me.

But access to resources could also cause another clash.

While there's plenty of room on the Moon, areas close to ice-filled craters are the prime lunar real estate. So what happens if everyone wants the same spot for their future base? And once a country has set one up, what's to stop another nation establishing their base a bit too close?

"I think there's an interesting analogy to the Antarctic," says Jill Stuart, a space policy and law researcher at the London School of Economics. "We'll probably see research bases being set up on the Moon like they are on the continent."

But specific decisions about a new lunar base, for example whether it covers a few square kilometres or a few hundred, may come down to whoever gets there first.

"There will definitely be a first-mover advantage," Jill Stuart says.

"So if you can get there first and set up camp, then you can work out the size of your zone of exclusion. It doesn't mean you own that land, but you can sit on that space."

Right now, the first settlers are most likely to be either the US or China, bringing a new layer of rivalry to an already tense relationship. And they are likely to set the standard - the rules established by whoever gets there first may end up being the rules that stick over time.

If this all sounds a bit ad hoc, some of the space experts I've spoken to think we're unlikely to see another major international space treaty. The dos and don'ts of lunar exploration are more likely to be figured out with memorandums of understanding or new codes of conduct.

There's a lot at stake. The Moon is our constant companion, as we watch it wax and wane through its various phases as it glows bright in the sky.

But as this new space race gets under way, we need to start thinking about what sort of place we want it to be - and whether it risks becoming a setting where very Earthly rivalries are played out.

1390 words

► **See also: For the first time in half a century, astronauts are going back to the Moon**
The Economist, January 28th, 2026
https://www.economist.com/interactive/science-and-technology/2026/01/29/for-the-first-time-in-half-a-century-astronauts-are-going-back-to-the-moon

Guest Essay

Document 2 - Don't Cede the Space Race to China and the Billionaires

The New York Times, Feb. 18, 2022 By Jeff Shesol

Credit...Golden Cosmos

Mr. Shesol, a historian, has written extensively about the space race. His most recent book is about John Glenn and NASA's Project Mercury.

Leer en español

The crowds that cheered the astronaut — about a quarter-million in Washington, four million in New York — adorned themselves in numerous ways. Some wore space helmets fashioned from cardboard and plastic. Others, less showily, wore buttons *proclaiming John Glenn* "the New Frontier man of the year," a nod to John F. Kennedy's famous phrase. Sixty years ago, Glenn became the first American to orbit Earth, opening up the frontier of human exploration in space — a frontier that stretched to the moon and beyond. The flight of Friendship 7 made it all seem possible.

Glenn's feat marked the start of a spectacular decade: spacewalks, trips around the moon, *six lunar landings*. Then the frontier receded. Since 1972, no human being has ventured outside Earth's orbit. A generation has reached middle age without any memory of Americans on the moon.

That could change soon. If *NASA's plan* holds, its Artemis program will land the first woman and the first person of color on the moon in 2025. And this, NASA says, is just the beginning. The agency envisions *at least 10* lunar landings. Its administrator, Bill Nelson, is waging a campaign to beat other nations in placing "*boots on the moon*" — not just boots but also, in time, a base. And "the sooner we get to the moon," *NASA has said*, "the sooner we get American astronauts to Mars."

But why bother? There is certainly much of interest on Mars — *NASA's newest rover, Perseverance*, and its companion, the tiny helicopter Ingenuity, have made that clearer than ever. What is less evident is the role, the value, of human explorers. To most Americans, machines seem sufficient to the task. A *Morning Consult poll* last year showed a general interest in space exploration but not in having humans do the exploring. (…)

Mr. Nelson has been making a persistent pitch for funding, but Congress appears unpersuaded. President Biden, for his part, has signaled support for Artemis but is more focused on the *nation's commercial and military capabilities in space*, as well as the vantage point that space provides to observe climate change. Vice President Kamala Harris, the chair of the National Space Council, rarely mentions human spaceflight, *stressing* instead "the responsibility to look to our home planet."

And reasonably so. Our planet has plenty to worry about, not least the damage we do to its atmosphere. But there is an argument to be made for the human exploration of space — a better argument, at least, than the White House and NASA have put forward. If the administration fails to sharpen and press its case, if it shies from insisting that humans, not just our inventions, should roam the heavens, the United States will likely cede the moon — and a good deal more than that — to more determined competitors.

Chief among them is China. Its goal is plain: to become a "great space power," *as President Xi Jinping has said*. China's Mars rover, arriving on the heels of our own, has been an impressive success; China also has a *probe on the far side of the moon* — a first for any nation. Its space station is nearly complete, while the International Space Station, after more than two decades orbiting Earth, approaches obsolescence and NASA turns to *private companies to build and run its successors*. Like the United States, China hopes to build

a research station *on the lunar surface*. Unlike the United States, China gives no reason to doubt its resolve. It will also have a partner: *Russia*. The two countries have already begun to *align their efforts*.

Mr. Nelson cites an "aggressive" China as a reason for Americans to "get off our duff," but a few national security questions require a fuller airing. What if, for example, China stakes out strategic positions on the moon? What if it asserts control over the resources it and other nations are searching for there: silicon, titanium and, not least, the water that is needed to sustain a human settlement? As Namrata Goswami, an expert on China's space policy, *has argued*, "An advantage in accessing the vast wealth of the inner solar system could have an effect on the balance of power" on Earth.

If anyone is as bullish on the new frontier as China, it is the billionaires. Their ambitions, too, should spur NASA to stay in the game. Jeff Bezos and Elon Musk might or might not be visionaries, but they are easily the most powerful people on this planet to speak with a straight face about colonizing other ones. Mr. Musk *warns* of an "extinction event" that will require us to leave Earth behind. There is a certain egalitarianism in the idea of an escape hatch for humanity, though it is the egalitarianism of rats leaving a sinking (or overheating) ship. It would have to get pretty bad down here before ordinary people follow the billionaires into the black void of space rather than bid them adieu (…)

Of course, this takes nothing away from the achievements of Mr. Musk's aerospace company, SpaceX. Rarely in any industry has such boldness of imagination been matched by such brilliance in execution. The company is an indispensable partner to NASA; a SpaceX *landing system* will carry astronauts to and from the moon's surface.

But there is an essential difference between exploration and colonization, and both are a far cry from commercialization. Left to the billionaires, space is less likely to become a haven for humanity than a playground for its wealthiest members. In that event, there will be no more John Glenns — no more astronauts to look up to and emulate, astronauts whose humility and awe in the vastness of space define them as much as their bravery does. (…)

Science "is simply the exploration of the unknown," James Head, a planetary geologist at Brown who helped train the Apollo astronauts, told me, adding that "the moon is unknown. Mars is unknown." Perhaps this is what NASA should say, and without apology: We don't know what we'll find. We don't know what the moon and Mars can tell us about the origins of the universe and life on Earth and possibly beyond it. And that, above all, is the reason for going. 1033 words

Document 3 - Europe is struggling to compete in the second space race

Its governments are starting to take action

Photograph: Reuters

The Economist, Nov 27th 2025|OTTOBRUNN|3 min read

As commercial and military interest in space continues to grow, many in Europe are keenly aware of the risk of being left behind. As *The Economist* went to press, the European Space Agency (ESA) was holding its latest triennial gathering, during which ministers from the agency's 23 member countries will decide on the agency's budget—its leaders hope for at least €22bn ($26bn), up from €17bn in 2022—and its main programmes for space exploration and Earth observation. The gathering may be the most consequential in ESA's 50-year history.

Globally, the space business is booming. A study by Roland Berger, a consulting firm, and the Association of German Industry (BDI) forecasts that the overall market will grow from around €470bn in 2024 to €2trn by 2040, or around 9% a year. That figure includes spending by governments and research organisations, as well as companies that rely, for example, on satellite communications.

Next to America, however, Europe is a tiddler when it comes to the space business. The American government spends $77bn a year on space; Kai-Uwe Schrogl, a special adviser to Josef Aschbacher, the boss of ESA, puts European spending at around $10bn. And Europe's private space enterprises are lightyears behind the likes of Elon Musk's SpaceX, which last year accounted for over half of all rocket launches worldwide.

Still, ESA is managing to boost interest in Europe's space industry. It has signed agreements with 72 investors, including venture-capital firms, banks and public institutions. Last year European space startups raised over €1.5bn, 56% more than in 2023. ESA estimates that from 2019 to 2024 the share of global private investment in space captured by European companies grew from 3% to 22%, thanks largely to interest from defence customers.

Germany, Europe's biggest economy and long home to several space startups, is also looking to boost investment in the industry. This month the government presented its first space strategy, promising to allocate €35bn to military space technology by 2030. Isar Aerospace, which makes rockets for satellites at Ottobrunn in "Space Valley", an industry cluster near Munich, is among those hoping to benefit from the spending. Its first rocket, launched in Norway in March, crashed into the sea after 30 seconds, but has provided valuable data for another launch planned in the next few months.

Germany's neighbours are also doing more. This month France unveiled a new space strategy of its own. In October, after years of deliberation, Airbus and Thales, both based in France, and Italy's Leonardo agreed to merge their space businesses. The model for the joint venture is MBDA, a missile-maker created in 2001 by Airbus, Leonardo and BAE Systems, a British defence company.

Europe is eager to reduce its dependence on America's capabilities in space. For example, the continent would like to wean itself off Starlink, SpaceX's satellite-internet service, which has been vital to Ukraine's defence effort. Yet that will not be easy. France's Eutelsat, which runs OneWeb, a Starlink rival, also operates in Ukraine with German funding, but cannot match its scale or prices. In December last year the EU launched a €10.6bn initiative to develop iris2, another satellite constellation. But it will have only 290 satellites against Starlink's current 9,100, and will be operational in 2030 at the earliest.

Europe has already done admirable things in space: Mr Schrogl points to Copernicus, an Earth-observation programme, and Galileo, a satellite-navigation system more accurate than America's GPS. The continent may never match America commercially in space—but more than money is at stake. ■

Document 4 - U.S. Is Losing Race to Return to Moon, Critics Say, Pointing at SpaceX

The company's Starship rocket, which has suffered a series of recent test explosions, is still years away from being ready for the mission, former NASA executives say.

By Eric Lipton

The New York Times, Sept. 20, 2025

Elon Musk has a history of making promises to rapidly deliver technological breakthroughs, only for them to end up taking longer than predicted or to fail to materialize.

Among these are his promises for fully autonomous self-driving cars or tunnels under Los Angeles to solve traffic congestion. Now some federal government officials worry that his pledges for landing astronauts on the moon will suffer similar delays.

That is why one of the largest federal contracts Mr. Musk has ever secured is now under intense scrutiny: a multibillion agreement with NASA for this crewed mission to the moon, the first in more than five decades.

The plan to invite private companies to develop a lunar lander for NASA was kicked off with much fanfare during President Trump's first term, with a target of completing the mission by last year.

Other parts of the NASA moon mission are nearly ready, after their own delays and cost overruns, and are set to be subject to a full-scale flight around the moon with astronauts next year. But SpaceX's lunar lander project is now so far behind schedule that there are increasing doubts the United States will beat China, which has its own plan with a targeted landing date of 2030, back to the moon.

The concerns, which have reached the White House, follow the falling out between Mr. Musk and President Trump, which led to a call by Mr. Trump and others inside the administration to at least initially look for SpaceX contracts to pare back or cancel.

But seven current and former senior NASA officials, in recent public statements and interviews with The New York Times, said their questions about SpaceX and its new Starship rocket had nothing to do with the public spat between the president and his biggest campaign donor.

Rather, they are nervous that Mr. Musk has once again overpromised on what he could achieve by now.

The 15-story-tall Starship has not yet carried any astronauts or commercial cargo. It has exploded during three of its four recent tests, sending a spectacular but potentially dangerous plume of debris over the Caribbean on two of those aborted trips to space. And its current version can carry only a fraction of its promised payload of at least 100 tons into low-Earth orbit.

Making matters worse, they say, Mr. Musk's plan to carry two astronauts to the surface of the moon relies on a never-attempted refueling in space that the former NASA engineers say is so risky and behind schedule that it could be years before it is ready for the moon mission, meaning China is likely to get an astronaut there before the United States.

"This is not anything against SpaceX — they have done incredible things," said Douglas Loverro, who served as the head of NASA's human spaceflight division early in Mr. Trump's first term. "But the further you move from known technology, the longer it takes to go ahead and get something done."

Mr. Musk has missed a number of his own announced deadlines for the lunar project. For example, he predicted, and NASA announced, that SpaceX would attempt its first ship-to-ship fuel transfer test early this year, but that has now been delayed until at least 2026.

Mr. Musk, in remarks this month, expressed confidence that the Starship project continued to make progress.

"Unless we have some very major setbacks, SpaceX will demonstrate full reusability next year, catching both the booster and the ship, and being able to deliver over 100 tons to a useful orbit," Mr. Musk said during a podcast, referring to three of SpaceX's goals.

NASA is currently targeting 2027 for its mission, Artemis III. That will rely on a separate Space Launch System rocket, built by contractors other than SpaceX, to carry a spacecraft called Orion to get the astronauts to lunar orbit. The astronauts will then be transferred to SpaceX's Starship for the moon landing — a sequence that is much more complicated than earlier NASA moon missions.

But privately, NASA officials are already acknowledging that the mission date is likely to slip to 2028. Mr. Loverro and other former NASA officials predicted that Starship, given its current challenges, would not be ready for its part of the moon mission until perhaps 2032.

Part of the problem, former NASA officials acknowledge, is they chose an excessively complicated lunar landing plan, starting during Mr. Trump's first term. Trump administration officials back then did not take up a proposal to construct a lander based on existing, proven technology, said Mr. Loverro, who helped devise the alternative lander proposal starting in late 2019 when he joined NASA.

The White House liked the commercial approach. It shifted NASA toward the goal of buying space travel as a service, instead of the agency directly overseeing the work plan. That was less expensive and had a fixed price, avoiding the possibility of federal cost overruns, Mr. Loverro and a second former NASA official then involved in the deliberations said. But the SpaceX plan meant far more risk.

"I was not firm enough in pushing what I should have pushed," Mr. Loverro said in an interview this month.

Transportation Secretary Sean Duffy, the acting NASA administrator, said in a statement to The Times that he was standing by the current SpaceX plan.

The company, Mr. Duffy said in a recent interview with CBS News, has proved skeptics wrong before. In the process, it has built itself into the most important launch provider in world history. SpaceX's workhorse Falcon 9 rocket has already carried nearly 120 successful missions to orbit this year.

"Secretary Duffy is focused on executing Artemis III under the current, long-planned architecture," NASA said in a statement to The Times, adding that Mr. Duffy was "focused on ensuring we do everything we can at NASA to meet our targets and hold our commercial partners accountable to fulfill their contractually obligated deadlines."

SpaceX did not respond to requests for comment.

Mr. Musk has acknowledged that SpaceX must clear considerable hurdles to get Starship fully operational, calling his effort "a candidate for most difficult engineering project ever." But when discussing Starship, Mr. Musk is almost always focused on his eventual plans to take humans to Mars, not the moon mission, for which SpaceX has been paid about $3 billion.

"There are thousands of engineering challenges that remain for both the ship and the booster," Mr. Musk said last month in a webcast from SpaceX's offices before the most recent full-scale Starship test, its 10th such attempt, which was considered a success. Perfecting the heat shield on the Starship, so it can survive the fiery return to earth and quickly be reused, is one of the biggest challenges, he said.

NASA realized when it hired SpaceX that the company was taking on an enormous feat.

"SpaceX's mission depends upon an operations approach of unprecedented pace, scale and synchronized movement of the vehicles in its architecture," NASA said in its official selection statement in 2021, when it formally picked Starship.

The lander mission is supposed to place two astronauts at the south pole of the moon, where they would remain for about a week before being carried again by Starship to lunar orbit, then return to Earth in the Orion capsule.

All of the stages of the Artemis III project have encountered delays. The Orion and Space Launch System, built by a group of contractors including L3Harris Technologies, Boeing and Lockheed Martin, are also billions of dollars over budget.

But the Starship piece is considered by most former NASA officials to be the riskiest, and most likely to face significant additional delays. That is because it is responsible for the largest number of unproven technological advances necessary to complete the mission, according to a NASA report last year.

These include a reusable Starship two-stage rocket system, the largest ever built. It also requires Starship launchpads and other ground operations that can handle 15 or more rapid-in-succession launches needed to refill the Starship tanks once they get to orbit, which creates considerable risk for an accident.

Landing such a tall rocket — Starship moon lander will be about 165 feet, compared with the Apollo Lunar lander that was 23 feet tall — means it can carry much more cargo, but it creates greater risk that Starship could topple once it arrives on the moon, Mr. Loverro said.

After it has all the pieces built, SpaceX still needs to fly at least one uncrewed mission to the lunar surface to prove it can work, adding more time.

"This is all important technology that I agree we're going to need when we go to Mars, for sure," said Douglas Cooke, who spent nearly four decades at NASA before retiring in 2011, and has recently served on a NASA independent review team and as a consultant to Boeing. "But it's in the path of trying to get back to the moon quick."

Mr. Loverro, Mr. Cooke and a third former senior NASA official, Daniel Dumbacher, in an opinion piece in SpaceNews this month, argued that NASA needed to devise a new plan to get quickly to the moon. "If a 'Plan B' is needed,

that planning needs to start now," they said, or the United States will lose the race back to the moon.

This could include reviving the earlier plan for a simple, proven lunar lander design that could be built in about five years and not require orbital refueling, the former NASA officials said.

Without such a shift, the United States is likely to lose the race, the former NASA officials predicted.

"I doubt that's going to be accomplished by 2030," Mr. Dumbacher said of the SpaceX moon landing plan in an interview, "and that makes it likely that China will beat us to the moon."

Mr. Duffy reacted angrily to these recent predictions that the United States was behind China, in part because of Starship delays.

"We are going to beat the Chinese to the moon," Mr. Duffy said, according to a recording of a virtual town hall meeting with NASA employees this month. "We are going to make sure that we do this safely. We're going to do it fast. We're going to do it right."

William Gerstenmaier, an aerospace engineer and a former NASA senior administrator who is now a top SpaceX executive, said in a speech this month that by next year an uncrewed Starship would have made a full orbit of the earth, for the first time.

Again his focus was on Mars, another planned mission where Mr. Musk has made bold predictions for how quickly he might get there.

"Ultimately, SpaceX is about really Mars," Mr. Gerstenmaier said. "And that's what we're trying to do."

Kenneth Chang contributed reporting.

Eric Lipton is a Times investigative reporter, who digs into a broad range of topics from Pentagon spending to toxic chemicals.

Document 5 - The big ambitions of China's private space industry

Chinese firms race to catch up with SpaceX

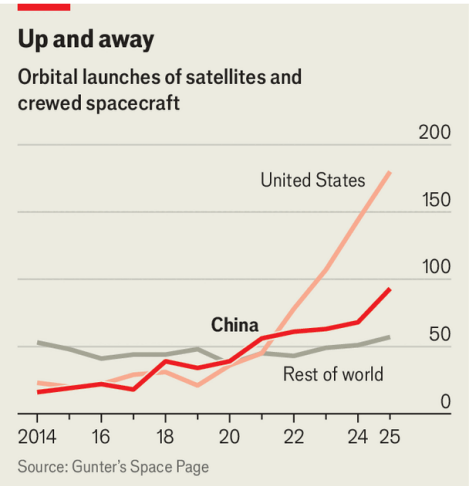
The Economist, Jan 11th 2026 | Beijing

AROUND A DECADE ago Xi Jinping said he dreamed of making China a "space power". Since then, the country has put a rover on Mars and built one of the two operational space stations orbiting Earth. Now its private space industry aims to make an even bigger impact. China's companies may, for the first time in their histories, successfully recover the first stage of a rocket—a vital step for slashing launch costs. This would open a galaxy of opportunity. Meanwhile, new private launchpads will be completed, new satellite factories will ramp up production and a new government department will funnel more state resources into the industry.

China's space firms still lag behind rivals abroad (see chart). None of the 600 companies in the Chinese sector towers over it as Elon Musk's SpaceX does in America, though a clutch of entrepreneurs have emerged who hope to. Among the most prominent are Zhang Changwu, a former financier, and Kang Yonglai, an engineer, who respectively founded LandSpace and Space Pioneer, two launch companies. China conducted nearly 100 orbital launches in 2025, but its private firms were responsible for only 16 of these. (America, meanwhile, conducted 180 launches, of which SpaceX managed over 160.)

Eyes on the stars

The global space economy—which grew from $300bn to about $600bn over the past decade and is projected to triple again in size by 2035—is still dominated by America, even as China makes gains in other high-tech industries. Still, China's commercial space industry shares advantages with other high-tech sectors: lots of engineers, ambitious entrepreneurs and a supportive government that deems it a strategic necessity. So it is probably a matter of when, not if, China will catch up.



Despite heady ambition, almost all of China's launches still rely on the "Long March" series of rockets built by the state-owned China Aerospace Science and Technology Corporation (CASC). They are reliable workhorses. But much of CASC's capacity is taken up serving the needs of China's civil and military space programmes. And as a government-run body, it is risk-averse and so has less incentive to bring costs down. On average a customer would have to pay about 60,000 yuan ($8,600) to get a kilogram of cargo from a Chinese space port to low-earth orbit (LEO), which is easier to reach than higher orbits and a good spot for commercial satellites because, being closer to Earth, they can provide data faster.

The Falcon 9, SpaceX's standard rocket, can get a kilogram to LEO for around a third of that price. It is large and its booster can be captured after use, refilled with fuel, and fired up again. SpaceX got the hang of launching such rockets back in 2017, and is now testing a vast new space vehicle called Starship, which could get many more—or much bigger—satellites into orbit with every launch. Chinese companies

have so far built only one-time-use rockets, which are more expensive.

But that is changing. In December both CASC and LandSpace test-launched reusable rockets (named the Long-March 12A and the Zhuque-3, respectively). In both cases the reusable booster stage exploded before being recaptured, but the non-reusable second stage still reached orbit successfully. In 2026 Space Pioneer is expected to test its reusable Tianlong-3 vehicle. Reusable rockets from several other companies are probably also going to try their luck. "Making rockets is still very complicated," drily notes Jiang Luye, the chief technology officer at Arktech, a rocket company based in Beijing.

Cheaper reusable rockets would hugely increase China's capabilities in space. Chinese firms could quickly build large constellations of satellites in LEO. So-called "megaconstellations" are needed to provide global satellite internet coverage. China has two in the works: Guowang, which is projected to use 13,000 satellites, and the "Thousand Sails", which will use 15,000 of them. At the moment both have only around 100 satellites apiece (Mr Musk's Starlink constellation has over 9,000). But more are on the way.

Finding consumers for the services of all these satellites may be a challenge. Starlink says it has 8m subscribers worldwide, with around a third in America, where there are plenty of rural areas with poor ground-based internet coverage. But it is more complicated for China. Most of the country already gets cheap zippy internet from domestic telecom providers, while those who live in more remote areas are probably not able to afford satellite internet. Western countries are wary of getting their internet beamed in from Chinese platforms; potential customers in developing ones might find the service too costly.

All this creates a "chicken-and-egg" problem, explains Blaine Curcio, an industry consultant. Without lots of demand for satellites in orbit, it is hard to justify the big investments in rocket launches that could bring down the costs of getting them up there. "Only when the data and information generated by satellites can be truly used on a large scale…will subsequent links in commercial spaceflight (including rockets, engines, launch pads, etc) see faster development," says a spokesperson from Orienspace, a rocket company based in Shandong province in eastern China.

Still, there are signs that demand might be heating up. In December Airbus, a European planemaker, signed a deal for China's "Thousand Sails" to provide internet during flights. Geely, a Chinese auto giant, is launching a constellation of several dozen satellites to help its cars navigate. Huawei and Xiaomi, two Chinese tech firms, have started including satellite call functions in their smartphones.

China hopes its firms move into more speculative businesses too, such as space tourism and space-based biomanufacturing (cells behave differently in micro-gravity, which might help with developing drugs). On December 13th AZSpace, a private launch company, sent a spacecraft into orbit carrying cargo including yeast, plants and probiotics for experiments.

Controlled explosion

However successful Chinese space companies become, there is no chance China will allow one of them to amass the power enjoyed by the largest such American firms (NASA now relies entirely on SpaceX and other private firms for launches). But China does want to integrate private businesses more efficiently into government plans. In November the China National Space Administration set up a new department to oversee commercial space and released a two-year plan to support the sector. The plan calls for opening state facilities (like rocket-test stations) to private companies and creating a national fund to invest in commercial space. It will also allow private companies to bid for projects under China's civil space programme.

When China's space firms do take off, they may bring more than just economic benefits. Many of the technologies they are trying to master have military uses, too: from providing communications to removing unwanted satellites. Last month Chinese officials claimed Starlink and other foreign constellations present "pronounced safety and security challenges". On December 13th Starlink claimed that a recently launched Chinese satellite came "dangerously close" to one of its own. Some day a Chinese satellite internet provider might help China's armed forces co-ordinate an invasion of Taiwan, reckons Steven Feldstein of the Carnegie Endowment for International Peace, a Washington-based think-tank. ■

Environmental impact

Document 6 - Satellite boom obscures view of distant galaxies

Light pollution from growing number of spacecraft is degrading images from space telescopes

Michael Peel in London, ***The Financial Times***, DEC 3 2025

A boom in satellites is brightening the night sky and hindering astronomers' ability to study distant galaxies, sharpening concerns over who controls access to space.

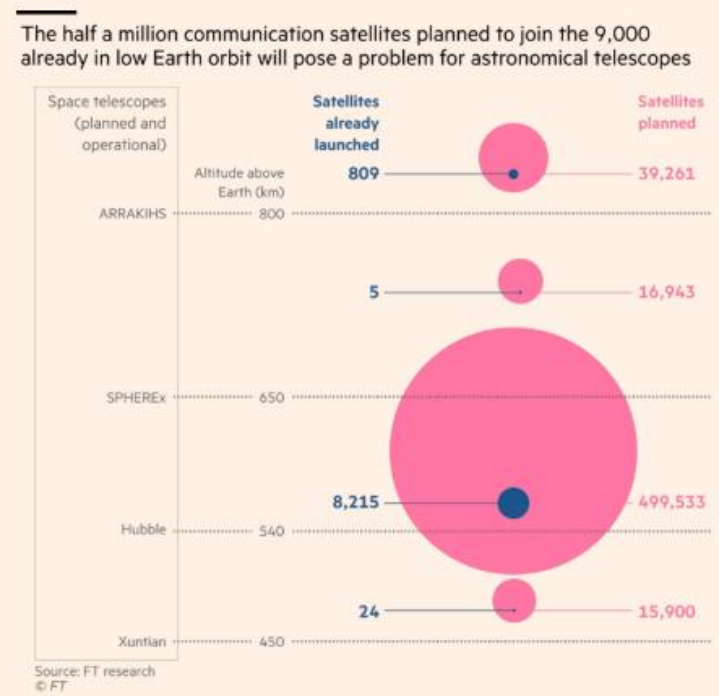
Planned spacecraft launches are surging and will degrade images from major space observatories including the Hubble telescope, according to research from Nasa scientists.

The findings highlight how a lack of international rules threatens crucial astrophysical measurements taken from both Earth and outer space. The constellations of spacecraft reflect light that can interfere with telescopes' images.

“An alarming increase in the rate of satellite trails is being detected in telescopes of all types,” said Alejandro Serrano Borlaff, a Nasa researcher and co-author of the research published in Nature on Wednesday. “[Our] forecast should be seen as a worst-case scenario and as a cautionary warning for the scientific community.”

The number of satellites orbiting the Earth is growing rapidly, as governments and companies such as Elon Musk’s Starlink rush to set up their own constellations to meet rising demand for wireless connectivity. Cheaper production and the growing value of the data that satellites collect are also driving the trend.

The scientists examined the impact of the rapid rise in the number of satellites, which is forecast to grow rapidly from about 15,000 today. About 100,000 could be in orbit by 2030, the European Space Agency has estimated. The number could top 500,000 by the end of the 2030s if all filings to the US Federal Communications Commission lead to launches, the Nasa researchers said.



The researchers ran simulations of the effects on four space-based telescopes operating or planned for low Earth orbits between 400km and 800km — Nasa’s Hubble and SPHEREx, the European Space Agency’s proposed ARRAKIHS and China’s planned Xuntian. They found that 560,000 satellites would contaminate about 39.6 per cent of Hubble’s images and more than 96 per cent of images from the other three.

For 100,000 satellites, almost 20 per cent of Hubble’s output would be affected, rising to more than 80 per cent for the rest. The results echoed previous research that suggested satellite proliferation was causing the “outright vandalism of cutting-edge astronomical research”, said Jeff Grube, senior lecturer in the physics department at King’s College London.

The findings were “alarming” and could affect all areas of study from galaxies to stars and dark matter, said Noelia Noël, senior lecturer in astrophysics at the University of Surrey.

“Satellite trails don’t just make ugly streaks,” said Noël, who is leading a pioneering experiment to reduce satellite light pollution through the use of non-reflective coatings. “They add noise, scattered light and saturation that can wipe out the very faint signals we care about.”

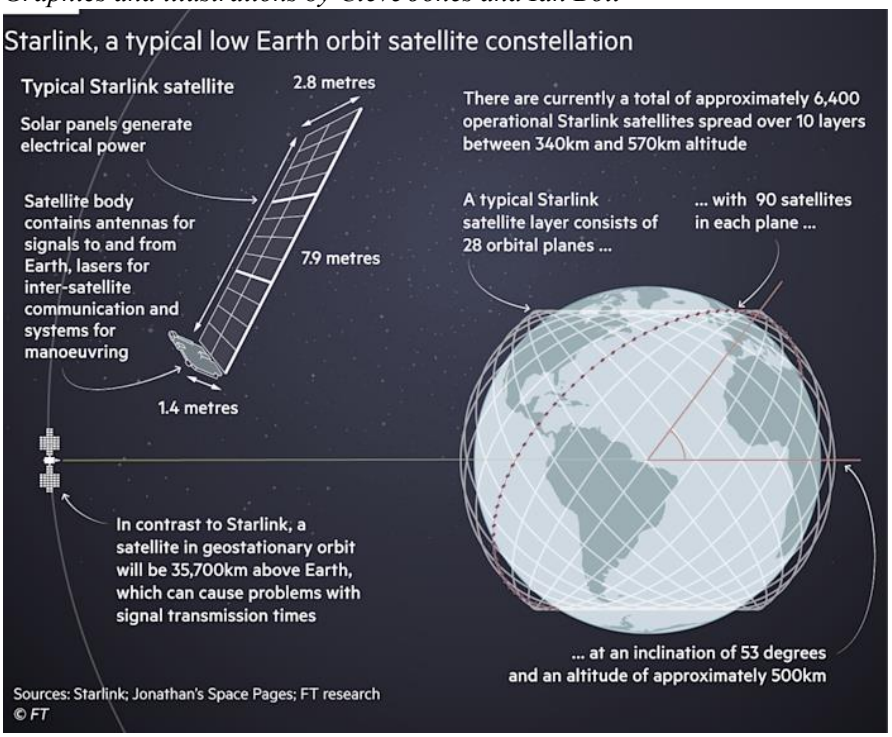
The question of what to do about light pollution is wrapped up in the much bigger subject of the regulation of governmental and commercial activities in outer space. The scientists suggest deploying satellites at orbits below those of the telescopes, although they acknowledge this could produce chemicals that deplete Earth’s ozone layer.

This and other potential solutions all come with their own problems, said David Clements, associate professor of astrophysics at Imperial College London. These include imposing a light pollution levy on satellite operators, or making less use of space-based internet and more of wired connections on Earth.

“What is needed is a proper regard of low Earth orbit as a commons for all humankind to share, with proper oversight and regulation with teeth, rather than a resource to be strip-mined for short-term corporate and nationalistic profit,” Clements said. Scientists and some countries are pressing for light pollution to be tackled by the UN, said Robert Massey, deputy executive director of the UK Royal Astronomical Society.

"Governments and certainly international organisations are outpaced by the rate at which satellites are being launched," Massey said. "If we want to preserve astronomy and prevent wider environmental harm, that needs to change."

Graphics and illustrations by Cleve Jones and Ian Bott



Environment

Document 7 - We're about to turn night into day. Is that a good idea?

Proposals before the FCC involve mirrors that could bathe entire cities in sunlight and, from SpaceX, a million satellites to serve as data centers.

The Washington Post, February 27, 2026 Column by Dana Milbank

In the beginning, the Bible tells us,

God divided the light from the darkness.

And God called the light day, and the darkness He called night.

And so it has been ever since — until now.

Here in the 21st century, we humans are on the cusp of turning night into day — and bidding good night to the stars that have guided us home for thousands of years.

Two little-noted applications under review by the Federal Communications Commission would, if fully implemented, fundamentally remake the night sky. But the FCC, the satellite regulator, appears to have fast-tracked approval without much of a pause to weigh the benefits of these proposals against the harms they could cause to life on the planet.

A start-up called Reflect Orbital proposes to use large, mirrored satellites to redirect sunlight to Earth at night, with plans to bathe solar farms, industrial sites and even entire cities in light that could, if desired, reach the intensity of daylight. At the same time, Elon Musk's SpaceX wants to launch as many as a million satellites to serve as orbiting data centers — 70 times the number of satellites now in orbit. We could have a million points of light streaking across our skies at night.

The public comment periods for the proposals close on March 6 and March 9.

To be sure, there's a lot of hype in these proposals. Musk is known to make wild forecasts, and SpaceX has launched not quite a quarter of the Starlink satellites for which it originally sought approval. Reflect Orbital expects to launch its first satellite in April, but its grand vision is largely "aspirational," as its young founder, Ben Nowack, told me.

There's also a lot of promise in these proposals. Moving data centers into space could advance AI capacities without devouring land, water and energy on Earth, while reflected sunlight could boost our clean energy supply and help with everything from food production to search and rescue.

But at what cost?

Scientists warn about metal pollution in the atmosphere depleting the ultraviolet radiation-blocking ozone layer, as well as diminished ability to detect near-Earth asteroids, debris and collisions. Above all, they expect a massive increase in light pollution. Even before anybody contemplated a million-satellite mega-constellation and satellites that intentionally brighten the Earth at night, a 2021 study found that the "skyglow" effect from orbiting bodies had increased light pollution by 10 percent. And that's on top of terrestrial light pollution, which has been increasing up to 10 percent per year since 2011.Ask The Post AIDive deeper

This untimely light contributes to the loss of insect and bird populations. It disrupts migration, the seasonal patterns of plants and the circadian rhythms of animals ranging from sea turtles to mountain lions. Humans lose sleep because of artificial light, which potentially contributes to obesity and cancer. Light as faint as a full moon has been shown to alter our sleep patterns. Reflect Orbital aspires to produce for its customers the light of up to 1,000 moons by 2028 and 360,000 moons by 2035.

Then there's the philosophical question: How will it feel if we can no longer gaze upward and see Orion, Ursa Major or the other constellations our ancestors have traced since Ptolemy? How will we perceive our place in the universe if we can no longer take in the twinkling starlight that began its voyage to us before the Pyramids rose in Egypt?

Ruskin Hartley, head of DarkSky International, said he worries the new satellite plans will eliminate something that "has been part of the human experience for as long as we've been humans."

Weak international rules leave much of the regulation of satellites to the countries that launch them. In the U.S., which produces by far the most satellites, this falls to the FCC, which bases its decisions on things such as radio-frequency interference. The FCC has mostly exempted satellites from the National Environmental Policy Act, which requires federal agencies to take into account environmental considerations. In fact, the current FCC has proposed strengthening the exemptions for satellite operations. Satellite operators including Amazon, whose founder owns this news organization, support that effort. And bipartisan legislation that just cleared the Senate Commerce Committee would further speed approval of new satellites.

In short: There is nothing left to protect the night.

Reflect Orbital's Nowack describes a scene right out of sci-fi: An extremely bright star appears on the northern horizon and makes its way across the sky, illuminating a 5-kilometer circle on Earth, then setting on the southern horizon about five minutes later, just as another such "star" appears in the north. To make the night even brighter, a customer could make 10 "stars" appear at once in the north by ordering them on an app.

Two such artificial stars are in development in Reflect Orbital's factory. Nowack showed them to me on a Zoom call. The first to launch is 50 feet across, but he plans later to build them three times that size. If all goes according to plan, he'll have 50,000 of them circling the Earth in 2035 at an altitude of around 400 miles.

Nowack plans to start selling the service "in mostly developing nations or places that don't have streetlights yet." Eventually, he thinks, he can illuminate major cities, turn solar fields and farms into round-the-clock operations for any business or municipality that pays for it. He likened his technology to the invention of crop irrigation thousands of years ago. "I see this as much the same thing," he said, arguing that people would no longer have to "wait for the sun to shine."

If Reflect Orbital succeeds — a big "if" for a company that has yet to launch a single satellite — it would by definition increase light pollution when it illuminates areas that have been in the dark. But Nowack said he can light cities with "less total photons spilling into the environment than streetlights, with the same illumination level on the ground." As for its effects on birds and other creatures, he said, "we're going to be doing these studies with the first satellites."

If he does those studies, he will likely discover what Mike Parr, president of the American Bird Conservancy, can already tell him: "There's an overwhelming amount of information that suggests that birds are affected during night migration by light."

SpaceX's orbiting data centers, some 300 to 1,200 miles above the Earth, would individually be less noticeable than Reflect Orbital's reflectors, because they don't intentionally direct sunlight toward Earth. But the sheer number of them, and SpaceX's ability to launch a large volume of satellites, means these could alter the night sky more quickly. "Launching a constellation of a million satellites that operate as orbital data centers is a first step towards becoming a Kardashev II-level civilization— one that can harness the Sun's full power," the company boasts in its FCC filing.Ask The Post AIDive deeper

SpaceX and the FCC didn't respond to my requests for comment. SpaceX said little in its FCC filing about how it would limit the light pollution from its million satellites, beyond its assurance that it has been "developing industry-leading brightness mitigations." But while SpaceX and others have found ways to reduce the amount of light their ordinary satellites reflect toward Earth, "these orbital data centers are probably going to be a lot larger," said Roohi Dalal of the American Astronomical Society, and "when you make something bigger, it's going to get brighter."

Dalal said the new SpaceX satellites would compound problems for the $1 billion Vera C. Rubin Observatory, which is just coming online in Chile and will map the universe with the largest camera ever built. Studies indicate satellites will impair its ability to measure dark matter and fill its images with streaks. "The biggest potential for this observatory is what it's going to discover that we weren't expecting to see, and that's challenging when you have satellite streaks going through," Dalal said.

And astronomical interference may be the least of it. "Earth's orbit is on track for a catastrophe," an astronomy professor and a space lawyer wrote last week in the Conversation, an academic news site, about SpaceX's proposal. In their long list of cultural and environmental harms, they noted that the average satellite lasts only five years, requiring constant launches to replace them and depositing "vast quantities of metals into the stratosphere" when the decommissioned satellites burn up. On Feb. 19, German scientists reported that they had documented a discarded SpaceX rocket releasing a plume of chemical pollution as it reentered the atmosphere.

Maybe the significant gains to humanity from these new satellites are worth the losses to astronomy, to the atmosphere,

to biodiversity, to human health and to the night sky. Reasonable people can disagree about that.

But nobody is making that cost-benefit calculation, even though the actions of American satellite companies are altering the environment in every country on Earth. Instead, the FCC gives satellites a "categorical exclusion" from environmental review because, it claims, satellite operations "normally do not have significant effects on the human environment."

You don't have to be an astronomer to know that's just incorrect. You only have to look at the night sky.

Here is the link to the article with (stunning) photographs
https://wapo.st/4uMWZ8J

Document 8 - Satellites encased in wood are in the works

Timber is cheaper and better than alloys, and may be less polluting
The Economist, Jan 21st 2026|3 min read

LignoSat's communications failed as it was launched from the International Space Station (ISS) on December 9th 2024 (see picture above). But it was a breakthrough all the same. For much of it was made of magnolia, a wood its builders at Kyoto University had picked for its strength, ease of working and (as demonstrated by previous experiments on the ISS) resilience to the hostile environment of space.

It proved a good choice. Though LignoSat's temperature oscillated from -100 to +100°C as it passed in and out of Earth's shadow, and it was also bombarded by the radiation of the solar wind, its wooden panels held firm, according to tracking by America's Space Force, until its fiery atmospheric re-entry 116 days later.

Huld, a Finnish firm, prefers birch plywood to magnolia for WISA Woodsat, a test vehicle it helped design that is due for launch this summer. Such plywood is routinely cooled to -163°C when used to insulate tanks carrying liquefied natural gas.

Wood has several advantages over metal alloys as a satellite material. One is to reduce the amount of metal vaporising when satellites burn up on re-entry. In 2023 some 290 tonnes of space junk fell into the atmosphere. A study published that year found a tenth of the stratospheric sulphuric-acid particles it sampled contained such metal.

How much that matters, if at all, is unclear. But some people fear a build-up of metals at altitude will trigger chemical reactions which might, for instance, destroy ozone, a form of oxygen that absorbs harmful ultraviolet radiation. And build up they surely will. One forecast suggests that, by 2035, more than 2,800 tonnes of space junk a year will fall from orbit.

Swapping metal for wood, though, is not without hazard, observes Daniel Cziczo of Purdue University, who was one of the authors of the stratospheric-particle study. What might emerge from a reaction between the resulting soot and vaporised electronics remains unknown.

Such fears are unlikely, however, to rule wood out as a space material, for it has another advantage. Regulators are tightening the "design for demise" rules, intended to stop chunks of falling spacecraft reaching the ground. Satellites weighing more than about 300kg usually need special guidance systems to comply with these rules by ensuring controlled re-entry into a deserted part of the ocean. Dr Sakraker's team think incorporating wood, which would burn up in the atmosphere, might permit spacecraft weighing up to a tonne to duck that additional cost and re-enter uncontrolled.

A further benefit is that radio signals are unperturbed by wood, so communications equipment need not be specially deployed once a satellite is in orbit. That will protect it from flecks of space debris, such as paint chips, and should reduce drag from errant atmospheric molecules, a big problem in low orbits. LignoSat2, intended for launch in 2028 into an orbit 400km up, will test this idea. Doi Takao, a former astronaut who is a member of the LignoSat team, reckons the reduced drag will extend the craft's flight time by about 50%.

Wood is also cheaper than spacecraft alloys. And it absorbs vibrations, a plus for sensitive instruments. It insulates better than metal, too, meaning a craft's heating coils will not have to be turned on so often.

It does have a downside. The vacuum of space can suck out moisture and organic compounds, weakening it—though not, experiments on the plywood used in the WISA Woodsat suggest, enough to matter. A protective coat of aluminium oxide may help. Overall, then, it looks possible that small spaceships may soon reverse the example of their maritime namesakes by rejecting man-made materials for their hulls and reverting to wood. ■

Document 9 - I'm an astronaut. The Crew-11 emergency exposes a NASA blind spot.

Missions to Mars and the moon will require more advanced medical technology.

The Washington Post, January 13, 2026 By Clayton Anderson

Clayton Anderson is a retired NASA astronaut, author and adjunct professor at Iowa State University.

Human spaceflight is cool again, but still very, very hard. America just makes it look easy.

Last week, for the first time in the International Space Station's 25-year history, NASA decided to bring a crew home early, citing a serious but "stable" medical emergency involving an astronaut. NASA did not describe the health problem or identify the astronaut. The four-person Crew-11, which launched in August, has been directed to return no earlier than Thursday. The need to treat the astronaut with medical equipment on Earth may have driven the decision.

As an astronaut, I believe our current technology may not have solutions for critical situations we are bound to face moving away from low Earth orbit, and this incident illustrates exactly that. NASA needs to address some urgent and sometimes uncomfortable questions. For example, should a doctor always be on the crew? Should a spaceship heading to Mars have high-tech medical capabilities and facilities — not just a "med kit?" A kit consisting of only medications, saline solution, a defibrillator and a few basic instruments places a crew at a serious disadvantage if things really go south.

What if an IV, which the ISS currently has, was required for the Crew-11 astronaut? How would the spacesuit be put on? Would they come home not wearing their suit? To mitigate risks faster, we need to bring the best minds to bear on these questions so that when emergencies such as a stroke, heart attack or appendicitis happen, NASA and its astronauts know what to do. Human spaceflight demands expeditious advancement in space medicine.

NASA has always said its top priorities are crew safety, vehicle safety and mission success. This prudent focus should reassure the public that NASA is addressing the right priorities. Yet, even as the fascination grows with advancements in robotics and artificial intelligence — I know thousands have already asked Grok how to solve this problem — this Crew-11 episode shows we will only succeed with better medical safeguards for deep-space goals.

The Artemis II moon mission planned for this year is poised to take center stage and prefaces what many Earthlings feel we're also ready for: a visit to the glamour destination of Mars. A 6- to 9-month trip to the Red Planet puts this medical situation in a different light. We simply couldn't "bring them home." Health factors experienced thus far in space have been rectified (consider my very personal ISS battle with diarrhea), but the need to develop solutions for advanced medical challenges is paramount.

The effects of microgravity are numerous — bone and muscle loss, fluid shifts causing vision issues and radiation exposure. At issue is the lack of capabilities to confront these risks given limited diagnostic and surgical equipment in orbit, and unproven telemedicine, robotic, and AI possibilities.

NASA is developing medical technologies for Mars, focusing on diagnostics, telemedicine, wearable biosensors, portable imaging, 3D bio-printing and integrated health monitoring systems. But is there appropriate urgency? Can we deal with the implications of lunar stays or Mars trips where evacuation isn't possible unless you're Mark Watney?

Reduction in communication — a huge obstacle — requires crews to be more autonomous. Calling Houston for medical issues and psychological crises will be limited. Survival will depend not only on crew abilities to recognize, evaluate and fix situations but on the technological level of their environment. Systems need to be significantly more autonomous, and diagnostic abilities must increase, perhaps even to levels utilizing AI (watch out for HAL!). Procedures need to be so clear that there is no question about what the crew must do. We cannot, during critical medical situations, simply rely on a steely-eyed astronaut having the right stuff. They need the tools to pull it off.

Physical and mental tolls on crew members, constantly balancing workload with simply staying alive, will be magnified by a tremendous sense of isolation and no real-time coordination with mission control. Help will come from a crew's ability to troubleshoot a range of problems.

The United States has accomplished marvelous things. Its space history is nothing short of amazing, but we have much more to do.

We must welcome all ideas, suppressing the "not invented here" syndrome. Funding new research, advanced monitoring, AI diagnostics, radiation countermeasures and perhaps even genetic modification testing on astronauts should all be on the table, buoyed by full transparency to increase public trust in America's deep-space plans. We must treat medical resilience with the same urgency as rocket reusability.

Space exploration is dangerous. It's difficult and expensive. NASA's cautious ISS evacuation decision should spark urgency, so we don't get caught flying blind. NASA's catchphrase of "we *are* going" — to the moon and Mars — is inspiring and ambitious, but it's only meaningful if, in arriving, we ensure humans can survive the journey.