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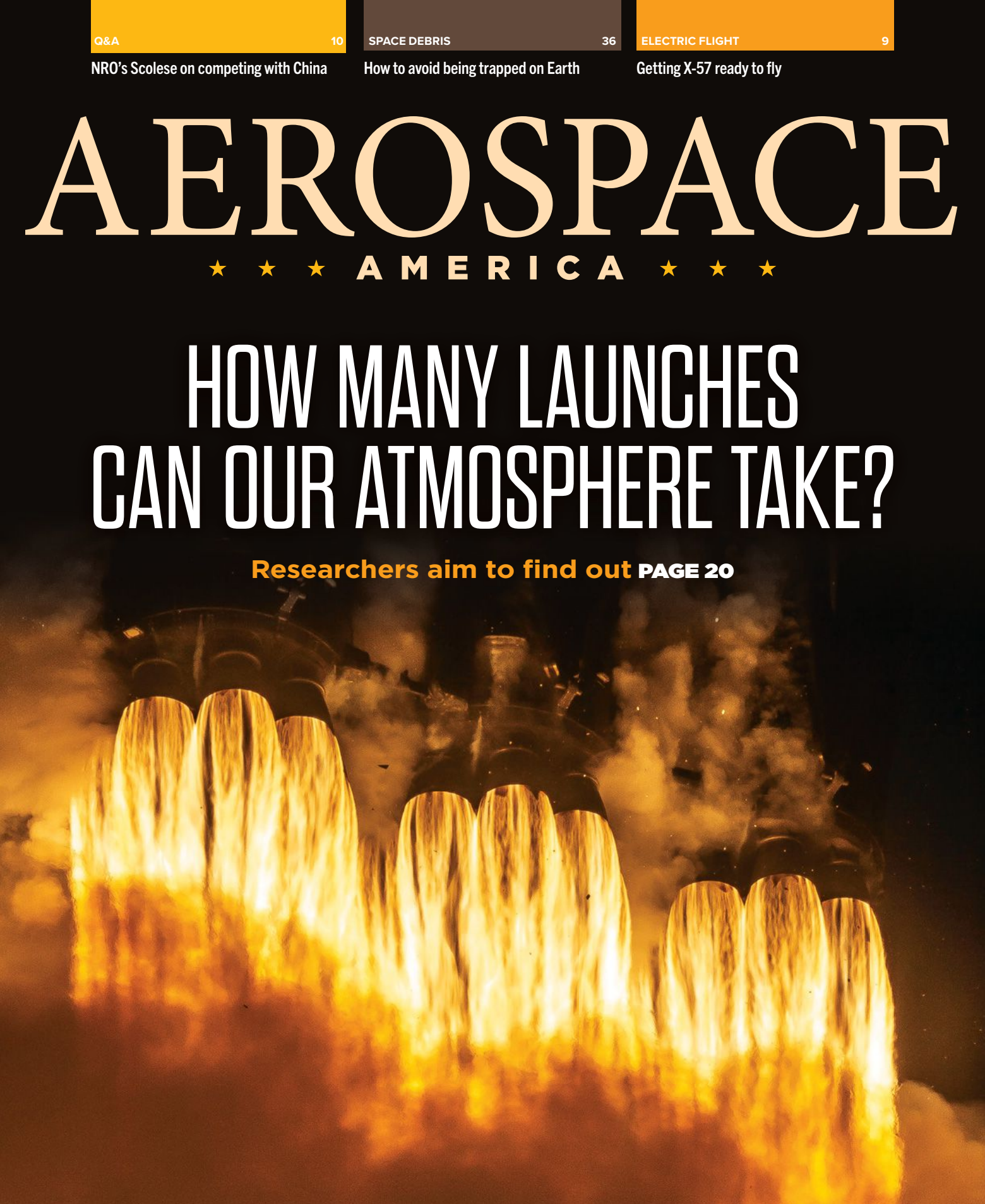

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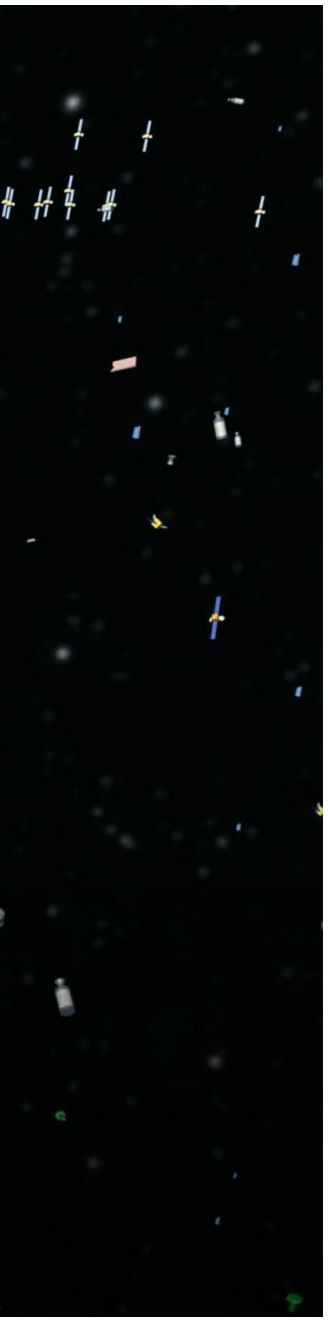
SHAPING THE FUTURE OF AEROSPACE

Act now, before we're trapped on Earth

Human society is on the cusp of expanding into space and improving lives on Earth through a host of space-derived innovations. Threatening this revolution is the limited ability of corporations and governments around the world to manage their space traffic and avoid collisions. Kerry Buckley of the MITRE Corporation analyzes the problem and offers solutions.

BY KERRY BUCKLEY



From our Earthly vantage point in the United States, just how much we depend on space may not be foremost on our minds. But every day, national security satellites protect us from strategic surprise; GPS signals help us navigate our world and keep our bank transactions flowing smoothly; commercial communications satellites give us internet on the go and more. And the space industry here and abroad has barely scratched the surface of what's possible.

But unless we change our current trajectory, we're setting ourselves up for a space traffic jam that will literally trap us on Earth. That's because sometimes satellite paths cross, like cars at an intersection. These "conjunctions" can result in catastrophic collisions — and produce massive amounts of potentially dangerous debris. This is no longer a problem of tomorrow. It's already beginning. Safe windows for satellite launches are becoming increasingly scarce. And safe opportunities for launching spacecraft with humans aboard to 700 kilometers (within low-Earth orbit, where most Earth-orbiting objects are) or beyond, meaning higher than the International Space Station, are now extremely rare under current safety standards.

The longer we defer solutions, the more durable the problem becomes. Objects stranded in low-Earth orbit require decades of atmospheric drag to decay their orbits. Above low-Earth orbit, Earth's atmosphere is not a player, so orbital debris will normally continue circling the Earth indefinitely.

While the commercialization of space that we're witnessing around the world is vital to economic growth, it also creates growing concern. Due to the proliferation of satellites in low-Earth orbit, the number of space collision warnings routinely issued by U.S. Space Command each week rose by more than five times in 2020 alone. MITRE's "conjunction" predictions show a future that's vastly worse, maybe by 1,000 times. What's coming? More satellites: Starlink (from 1,800 now to 42,000), OneWeb (6,000), Amazon's Project Kuiper (3,000), China's planned proliferated low-Earth orbit constellation (13,000), and more.

Further, the screening and reporting functions of the U.S. Defense Department's Combined Space Operations Center at Vandenberg Space Force Base in California rely on an incomplete (and rapidly growing) space catalog containing around 23,000 small-to-large orbiting objects. NASA estimates that another 100 million objects smaller than roughly 2 centimeters — about the size of a dime or smaller — can't be reliably tracked. These untrackable objects do not factor into the department's screening and reporting process, even though they could cause mission-ending — or even life-threatening — damage.

These are just some of the reasons that low-Earth orbit is often called "The Wild West." Unfortunately, though, the situation is even more complex and chaotic than that. Unlike the American West, the U.S. does not "own" space. We share it with all nations, so we can't make unilateral rules. And, with the exception of spacecraft operating in geosynchronous-Earth orbit, where longitude "slots" are assigned, every commercial company launching satellites currently has a right to choose their orbital behavior, no matter the consequences, meaning the current system incentivizes them to trade global safety for their own economic benefit.

Add to the mix irresponsible behavior by foreign governments, such as China and Russia's anti-satellite tests in 2007 and 2021, respectively, which created substantial amounts of dangerous space debris and demonstrated the importance of creating enforceable norms and standards for responsible activity in orbit.

We're at an inflection point here in the United States: Decisions our government makes now will dramatically impact whether safe space development is achievable in the future. Below are five key recommendations demonstrating U.S. leadership, paving the way for government, civil, commercial, and international entities to work together to move away from the current Wild West scenario to a more stable future in space:

1. Design satellites and launch vehicles that are less likely to create major debris fields. There are several ways to do this, such as building rocket body structures that limit on-orbit explosions or shielding spacecraft to better withstand collisions with objects smaller than 1 centimeter. Additionally, satellites could be equipped with onboard GPS transponders operating on a separate power supply, mitigating tracking challenges and helping to avoid collisions. We also urgently need policies (see No. 5 below) to prevent the intentional creation of major debris fields. Russia's recent destruction of one of its old satellites by hitting it with an anti-satellite missile (a surface to space rocket) created a large debris field at an economically important orbital altitude that will remain a hazard to all for years.

2. Avoid crowded orbits in the first place, with better mission planning. The current trend of everyone going to the same set of orbits to maximize return on investment is unsustainable. In November, MITRE released a free tool to help mission planners understand areas of space congestion and adapt to this reality. Called Probability of Conjunction, or PoCj, it provides information about potentially congested orbits — much like a traffic report. PoCj does not predict potential collisions of individual satellites. Instead, much like Waze can help you see that traffic on your chosen route next Tuesday will likely be heavy, PoCj can project how congested different orbital bands will likely be in the future and estimate collision risk in those bands. That

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way, mission planners can better understand the operating environment and hopefully choose to perform their missions in less-congested orbits.

3. Develop satellites that will deorbit or remove themselves from crowded orbits upon mission termination. Space-tug satellites are expensive and likely won't be able to mitigate the bulk of the space debris problem. And atmospheric drag only affects the closer orbiting space objects, leaving the remainder circling for a very long time. Onboard systems should provide satellites in low-Earth orbit the ability to deorbit after mission operations terminate. Even objects above low-Earth orbit will need to be deorbited eventually, though in the interim, those satellites should be moved (on their own or with a space tug) into less-crowded orbits upon mission termination.

4. Field better human-machine methods for handling current and future collision prediction and warning workloads — and thereby improve space traffic management. Reengineer the collision screening and reporting process and consider machine learning and artificial intelligence techniques. As part of this reengineering, we need improvements in our understanding of where space objects are. Manufacturers are stepping up briskly to the challenge of building new space-sensing telescopes and radars, but we need better methods to gather and process sensing data.

One capability for enabling a next-generation sensing approach is the Sensor Network Autonomous Resilient Extensible, SNARE, tool, which improves positional awareness of objects in space by directing radars and telescopes more effectively. MITRE has demonstrated that SNARE can provide an average improvement of 800 meters, and often much more, in the accuracy of tracking space objects in Space Force's catalog. This improved knowledge can be critical in two respects: 1) turning collisions into misses for controllable spacecraft — most potential collisions need only 10 meters displacement to achieve that — and 2) increasing assurance that objects are truly safely separated.

5. Form a worldwide body to provide best practices and administer incentivized space norms and operations across the planet, as is done with air traffic. Start with U.S. and industry groups to quickly establish best practices for sharing intent and ability to maneuver, to give other satellite operators advance notice. In parallel, begin the longer course of international space community engagements and United Nations adoption of commercial standards to enact planetary space norms of behavior and establish a robust space traffic management system. Compliance incentives could include establishing a responsible operator rating and a space sustainability rating, as well as tax and licensing benefits for responsible behavior. Additional possibilities include partnering with small companies to help them with compliance design and deployment and participating in governmental and nongovernmental safety evaluations.

Taken together, these recommendations are definitely a "moonshot."

But look at it this way: We've already been to the moon. If we keep on our current trajectory, in the not-so-distant future, we may not be able to get back there — or beyond.

So, let's take bold action now to avoid trapping ourselves on Earth for centuries to come. ★

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