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OCTOBER-DECEMBER 2025

# AEROSPACE

## — AMERICA —



**HEAVY  
TRAFFIC  
AHEAD**

**The second wave of megaconstellations could  
make it harder than ever to avoid collisions. **PAGE 24****



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
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
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*Aerospace America* presents readers with independently produced news and feature articles and a rich variety of opinions relevant to the future of aerospace. The views expressed in these pages are not necessarily those of our publisher, AIAA.





SpaceX conducted the 10th Starship-Super Heavy flight test (left) in August, and in September, the second B-21 test aircraft (right) arrived at Edwards Air Force Base in California.  
SpaceX and U.S. Air Force

## EDITOR'S NOTEBOOK

# Our path forward

**A**erospaceAmerica has begun a new chapter. We've moved to a quarterly print edition and are dramatically increasing the amount of news we're posting on our redesigned website. Our site now includes a multimedia section, where you can catch up on videos and webinars from AIAA. We're ensuring AIAA's daily email newsletter, My Daily Launch, is packed with the Aerospace America news you need. We are rapidly responding to news as it happens — and making sure it reaches you by email, social media and on our website.

I joined the publication three months ago and have spent my time helping us make those changes, as well as learning more about the Aerospace America brand and its strengths.

Amid lots of change, here are some constants you can expect: Our news is meant to inform and delight AIAA members — and those who aspire to be members. We want to write stories that alert you to new research, that connect the dots on trends in your industry and that better connect you to the technology, the people and the policies that matter.

I have been a journalist for more than 20 years and am committed to ensuring our work meets the highest standards. You can count on our accuracy and our fairness.

I spent three years leading Defense News, a magazine and website covering the business of defense, and about a decade at Inside Defense, a group of newsletters and websites closely tracking defense policy, acquisition and budgets as well as industry moves.

I'm well-versed in the defense world and am learning more about commercial space and aviation. As I do, I want to hear from you. What do you want to learn about in our pages? How do you get your news? What voices do you want to see in our articles? Please don't hesitate to say hello and to let me know what you think.

In this issue, don't miss our cover story about what the dramatic growth in megaconstellations could mean [page 24]. While the industry has avoided collisions thus far, experts say the boom will force companies and countries to work harder to maintain that track record. And I sat down with the head of Leonardo DRS to discuss the federal workforce, Golden Dome and defense priorities [page 10]. We also dig into the feasibility and potential hurdles of SpaceX's plan to get humans to Mars [page 36]. ★

*Marjorie Censer*



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## GERMAN AEROSPACE CENTER (DLR)

The German Aerospace Center (DLR) is Germany's national research and technology center for aviation, space, mobility, security, and defense. The work of the DLR covers a wide range of applications, delivering results and innovations that benefit industry and the economy, government agencies, and the public sector. At the heart of DLR's mission is its commitment to society, which it fulfills through extensive knowledge exchange and targeted technology transfer. It is therefore funded by federal funds. The German Space Agency within DLR is responsible for planning and implementing German space activities on behalf of the federal government. All 11,000 employees of DLR pursue a common goal: to explore Earth and space while developing technologies for a sustainable future. DLR technologies are not confined to the laboratory, but are transferred to society, thereby strengthening Germany's position as a first-class location for research and industrial innovation. To join our team visit the DLR job portal at [DLR.de/en/jobs](http://DLR.de/en/jobs) or submit a speculative application through [s.DLR.de/cometogermany](mailto:s.DLR.de/cometogermany)

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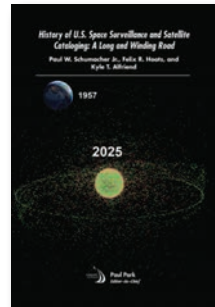


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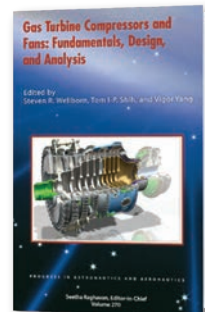


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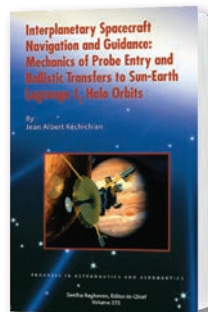


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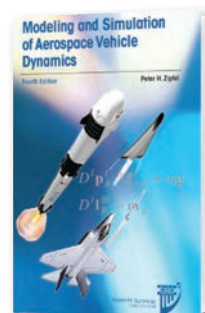


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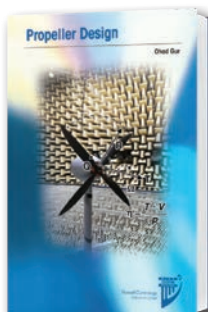


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## FLIGHT PATH

# Embracing Disruption to Unlock Top Technologies for the Future of Aerospace

“Linear thinking is easy. Taking into account disruption is really hard,” said Institute President Dan Hastings, setting the tone for AIAA’s 2025 CTO Summit.

The special conclave of engineers was held 2–3 September at The MITRE Corporation’s headquarters in McLean, Virginia. Chief technology officers, chief scientists, and VPs of engineering from AIAA’s corporate member and partner organizations gathered for our second CTO Summit designed to shape the future of aerospace.

This year’s Summit fostered candid dialogue and cross-sector collaboration to address the most pressing technical challenges facing the rapidly evolving aerospace sector. We convened 47 of the leading minds driving aerospace innovation. The event started off by establishing a trusted environment to exchange insights about transformative technologies and trends. Then we dug into the federal budget and asked questions about the direction of spending on new programs and technologies. Experienced technology leaders also spoke to best practices and messaging to elected and appointed officials who are making critical budget and procurement decisions.

The aerospace sector is known for embracing disruptive technologies that profoundly connect the world. From the earliest days of powered flight, aviation pioneers created a standard of rapid technology development and implementation we continue to rely on today. Today’s newest aerospace technologies promise vast improvements, greater efficiencies, and new ultra short/vertical lift capabilities to dramatically change how people move. Across our community, we are challenged to balance the benefits gained from new technology with smart integration into tomorrow’s air traffic systems, ensuring they are resilient, secure, and safe.

Our discussions were so valuable I want to share some of the early insights we gained. We are finalizing the Institute’s comprehensive CTO Summit Report with their top insights and recommendations in the coming weeks.

Our facilitators at Oliver Wyman identified the top technology topics we tackled during the Summit:

- Overcoming resistance to broad adoption of AI in aerospace
- Accelerating the use of digital thread engineering
- Scaling autonomy across manufacturing and mission applications

It’s not surprising this esteemed group identified AI and autonomy as the technologies likely to have the largest impact on the aerospace and defense industry in the next five years, while also seeing the most significant unresolved technical challenges.

A majority confirmed they are actively investing in AI, machine learning (ML), and autonomy. They also shared that their deployment of AI/ML in mission-critical or safety-critical systems remains uneven. As we witness the adoption of many AI features in aircraft, spacecraft, launch systems, national security applications, and supporting ground systems, our industry as a whole lacks a comprehensive methodology

for certifying AI-driven technologies.

We recognized that the next generation of aerospace professionals are both digital and AI natives. I hear from AIAA university branch students and young professionals that they are actively teaching mid-career engineers how to employ AI tools in their capacity as interns or newly hired engineers. They have an innate capacity to quickly adopt new technologies and digital approaches to problem-solving. We want to ensure that aerospace gives them attractive career opportunities to help us leverage the latest computing technologies to advance the state of the art.



**Clay Mowry**  
AIAA CEO

### Embracing AI in Aerospace

Coming out of AIAA SciTech Forum, I wrote about the power of AI as one of this year’s top technology trends. We had been fortunate to hear the perspectives of some of our industry’s leading thought leaders at the industry’s premier aerospace R&D event. Throughout the year, AIAA has continued to lead the industry in addressing AI, delivering six Continuing Education courses on AI and ML. We continue to publish papers and journal articles on AI/ML in our vast online library, Aerospace Research Central (ARC), with more than 600 references available – some dating back to the early 1980s. We have read the frequent reporting on the impact of AI across our industry from the *Aerospace America* team.

### Next Steps Forward

The CTO Summit brain trust challenged the Institute to think and work across industry, academia, and government as we build upon their collective ideas and strategies. Their recommendations around AI adoption included: setting standards, developing acceleration roadmaps, providing education resources, and emphasizing the topic with task forces and in AIAA event sessions, as well as supporting workforce development. We will use the findings from the Summit as a tool to inform the Institute’s work going forward.

We were cautioned by MITRE’s CTO Charles Clancy to recognize what’s at stake. “In today’s world, the aerospace domain is increasingly a contested battlespace, even our commercial and civil systems and their ground systems are targets. Aircraft and spacecraft are potential targets. That reality must shape how we design, deploy, and defend the next generation of aerospace technologies.”

AIAA is taking these insights to heart, ensuring that disruption is not only acknowledged but embedded in how we serve the aerospace community. We will continue aligning the Institute’s work with the technologies that will most profoundly shape our future. ★



# "Seeing" dark energy

ENCORE

We ran this puzzler in April 2022  
and didn't get any correct responses,  
so let's try again.

**Q:** Dark energy, of course, is invisible. Yet scientists discovered the existence of it partly through visible light observations from the Hubble Space Telescope. How can this be?

**SEND A RESPONSE OF UP TO 250 WORDS to [aeropuzzler@aerospaceamerica.org](mailto:aeropuzzler@aerospaceamerica.org). By responding, you are committing that the thoughts and words are your own and were not created with the aid of AI. DEADLINE: 12 p.m. Eastern Nov. 21**



Scan to get a head start on  
the next AeroPuzzler

## FROM THE JULY-SEPTEMBER ISSUE

### 'NOTHING BUT BLUE SKIES,' BUT WHY?:

We asked if it's true that Earth's blue skies result from the same principle that exoplanet researchers rely on to study atmospheres.

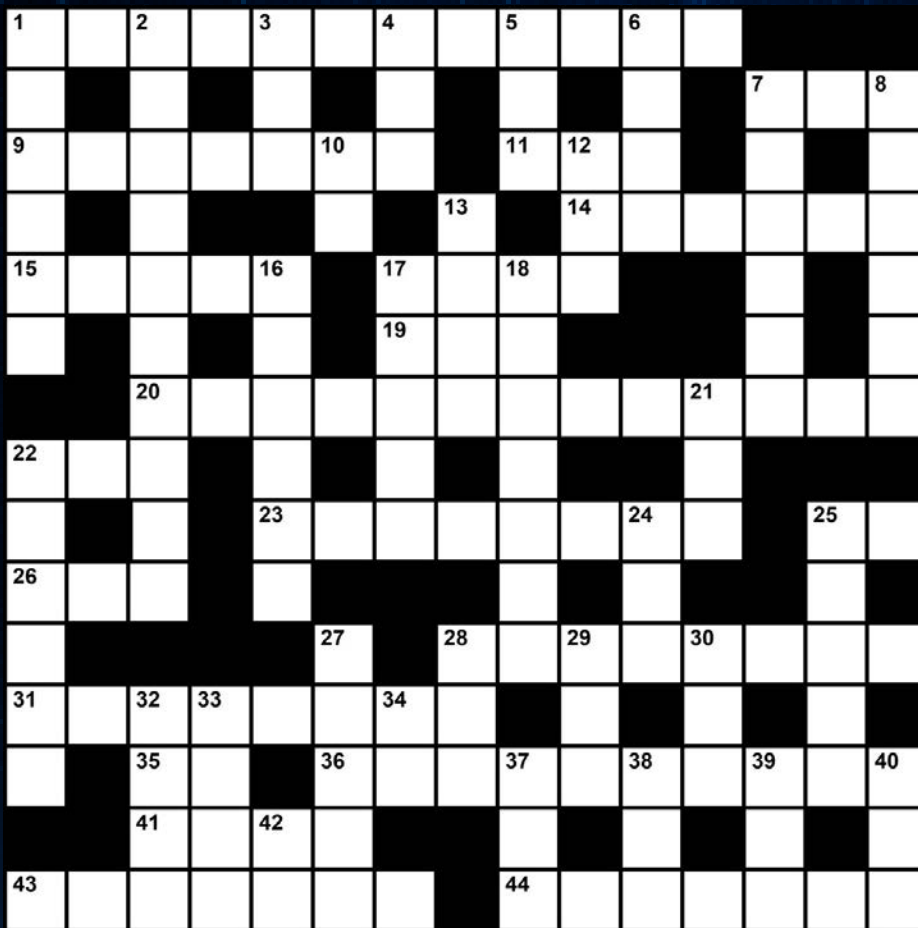


**WINNER** False. Our blue skies are the result of a phenomenon called Rayleigh scattering, which has nothing to do with absorption by molecular spectral lines. Rayleigh scattering is a largely geometric effect and depends most strongly on the radius of the scattering particles (by the 6th power) and the wavelength of the light hitting it (inversely by the 4th power). For a given size particle (e.g. nitrogen and oxygen molecules in air), the inverse dependence on wavelength means shorter wavelengths scatter more strongly than longer ones. So the blue sky we see is actually the shorter wavelengths of sunlight scattered by the gas particles throughout the atmosphere reaching our eyes. This same phenomenon is what causes sunsets to appear reddish, as the large air column along the line of sight toward the horizon preferentially scatters the blue light away, leaving a strongly red-biased spectrum to reach the observer.

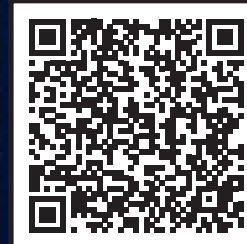
Asad Aboobaker, AIAA senior member  
Pasadena, California  
Asad is a systems engineer at NASA's Jet Propulsion Laboratory.

For more on molecular absorption, here's what retired NASA cosmologist John Mather had to say when he answered the original puzzler in 2022: "Astronomers use the James Webb Space Telescope to study planets when they transit in front of their host stars for a few hours. Some of the starlight goes through the atmosphere of the planet, if it has one, on its way to the telescope, and we analyze that. ... But Rayleigh scattering can't tell us what specific molecules are in an exoplanet. With Webb, we spread out the exoplanet light into a spectrum, a rainbow of colors. Many molecules absorb light very strongly at particular colors, and when we see an exoplanet spectrum with those features, we can identify the molecules."





# WORD CROSS WORD



Test your  
knowledge,  
then find  
the answers  
online.

## Across

- 1** Branch of mechanics relating to the pressures and flows around aircraft and spacecraft
- 7** Objective
- 9** Bepi\_\_\_\_\_: Mercury flyby mission
- 11** Will mark 25 years of continuous human presence in November
- 14** Opportunity's twin
- 15** First phase of a planetary landing
- 17** Kuiper, for one
- 19** This region has gotten thousands more visitors in the last six years
- 20** This heavy-lift rocket had two launches in 2024
- 22** Astronauts get these scans after completing a space flight
- 23** Possible successor to the Concorde
- 25** Naming convention for Starship prototypes
- 26** If at first you don't succeed, do this again
- 28** The last word of the three-word cosmic feature photographed by Hubble and JWST
- 31** This NASA spacecraft is New Glenn's first planetary payload
- 35** Mons Mouton is one, abbr.
- 36** A cartoon inspired the name for this famous and secretive division
- 41** What golden and iron have in common
- 43** Military aviation facility, two words
- 44** Chuck Yeager's inspiration for the name of his X-1 rocket plane

## Down

- 1** Official air taxi provider for the 2028 Olympic Games
- 2** Einstein's most famous theory
- 3** The largest airport in the world, by land area
- 4** NASA is building a telescope to identify all of these
- 5** If you're already a flight instructor, you might consider adding on this certification
- 6** On the verge of
- 7** Boeing subsidiary known for its UAVs
- 8** The last name of the former NASA scientist who helped confirm the Big Bang Theory
- 10** Fly\_
- 12** Shorthand for airliners like Concorde
- 13** Observed
- 16** Our sun is this type of dwarf star
- 17** Joby in August purchased this company's passenger division
- 18** ADS-B acts as one
- 21** First word of Darth Vader's plane
- 22** What everything is made of
- 24** A less common abbreviation for aircraft controlled from the ground
- 25** The most famous Vulcan
- 27** Hydrogen and helium, for example
- 28** You may take an AIAA education course to receive this
- 29** The first kind of animal to be tracked via satellite in a 1970 NASA project
- 30** Abbreviation for the air traffic management concept that FAA believes will make air travel more efficient
- 32** The late Jim Lovell's role in Apollo 13, abbr.
- 33** From one point to another, three words
- 34** The country code for this Scandinavian nation that recently ordered 27 F-35s
- 37** To bother
- 38** Trouble
- 39** Director of "Solo: A Star Wars Story," \_\_\_\_ Howard
- 40** International distress signal
- 42** Sunita Williams' home state





R&D

# A new way to jettison fuel

BY PAUL MARKS | paulmarksnews@protonmail.com

An Airbus 340 dumps fuel over Nova Scotia in 2008.

Bobmil42 via Wikipedia Commons

In 1978, a perilous drama played out 2,700 feet above the Hauraki Gulf on New Zealand's north island, after the Royal Australian Air Force crew of a General Dynamics F-111C bomber got a warning of overheating in the nose wheel well. The pilots opened the landing gear doors to cool the well, and dumped fuel to prepare for an emergency landing.

However, some of the fuel streaming from the jettison nozzle behind the aircraft's twin engine exhausts was actually flowing forward beneath the fuselage, igniting an explosive fire in the hot wheel well. The crew ejected in the F-111C's twin-pilot escape pod and was rescued safely.

That "extraordinary" experience, says Richard de Crespigny, an RAAF pilot at the time and later an airline pilot and captain with Qantas in Sydney, was "a great example of the risks of forward airflow during jettison."

Boeing thinks a simple technology fix could alleviate those risks and described the method in question in a patent granted in August.

Today's fuel jettison systems tend to comprise a cylindrical tube on a wing's trailing edge, which might not always discharge the fuel at a fast enough rate, Boeing notes in U.S. patent 12,391,398. As a result, turbulent airflow emanating from the closely spaced control surfaces on the trailing edge — flaps and ailerons — may cause some of the ejected fuel to circulate locally and stick to the wing. And, as the F-111C crew found, "having fuel

adhere to aerodynamic surfaces of the aircraft creates undesirable risks," the patent reads.

What is needed, say authors Sarah Barrett, Patrick Tang and Jonathan Lipstate — all aircraft structures engineers at Boeing's Everett, Washington, facility — is a design that ejects fuel much faster so that it does not get the chance to stick to flight surfaces.

In their patent, the trio describe how it could be done: First, fuel is channeled to a pump that employs the "venturi" effect — accelerating flow via constriction, akin to squeezing a garden hose to spray water faster. A motor pushes the venturi pump out of the wing shroud it is stowed in to a deployed position aft of the wing. At this point, air inlets in the pump ahead of the venturi are exposed to the powerful exterior airflow of flight, and this incoming air is used to drive fuel through the pump at ultra-fast speeds.

The result? "The fuel jettison system passively causes acceleration of the fuel via the venturi effect and the discharged fuel does not adhere to flight surfaces," the patent reads.

Boeing declined to comment when asked about its plans for the technology, but the company's interest appears to be high, as it moved to protect disclosure of the idea until just before the patent was approved. The U.S. Patent and Trademark Office didn't publish Boeing's application, received Feb. 5, 2024, until Aug. 7 — 12 days before the patent was granted. ★



**Paul Marks** is a London journalist focused on technology, cybersecurity, aviation and spaceflight. A regular contributor to the BBC, New Scientist and The Economist, his current interests include electric aviation and innovation in the new space sector.



R&D

# A closer look at contrails

BY KEITH BUTTON | [buttonkeith@gmail.com](mailto:buttonkeith@gmail.com)

▲ NASA and DLR partnered with Boeing and other organizations for a previous study, in which they measured the contrails emitted by a Boeing 737-10.

NASA/Jim Ross

Conversations about the aviation industry's environmental impact frequently revolve around carbon dioxide, but research in recent years has been increasingly focused on non-CO<sub>2</sub> emissions — specifically, contrails.

These thin clouds of ice crystals, which form when warm soot particles and water vapor from jet engine combustion meet cold atmospheric air, are aviation's largest contribution to atmospheric warming. However, scientists can't precisely predict how much contrail ice will be created by a specific jet fuel and its ingredients—an uncertainty that a group of European scientists aims to address with tests that began in September.

Led by Airbus, the consortium of organizations participating in PACIFIC — short for Particle emissions, Air Quality and Climate Impact related to Fuel Composition and Engine Cycle — plan to conduct lab and ground tests with various formulations of conventional and sustainable aviation fuels (SAFs), to determine the types and volume of contrail ice crystals they will form at high altitudes.

To kick off the projects, scientists from the German Aerospace Research Center (DLR) gathered 10 fuel samples. Each is burned in a vertical methane flame while a sheet-like laser beam shines through the exhaust, illuminating tiny carbon soot particles that ice crystals could form around at high altitudes. A camera records the size and number of particles.

In future bench tests, the scientists plan to ignite the fuels in the burners of business jet and passenger jet engines to record the amount of soot and other molecules, like aerosol particles. By the middle of 2026, they intend

to test three of the fuels in an A350 widebody at Airbus headquarters in Toulouse, France.

"You put the brakes on, you have a blast fence behind it and then you power up," says Georg Eckel, head of alternative fuels at DLR's combustion technology institute.

Meanwhile, University of Helsinki scientists will funnel the plane's exhaust through a 50-meter-long tube into a home-refrigerator-sized chamber, dubbed PINCii for Portable Ice Nucleation Chamber 2. DLR will also sample the A350 exhaust from a "measurement van" parked behind the plane.

As aerosol molecules are sucked through the PINCii, they will be exposed to precise humidity and temperatures, down to minus 50 degrees Celsius, to simulate contrail-forming conditions in flight, says Jonathan Duplissy, a researcher at the Finland university. A laser will shine through the exhaust while an optical particle counter detects the 10-micron-sized particles via light deflection. The Helsinki researchers will also use a spectrometer to detect tiny "newborn" molecules — some of which are thousands of times smaller than aerosol particles — that can later clump together to become large enough for ice crystals to form around, Duplissy says.

Contrail-forming potential is among the factors that should be taken into account when determining the environmental impact of particular SAFs, says Thomas Viguier, an Airbus climate specialist.

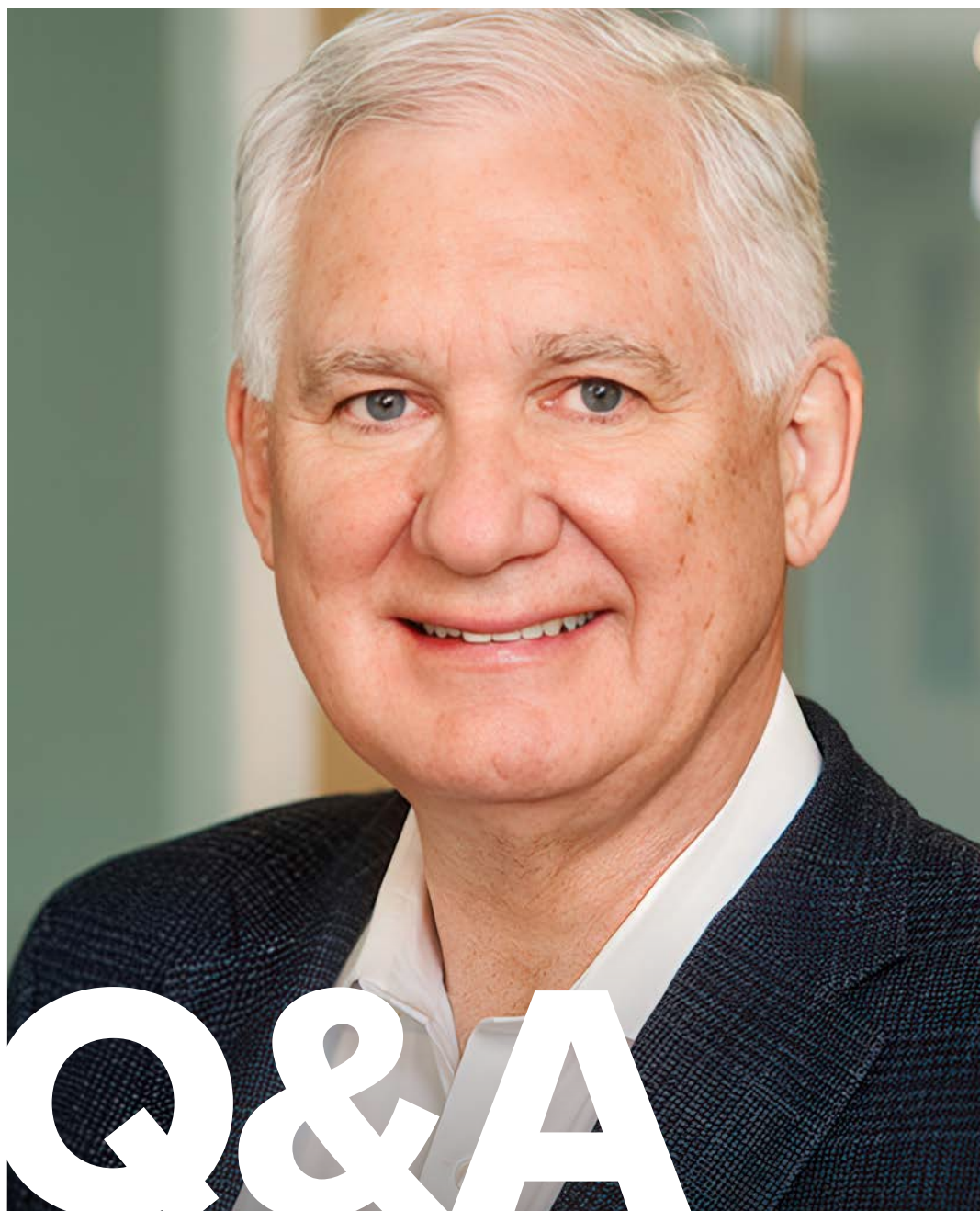
"We want to be able to determine in the end if it's worth revisiting the fuel specification, especially if there is eventually one day a SAF-specific fuel spec which would be different from the Jet A-1 current spec," he says. ★



**Keith Button**

has written for C4ISR Journal and Hedge Fund Alert, where he broke news of the 2007 Bear Stearns hedge fund blowup that kicked off the global credit crisis. He is based in New York.





## What to watch at DOD

**B**ill Lynn has experienced defense modernization both as a Pentagon insider and an industry executive. As deputy defense secretary from 2009 to late 2011, he unveiled the Pentagon's first cyberspace strategy in response to what he described as "a strategic environment that is unlike anything we could have imagined." Since leaving DOD, Lynn has returned to the industry side, serving as chief executive of Leonardo DRS, the U.S.-based subsidiary of Italian defense contractor Leonardo. The challenges facing today's Defense Department are very different, but the organization is once again making a massive technological shift. President Donald Trump has pledged that the Golden Dome missile defense shield will be operational by the end of his term and has requested billions to fund the required technology. At the same time, DOD, like other government agencies, is facing significant workforce reductions.

I sat down with Lynn at Leonardo DRS' headquarters in Arlington, Virginia, to discuss the challenges ahead and how DOD should proceed. — *Marjorie Censer*

### BILL LYNN

#### KEY POSITIONS:

- Since 2012, chairman and CEO of Leonardo DRS.
- 2009-2011, deputy secretary of defense, the No. 2 civilian job at the Pentagon tasked with overseeing day-to-day operations.
- 1997-2001, chief financial officer and under secretary of defense (comptroller).
- 1993-1997, director of program analysis and evaluation at DOD, focused on the Pentagon's program and budget development.
- 1992-1993, led the Clinton administration defense transition team.
- 1987-1993, counsel to the Senate Armed Services Committee for Sen. Ted Kennedy, D-Mass.
- 1982-1985, executive director of the Defense Organization Project at the Center for Strategic and International Studies, analyzing the Pentagon's organization and proposing updates.

#### NOTABLE:

- At DOD, oversaw the creation and 2011 rollout of the Pentagon's first cyberspace strategy and in 2009, announced plans to hire 20,000 more employees focused on acquisition.
- The Defense Organization Project he led helped prompt the 1986 Goldwater-Nichols Act, which reorganized the U.S. military.
- When working for Kennedy, helped advance legislation including the Military Childcare Act of 1989, which focused on making military child care safer and more affordable, and a 1991 law that overturned a ban on women flying in combat.

**AGE:** 71

**RESIDES:** Washington, D.C.

**EDUCATION:** Bachelor's degree from Dartmouth College (1976), JD from Cornell Law School (1980) and Master of Public Affairs from Princeton University (1982).

**Q: Let's start with the changes at DOD we've seen in the last six months. What is your sense of how those are going to affect the broader defense industry?**

A: You always have a reset with a new administration. I think a lot of what's going on is that. This administration is dramatic in all things and controversial, so people kind of lose that idea that no, no, with a new administration, whoever it was, people rethink and should. We rethink our strategy, we redo the budget, we try and upgrade the processes. All of that is normal and good, somewhat. For industry, it can be disruptive, but it's an opportunity as well, and you just have to balance. Most of what's going on is that. It's a progression. Programs will continue, and some will stop, and some will get increased, and there will be new ones. That's all what you'd expect with any new administration.

**Q: When you were in the building, the acquisition workforce in particular was an area you were interested in. Are you concerned about how the workforce cuts might impact that?**

A: When you disrupt the federal workforce, you worry about losing expertise, and that happened in the '90s. We lost a lot of contract expertise, a lot of subject matter expertise, as they downsized by several hundred thousand — not just in DOD, but the whole federal workforce.

*The Clinton administration in 1993 established the National Partnership for Reinventing Government, which included workforce reductions. According to a program official's congressional testimony, the effort cut the federal workforce by 426,200 between January 1993 and September 2000. — MC*

I don't think we know yet, but I think that's something you have to worry about. It's not that you can't have a smaller federal workforce. Like anything of that size, you can do it more efficiently, and you can do the same work more efficiently. What you have to worry about is: Does it lower the quality of the work? And that's, I think, an open question. Over the next year or so, we'll get a better sense of how they're doing on that. It's a worry item, but it's not a crisis at this point.

**Q: In terms of defense contractors, are you seeing any repositioning going on in the wake of this, or is it relatively unchanged?**

A: Some of the plates are shifting. The larger primes are having to defend their positions. I think this new administration has some affinity for the newer companies. They're less interested in somebody coming with a PowerPoint. They want to see a prototype; they want you to move fast.

**Q: Previous Pentagons have established entities like the Defense Innovation Unit to assess emerging commercial technology. What do you see as the path forward for those segments?**

A: I think it'll continue. We're in a world where the Defense Department has to access commercial technology. We rebalanced. It used to be defense was really a net exporter of technology. Think the internet, GPS, that kind of thing. Now, we're a net importer. The balance has shifted. So now it's autonomy, artificial intelligence. These are all technologies that really are stronger and originate in the commercial sector.

A lot of the enabling technologies are coming from the commercial sector, and DOD absolutely has to have access to them. I don't think there's one path to that access. DIU and the other things they've set up — not just in Silicon Valley, but in Austin and Boston — that's one path. It's equally important to have the defense industry itself reaching out so when you're looking at acquisitions, you're now looking at acquiring artificial intelligence capability, not just defense hardware, satellites or whatever. That's another path.

"It's not that you can't have a smaller federal workforce. Like anything of that size, you can do it more efficiently, and you can do the same work more efficiently. What you have to worry about is: Does it lower the quality of the work?"





Conceivably, you would have commercial entrants into the defense market. You've seen less of that. Defense is a difficult market. There's huge barriers to entry. I think the partnering, though, of commercial technology inside the defense industry, that is a key path for DOD to get the technology it needs.

**Q: Let's shift to Golden Dome. What are you expecting from an industry perspective? How many players do you think the DOD might need?**

A: I don't think you can answer that because there's so many dimensions to it. You've got everything from counter-UAS at the lowest level, both mobile and fixed site. You've got the intermediate to your THAAD [Terminal High Altitude Area Defense system] and Arrow [missile defense system]. And then you've got the intercontinental land-based and over-the-horizon radars. And then you've got the space-based transport and tracking capabilities that are going to be needed and are already being acquired. You may go to space-based interceptors. In each of those segments, you've got multiple competitors. So saying "How many players are there?" Well, which piece of it are you talking about? There are multiple players, and the larger ones play in multiple segments.

**Q: How much of the tech for Golden Dome already exists or is in the works versus brand-new tech that needs to be developed?**

A: The administration seems to be leaning a little bit toward existing, in that they've talked about having something by the end of the administration. If you're inventing it today, it's going to be hard to deploy it in three and a half years. But you don't have to do it all at once. This is a large architecture. The better way to answer it is, the initial pieces, I think, are going to have to be largely existing technology or derivations of existing technology. And then as you go further, you'll discover new needs and new technologies to meet those. Space-based interceptors, I think, would be a second phase.

**Q: Do you think that it's technologically feasible for DOD to get where it wants to go with Golden Dome in the time period being discussed?**

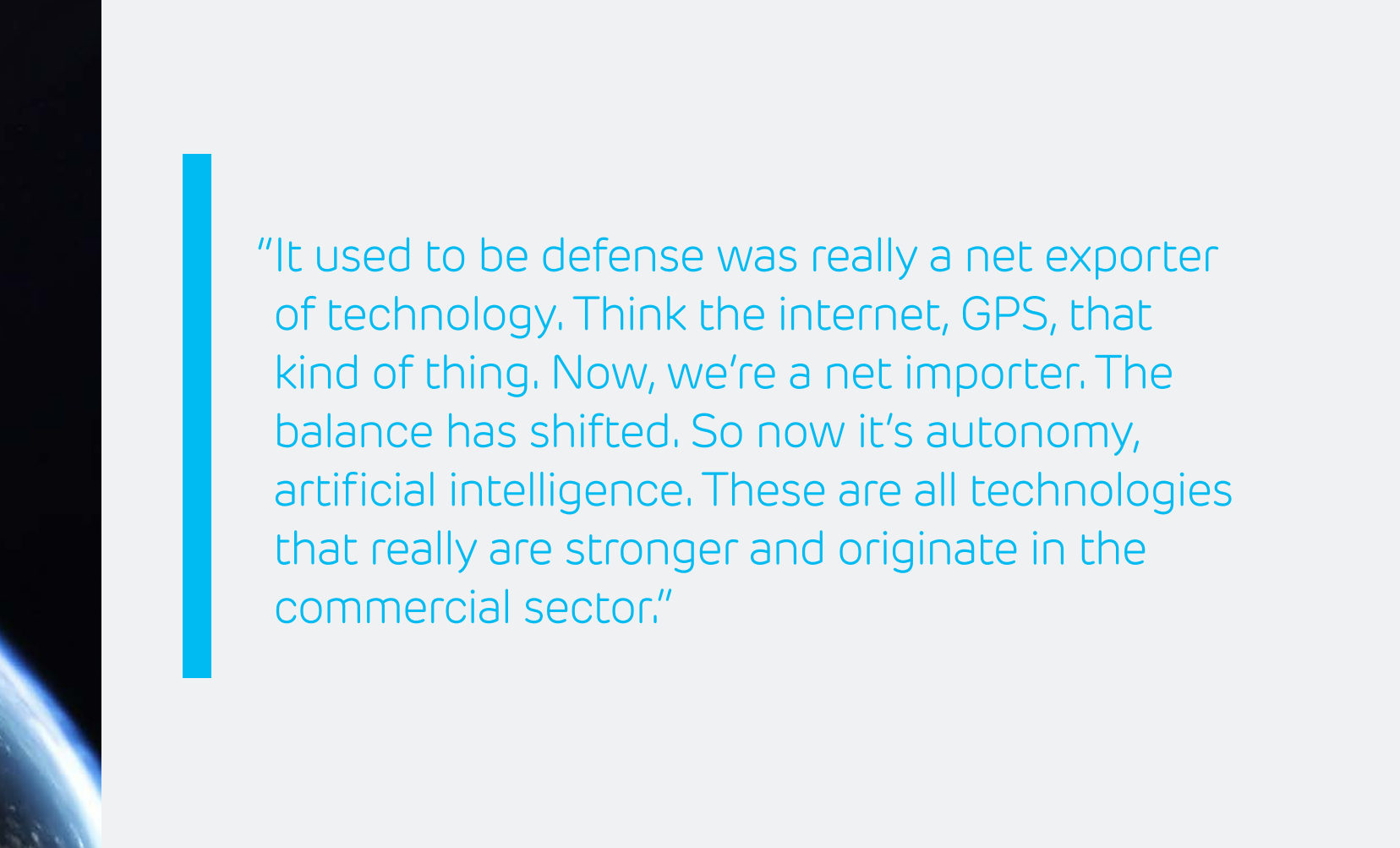
A: I don't think there's an end point with this. It's going to be sort of a constant upgrade. Yeah, I think they could get some capability, meaningful capability, in three or four years.

**Q: What do you think are the challenges or pitfalls they'll encounter along the way?**

A: If you have the priority that they put on early deployment, it's a little bit "come as you are." It's going to be hard to invent new technologies, as I said, in that time frame. But it doesn't mean you can't do both. You can deploy what we have to meet the threats that we can see, while developing newer technologies to either address new threats

▲ U.S. President Donald Trump has estimated that the initial phase of his proposed Golden Dome missile defense shield, shown here in an illustration, will cost \$175 billion. A May analysis from the Congressional Research Service estimated an \$831 billion price tag over the next two decades.

Lockheed Martin



"It used to be defense was really a net exporter of technology. Think the internet, GPS, that kind of thing. Now, we're a net importer. The balance has shifted. So now it's autonomy, artificial intelligence. These are all technologies that really are stronger and originate in the commercial sector."

or address the older threats better. We're in early days on this in the sense that they're just standing up the organization now, and they've set out some general objectives, but I think over the next period of months, you'll start to see much more of an architecture.

*Space Force Gen. Mike Guetlein, the Golden Dome program manager, said in July the architecture is due to the deputy defense secretary in 60 days. — MC*

**Q: From the industry perspective, what's the critical information needed to be able to participate?**

A: Like any program, you need to know what capabilities do you want. And then we would answer with "This is what we can produce at this cost, on this schedule." Golden Dome isn't just one program, it's multiple programs. In some cases, we have an existing counter-UAS system. You can just buy more of them and deploy them. We're doing things like putting directed energy on them. You could fund us to go faster and bigger on that. Those are the kinds of questions. We need to know if that's what you want.

**Q: Big picture, what do you think will be the real growth areas — or areas that may not see growth — in this Pentagon?**

A: Golden Dome is clearly a very, very large investment, and it wafts over into short-range air defense and counter-UAS on the battlefield as well, as we've seen the impact of drones on the battlefield. That's going to be an area of interest and investment.

Given where we are with shipbuilding and, in particular, the submarine industrial base, I think that's going to be a major area of investment. The sensing area has gotten somewhat less attention, but if we're going to increase the capability of our forces on the battlefield, that sensing capability and the ability to pull it all together and have a unified, fused, actionable picture of the battlefield that's shareable, up and down formations and higher, is going to be a critical investment for the department to make.

**Q: Anything you think might get left behind or pushed aside here?**

A: It's harder to do that than people think. If we're a global superpower, it's very hard to specialize. You can't just say, "Oh, well, we're not going to fight a ground war." We've tried that before a couple of times. It hasn't gone very well. You can have areas of emphasis and so on. But we do have to have full-spectrum capabilities. And some things are going to get funded bigger and faster than some other things, but to give up broad areas of capabilities is hard. ★





ENGINEERING NOTEBOOK

# An AI assistant for air traffic management

**While controllers in individual towers are managing the flights arriving at and departing from their respective airports across the U.S., FAA's air traffic managers are tasked with overseeing the overall flow of traffic across the country — and ensuring any small delays don't cascade into a widespread outage. Large language model tools in development at the University of Michigan could make this task easier, as well as help train managers on unusual scenarios. Keith Button spoke to one of the lead researchers.**

BY KEITH BUTTON | [buttonkeith@gmail.com](mailto:buttonkeith@gmail.com)

**M**ax Li's idea for artificial intelligence tools that could lighten the workload of FAA's air traffic managers came to him two years ago over a cup of coffee.

The University of Michigan aerospace engineering professor was on a break during a conference, chatting with an officer who mentioned a common on-the-job frustration: Drafting certain types of air traffic plans, including those that manage weather-related delays at airports with complicated traffic patterns, could be a pain in the neck.

"This kind of got me thinking, and I shelved it in the back of my mind," Li recalls.

That was the catalyst for Li's development of a large language model AI for air traffic managers and, now, an LLM tool to help train them. If Li and his team are successful, the technology could make it easier for managers to create and tweak the ground delay plans that adjust aircraft departures in response to weather and other factors, to make traffic flow more smoothly when capacity is restricted at a particular airport. And the other tool could help instructors create novel scenarios in which air traffic is disrupted to help managers in training.

"We're trying to look at: What are the things that these LLMs, generative AI techniques are good at, and how can we use them synergistically to relieve workload and relieve some challenges that human operators have?" Li says.

In the world of air traffic management, FAA-employed national traffic managers draw up the daily traffic flow plans and adjustments to those plans for the National Airspace System (NAS). While the air traffic controllers across the country are actively "pushing metal" in real time by directing takeoffs and landings and keeping aircraft separated in flight, Li says, traffic managers "are the worker bees in the nerve center, controlling the NAS

from a broad strategic view."

They start by developing an operations plan several days in advance for how each day's traffic will flow, balancing demand and capacity for takeoffs and landings at the major U.S. airports. They later revise that plan as needed, based on a particular day's weather forecast and other factors that would affect traffic or runway availability. These range from military flights to air traffic controller staffing shortages, or runway construction, space launches and even VIP travel.

When such events occur, managers issue a ground delay program, which sets a reduced arrival rate for the targeted airport and calculates the minutes of delay for each incoming aircraft. Those planes then have their departures delayed so they aren't stuck flying a holding pattern above their destination.

Writing this program can be tricky, Li says, even for airports in which delays are common occurrences. Take New York City, where the complex airspace and fickle weather prompt managers to create ground delay programs at least once a week. Even so, Li says traffic managers have wondered aloud to him, "Why does it feel like we're starting from scratch" every time?

A potential solution came to him in 2023, when the University of Michigan released U-M GPT. This set of internal LLMs — similar to ChatGPT — was available for university researchers to alter and adapt for their own projects. Could there be an LLM equipped to write ground delay programs? An air traffic manager "might not remember the specifics of the past 100 plans you've created, but perhaps a large language model trained on those plans could help you at least get over that initial writer's block," Li says.

At a glance, it seemed promising. LLMs are good at ingesting large sets of data and providing broad



**Keith Button**

has written for C4ISR Journal and Hedge Fund Alert, where he broke news of the 2007 Bear Stearns hedge fund blowup that kicked off the global credit crisis. He is based in New York.



summaries in a readable format; humans are good at on-the-spot, nuanced decision-making. An LLM could provide the broad brushstrokes of a ground delay program based on similar circumstances encountered in the past, then the air traffic manager could write the detailed plan.

"It lets [the human managers] focus on what they're getting paid for: their expertise," says Li, who co-leads the project with University of Maryland professor Alex Estes. Rounding out the team is Ph.D. student Sinan Abdulhak, student researchers at Maryland and Cornell University and Wayne Hubbard, the FAA traffic management officer whose coffee conversation provided Li the initial inspiration.

Over the last two years, they've trained their ChatATC model on 86,842 ground delay program text files issued from 2000 to 2023. Like ChatGPT, ChatATC was set up to answer conversational queries about past ground delay programs. As with other AI chatbots, ChatATC sometimes produces wrong answers, Li cautions, so the current version shouldn't be relied on to make decisions or for any safety-critical roles.

As the development of ChatATC progressed, Li heard about another air traffic management challenge that potentially could be addressed by LLM: developing realistic training scenarios for rare situations. And so, late last year, work began on another tool.

Like ChatATC, this LLM — which doesn't yet have a name — ingests data from past ground delay programs. But instead of discouraging the occasional tendency of LLMs to produce hallucinations, in this case, a degree of hallucinating is encouraged to make up situations that have never occurred before. Li's team presented its work in June at the U.S.-Europe Air Transportation Research and Development Symposium and published a corresponding paper, "Generative Stress-Testing for Air Traffic Management Resilience."

The idea is to create novel yet realistic scenarios of air traffic disruptions, and to provide the answer — meaning, the appropriate response by traffic managers. Li compares it to training the software for a self-driving car: "The important stuff isn't the 99.9% of the times when you're driving safely on the road, it's that 0.001% when a cat runs out on the street or a kid comes out on the street. It's that really rare instance that you want to train on."

An LLM is needed to create these uncommon scenarios because there aren't enough real-life examples from history to draw from, he says. And although humans today create training scripts themselves, he estimates that each takes 15-20 hours to write.

The researchers must walk the fine line between ensuring that the made-up scenarios are tricky enough to challenge in-training managers while still being in the realm of possibility.

"You don't want to give people 10 examples of Mount St. Helens erupting and disrupting traffic in the Pacific

#### Query GDP superlatives

"which gdp at sfo had the highest max delay"

#### Response GDP superlatives (incorrect response)

The GDP at SFO that had the highest max delay was the one mentioned in the message with RAW TEXT: ATSCC ADVZY 045 SFO/ZOA 02/16/2009 CDM GROUND DELAY PROGRAM with a maximum delay of 784.

[A manual search through SFO GDP reveals maximum delays of 1444 minutes, not 784.]

#### Query EWR GDP (in-prompt learning)

"tell me about the EWR gdp"

#### Response EWR GDP (in-prompt learning)

The ATSCC advisory for Newark Liberty International Airport (EWR) issued on November 18, 2022, is proposing a Ground Delay Program (GDP) due to weather conditions, specifically wind. The delay was calculated at 16:41 UTC (ADL time).

According to the advisory, the arrivals estimated for this delay lay between 18:00 UTC on the 18th of November to 03:59 UTC on the 19th of November.

During this period, the anticipated program rate is given as a repeating sequence: 34/34/34/38/38/38/38/38/38/38.

The delay is applicable for all departures from contiguous US and several departure points from Canada.

The estimated maximum delay time is 105 minutes and the average delay time is 44 minutes.

The message also mentions data issues prior to 21:00 UTC and a shift to DAS GDP mode to avoid possible delay limit in a UDP mode.

Additionally, user updates must be received by 17:05 UTC on the 18th of November. The effective time of the advisory is from 16:44 UTC on the 18th of November to 17:59 UTC on the same day.



► Large language models could assist FAA's air traffic managers in crafting and updating operations plans that dictate the flow of air traffic across the U.S. At the country's busiest airport, Hartsfield-Jackson Atlanta International, approximately 2,700 flights arrive and depart every day.

Harrison Keely via Wikipedia Commons

◀ To train their ChatATC large language model, the University of Michigan researchers shared the text of ground delay programs created by FAA air traffic managers between 2000 and 2023. They then tested the model's accuracy by asking prompts like those at left.

Max Li et al.

Northwest," Li says. "We wanted to get to a point where if you're a traffic management officer and I put in front of you two scenarios — one is actually from the LLM and one is from some day in the past two or three years — I want them to not be able to tell it apart."

To ensure the LLM was generating scenarios within a probable range of real-world conditions (think wind speeds, precipitation levels and thunderstorm locations) they built quantitative models based on data from past weather events and traffic delays, which generated random but realistic figures to represent scenarios numerically. They fed those numerical scenarios into the LLM, which was free to hallucinate scenario scripts, but within the realistic bounds set by the quant models, Li says.

In the future, they want to create scripts for disruptions from special events, like a Super Bowl or total solar eclipse, as well as expand the scenarios to include calculations of in-flight route capacities.

An air traffic management professor who isn't affiliated with Li's or other LLM research says the training tool seems promising.

"I think there's viability there in terms of training purposes," particularly for tabletop exercises, says Michael McCormick, a professor at Embry-Riddle Aeronautical University and a former vice president in FAA's Air Traffic Organization, who at my request reviewed the papers by Li's team.

The LLM training tool "can make it very dynamic so that it becomes more of an exercise and a challenge for the participants," he adds.

However, McCormick says he sees less promise for the ChatATC concept, mainly because, in his view, ground delay programs are relatively easy to analyze, write and monitor. "It's fun, but I don't see where it is going to do anything revolutionary or even evolutionary."

Going forward, Li and his researchers plan to incorporate user feedback to refine ChatATC and the training tool. This includes building an interactive web application for the training tool that will enable them to conduct experiments on the best ways to prepare traffic managers for severe disruptions. So far, they've built a phone app for ChatATC that could be adopted for research with a wide audience of FAA national traffic managers or airline operations managers who provide input on the NAS daily operations plan. That research could begin in 2026, Li says.

In the long term, he envisions ChatATC evolving from merely "a glorified chat bot" that summarizes knowledge from the past, into a suggestion box-like role that presents three or four ideas.

"Maybe two of them are completely unhelpful, but maybe the other two spark a decision in a human air traffic manager that he or she wouldn't have thought of before," he says. "The human could then go back and say, 'Hey, that third suggestion you gave me, that was really good, but I made some modifications.' And that becomes part of the feedback process." ★





# If government R&D spending is reduced, can industry take up the mantle?

**Not all research and development is created equal.** In few places is that more evident than in the rapidly evolving domain of space, where today's breakthroughs are frequently the culmination of decades-long research and studies.

In the U.S., the Trump administration has proposed increased funding for bold human spaceflight initiatives including NASA's Artemis moon program that aims to land the first crew on the lunar south pole as soon as 2027. On the defense side, the Pentagon is set to receive a budget exceeding \$1 trillion in fiscal 2026, a historic increase likely to accelerate near-term technological gains. At the same time, the White House has proposed cutting, by roughly one-third, basic research funding for NASA, the National Science Foundation and other civilian agencies.

China, which has its own lunar ambitions, has embraced a very different approach, adding millions in R&D funding every year. It spent roughly \$500 billion last year, \$35 billion of which was for basic research, according to the country's National Bureau of Statistics — an 8% overall increase from 2023 and a 10.5% jump for basic research.

Amid the rebalancing of U.S. budgetary priorities, can the commercial sector take up the mantle to drive innovation? Four experts with experience in government, industry and academia weighed in.

— *David Ariosto*

# Namrata Goswami

Professor of space security at Johns Hopkins University and former research fellow at the Institute for Defence Studies and Analyses New Delhi.



Where China has a strategic advantage — and I’m seeing it across the civilian, military and commercial sectors — is that they actually have identified space as a key strategic technology that requires priority funding. President Xi Jinping talks about it at the National People’s Congress. He meets the different scientists. He has directed long-term policy planning and thinking. This has resulted in the China National Development and Reform Commission recognizing satellite internet and other related technology like artificial intelligence, quantum as critical infrastructure.

That means three things: One, that particular technology will have priority funding and long-term funding, even if there is a dip in the Chinese economy. Second, when you declare something a critical infrastructure, it receives the highest level of deterrence and defense. So, in case such assets are targeted, China would view that as a threat to their capability to continue economically and respond in some manner. It could be a cyberattack, it could be some level of nonkinetic attack. Finally, they’re going to pass laws and regulations that declare long-term allocation of skill sets, sign MOUs with universities to develop that and long-term planning.

In the U.S. it seems like we do not explain what we mean when we categorize a particular technology as strategically vital. It’s one thing to say that a space technology is vital for U.S. national security, but it’s something else when you are actually scaling it up to the White House and congressional level. That says that without funding these particular missions and activities, America and the way America’s future is going to unfold will be affected. It’s a very different way of thinking.

I would argue that basic science and research are extremely vital when it comes to building capacity. So even when we are thinking about human spaceflight — long-term, not the short-term programs we had during the Apollo era — or we are thinking about, say, human missions to the moon and Mars, it’ll also require a lot of effort to actually support those missions. In some sense, investment in scientific capacity engineering will play a vital role.

The interesting thing about China is while they’re investing in pure science, they’re always doing so within that larger structure of national defense. Because of that, their funding is very much determined by the concept of strategic technologies. In the U.S., what I find fascinating is that when you actually do a much more comprehensive study beyond just say, looking at NASA, it seems like across different administrations there has been a growing focus on building some of the capacities.

Take the Golden Dome missile defense shield. The White House has proposed increasing the budget for the Space Force. Also, I don’t think people realize that the Department of Defense under several initiatives like the Air Force Research Laboratory, Defense Innovation Unit, actually fund a lot of R&D. When you put all that together, the funding is actually quite strong, even though the headlines make it appear there is some level of decrease.

“The interesting thing about China is while they’re investing in pure science, they’re always doing so within that larger structure of national defense.”



# Bhavya Lal

Professor at the RAND School of Public Policy, former NASA associate administrator for technology, policy, and strategy and the first woman to serve as NASA chief technologist.



The things to measure are outcomes and impacts, but those are hard to measure and we are lazy, so we just measure inputs, activities and outputs. And this is what's happening with our R&D sector. We are not willing to do the hard work of measuring what is truly being achieved.

Don't get me wrong, I am not supporting the current funding cuts. We do not want to be cutting funds in a time like this. But we need to think beyond inputs and go to the next level: How many of these government-funded activities are truly worthwhile? What are the outcomes of that work? Did the funding program produce flight demos? Did it generate patents or publications that were cited? Did it create spinoffs that industry can use? Did it enable Artemis or the James Webb Space Telescope? Did it strengthen the industrial base or give any kind of strategic edge over China?

On the other hand, there is value in open-ended, blue sky research. We want the best scientific minds to think about the most important things, and maybe someday it works. For example, when Einstein was talking about relativity, he wasn't saying that someday GPS would be based on relativity, right? We never funded Einstein saying that someday his stuff would be valuable. We funded Einstein because we said whatever he has to say is worthwhile for its own sake, for its own reason. Supporting the best scientific minds as they ask the biggest questions is part of what it means to be a society that values discovery. Competitiveness isn't only about GDP, patents or hardware in orbit. It's also about cultural strength — showing that as a nation we value curiosity, imagination and truth-seeking. And this is why the best and the brightest of the world come to America. Those are intangible assets, but they are every bit as important to long-term influence and leadership as tangible metrics.

My two points may sound contradictory, but they're not because I'm talking about two different categories of research. For most R&D, especially mission-driven work, outcomes and impacts are the right metrics. That's where we should be sharper and more disciplined. But there is also a separate category: truly basic, open-ended research. That we fund not because of measurable outcomes, but because it reflects who we are as a society. Science, art, music and poetry all fall in this same category.

For this category, we should deliberately set aside a portion of national investment with no requirement for immediate utility. Its "impact" is cultural and civilizational, not technical or economic. So the framework is: Most research should be judged by outcomes and impacts; a small but important slice should be funded simply because it represents the kind of civilization we want to be.

"Competitiveness isn't only about GDP, patents or hardware in orbit. It's also about cultural strength — showing that as a nation we value curiosity, imagination, and truth-seeking."



In its fiscal 2026 NASA budget, the White House proposed a nearly 50% cut to the Science Mission Directorate and a net increase of \$647 million for "human space exploration" to the moon and Mars. Plans call for sending the first astronauts to the lunar south pole as soon as mid-2027. The crew will travel to lunar orbit in an Orion capsule, then down to the surface in a Starship lander (shown here in an illustration).

SpaceX

## Douglas Loverro

A former NASA associate administrator for human exploration and operations, he's held a variety of leadership roles at the Department of Defense and the National Reconnaissance Office.



Fundamental research is the engine that drives everything else. It is absolutely a competitive force. And if you don't continue fueling that beast, we will fall behind.

The reason why the U.S. has more Nobel prizes every year than any other nation — and it's been that way for 30, 40 years — is because of the fundamental research we fund across the nation. That accumulates into the latest advances in whatever field you choose to look at. It is undeniable. When we cut that research, we are absolutely cutting off any U.S. competitive capability against our adversaries in China.

From what we see from the current administration, and certainly if I looked over the last 50 years, those kinds of dollars are down. But when you are approaching a trillion-dollar defense budget, most of that increase goes into some form of either later phase R&D or development. That boost in funding wipes out a lot of sins that happen at the lower levels of the National Science Foundation.

Now, I'd be the first to tell you that the Department of Defense doesn't invest in fundamental basic research very well. In DOD parlance, we call that 6.1 research. The reason we call it 6.1 is because

"Fundamental research is the engine that drives everything else. ... When we cut that research, we are absolutely cutting off any U.S. competitive capability against our adversaries in China."

the name of the program element numbers, the line numbers in the budget that fund those things begin with a 6 and a 1. We don't fund a lot of that. We do fund some of it from the DOD, but certainly we rely on other agencies like the National Science Foundation, National Institutes of Health, those kinds of things to fund fundamental basic research. Most of our funding goes to 6.2, 6.3, 6.4, which are higher levels of research. 6.4 research basically means research that is now actually aiming to create a product that has some fundamental use.





# Luca Rossetti

Founder and CEO of D-Orbit, an Italian space logistics company focused on satellite deployment and sustainable orbital services.



Decision-making is the main difference between China and the Western space sectors. In Europe and in the U.S., we are used to following procedures, standards, and so on, which take time. In the Eastern part of the world, the government can make decisions very fast — which means they can also make mistakes very fast and decide to change direction or to invest in something in no time.

The second variable is short-term versus long-term. If we really want private investors to keep investing, then of course they are expecting a return on their investments. That's typically a five- to 10-year wait, which means that the company needs to sacrifice investments in the long term to focus on the short term independently from the innovation.

Let's remember that SpaceX started in 2002 and became significantly profitable in 2023 — some 20 years later — and it's the most important launch company on the market today. *[Editor's note: SpaceX reportedly exceeded \$8 billion in revenue in 2023, nearly double its 2022 total.]* So if we focus just on profitability, of

course there is a ticket to pay: the loss of the long-term technologies. The question then goes to the government. Because if they say, "We need to maintain competitiveness because we want to have our position on the global chess board," especially with respect to China, then they need to invest in programs that are long lasting and favor the innovation.

In the past, even at NASA, there was a lot of investment in very interesting programs and technologies. But what was missing was the execution part: bringing all those technologies into the market, and into the application. This is something that should come first from the government, especially for those technologies that are early stage. And then the second question is, how can we make sure that this innovation will still be an innovation at the time it's realized?

Here's the potential compromise I see that would keep private investment flowing while ensuring that innovation is kept safe: It's for the government to fund innovation, making sure that this innovation can be sold to the market, can reach the market. So it's not just funding early-stage R&D, but rather funding the entire cycle to make sure that this cycle is within a real program. At that point, companies will say, "Look, we are not just co-financing our technology. We will be part of a real program with real customers in the future." And private investors will say, "OK, I see my return on the investment." So, public money and private money need to work together in a more consistent and better way. ★

◀ Artificial intelligence and quantum computing are among the emerging technologies for which China has increased research funding in recent years. In May, a Long March 2D rocket launched the first 12 satellites for the "Three-Body Computing Constellation," a planned network of 2,800 satellites whose onboard AI will process information on orbit.

ADA Space

"It's for the government to fund innovation, making sure that this innovation can be sold to the market, can reach the market."



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# ! HEAVY TRAFFIC AHEAD

SpaceX has proven that thousands of satellites can be operated without collisions in low-Earth orbit, but that task could become more difficult as Amazon and others deploy their own megaconstellations. **Jonathan O'Callaghan** explores the factors at play.

BY JONATHAN O'CALLAGHAN | [jdaoca@gmail.com](mailto:jdaoca@gmail.com)





In September 2019, when SpaceX had launched barely 500 satellites, the U.S. military found that one of them, Starlink 44, had an unnervingly high collision risk — a chance of 1 in 1,000 — with a European Earth observation satellite called Aeolus. After contacting SpaceX, the European Space Agency raised Aeolus’ orbit by about 350 meters to ensure the two spacecraft would miss each other, while Starlink 44 stayed put.

Despite the happy ending, the situation raised concerns that the arrival of Starlink and other megaconstellations would make collisions an increasingly likely prospect, each of which could produce thousands of new pieces of debris.

“I was one of the people that was doubtful,” recalls Victoria Samson, an expert in space security at the Secure World Foundation, a Washington, D.C.-based nonprofit.

Six years later, those fears have not materialized. As of this writing, SpaceX has encountered no collisions with Starlink, which numbers 8,300 satellites and growing — roughly two-thirds of all the active satellites on orbit.

“It’s been perhaps better than we feared,” says Samson.

But with a handful of companies across the U.S. and China beginning to launch and deploy satellites for their own megaconstellations, experts are bracing for a new era in which several Starlink-sized networks circle Earth. Old worries are re-emerging, in particular the probability that adding tens of thousands additional satellites in low-Earth orbit all but guarantees an increase in collisions, unless governments and companies can devise adequate rules of the road, including ample communication.

The megaconstellation era might not end with satellite broadband, either. There are proposals for erecting such networks to collect solar power and convert it to electricity that is beamed to Earth, as a means of providing clean power to cities and countries. Other ideas center on broader Earth observation fleets like that operated by Planet, or higher-precision navigation services from networks of small satellites.

If all this comes to fruition, managing multiple large constellations operating in close proximity will be “the next big challenge,” says Brian Weeden, a space policy expert at the California-based Aerospace Corp.

Among the concerns is how the two main U.S. operators, SpaceX and Amazon, will coordinate with in-development Chinese megaconstellations. Further complicating the issue, in Weeden’s view, is that these broadband constellations are more than just commercial endeavors. They’re “seen as an important national capability” increasingly relied upon for security and military use, Weeden says, making it all the more important that operators have a way to communicate with one another to deconflict and avoid potential collisions.

And that’s perhaps the biggest hurdle, given how little the U.S. and China have historically communicated about space assets.

“There’s really good coordination between the Western operators,” he says. “The challenge is China.”

## Mega numbers

According to SpaceX’s regulatory filings, its Starlink satellites between December 2024 and May 2025 performed 144,404 collision avoidance maneuvers, a number that was unfathomable several years ago when even just a few maneuvers per year for any satellite seemed like a lot.

“It is just incredible,” says Hugh Lewis, a space debris expert at the University of Birmingham in the U.K. “And that’s for a constellation that is one-fifth the size that it’s going to be,” referring to SpaceX’s aim of receiving regulatory approval to grow the constellation from 12,000 to 42,000 satellites.

Before Starlink, the biggest constellations were relatively modest: Think Planet’s fleet of about 200 Earth-imaging satellites, and Iridium’s 66 communications spacecraft. That changed in the mid-2010s when SpaceX and the U.K.-based WorldVu (now known as OneWeb) outlined plans for orbiting thousands of satellites in LEO to beam internet globally. OneWeb launched its first spacecraft in February 2019, and SpaceX followed in May.

Progress since has been rapid on these megaconstellations, a term that generally refers to at least 1,000 spacecraft working together. OneWeb now operates 648 satellites, the second largest constellation, while Starlink as of mid-September surged to 8,300 toward its initial





goal of 12,000. Both have avoided collisions so far.

Around 21 megaconstellation proposals have been put forward in the last decade, notes Jonathan McDowell, an astronomer at the Harvard-Smithsonian Center for Astrophysics who tracks launches and satellite activity. Some of these have simply been announcements of intentions to launch thousands of satellites, while others have received regulatory approval from the International Telecommunication Union, or ITU, which allocates spectrum for communication in orbit.

Not all efforts have been genuine. For instance, Rwanda in 2021 submitted a filing to the ITU for a constellation of 337,320 satellites in 27 different orbits, which Samson says may have been motivated by a desire to reserve space in orbit, rather than an actual plan to launch spacecraft.

“People are worried about slots filling up,” she says.

It’s a valid concern, given that several of the serious proposals have secured regulatory approval to launch and operate several thousands of spacecraft. Among them is Amazon’s Project Kuiper, which launched its first operational satellites in April and now has just over 100 in orbit of a planned 3,236 — 1,613 of which must be in orbit by July 2026 to comply with requirements from the U.S. Federal Communications Commission. Amazon did not respond to a request for comment about the deadline and its plans to safely operate the Kuiper satellites.

In China, multiple efforts are underway. Since August 2024, Shanghai Spacecom Satellite Technology has launched 90 spacecraft for its Qianfan constellation — which translates to “Thousand Sails” — with plans to eventually orbit 15,000 satellites. China Satellite Network Group plans 13,000 satellites for its Guowang network and has already put up about 80. Geely Holding Group is targeting nearly 6,000 satellites for its Geespace constellation, with about 40 in orbit so far.

Fueling this rapid growth are advances in manufacturing that have allowed operators to rapidly churn out the hundreds and thousands of spacecraft needed to achieve global broadband connectivity and then maintain it as their satellites reach the end of their lives and fall back into the atmosphere. SpaceX has pioneered this approach and says it produces eight Starlinks a day at its factory in Redmond, Washington.

“The reality is if you start launching satellites, you have to maintain the constellation,” says Richard Soden, director of space and satellite solutions at Keysight Technologies, a testing provider in Virginia.

SpaceX has achieved its high production rate by handling all its satellite manufacturing in-house. “They’ve got this vertical integration,” says Soden. “It’s easier to control the supply chain when you control the supply chain.”

## Mega potential

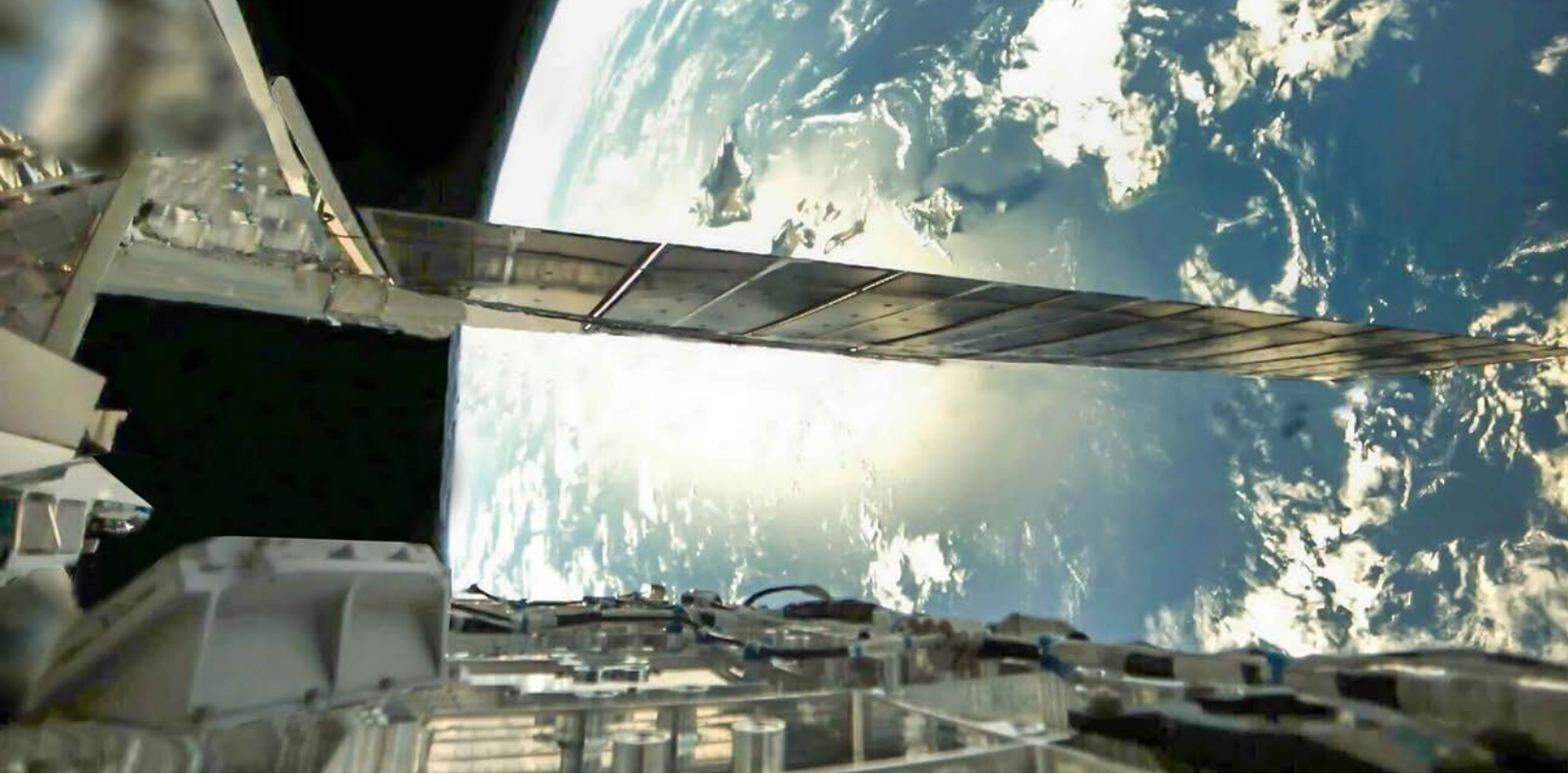
While the allure of megaconstellations is severalfold, perhaps most attractive is the possible financial return. In July, SpaceX said it had more than “6 million active customers” paying \$80 to \$120 a month for Starlink internet, plus \$349 upfront for a terminal, which translates to billions in annual revenue. Founder Elon Musk has previously said the system could generate about \$30 billion a year.

“Total internet connectivity revenue in the world is about \$1 trillion, and we think maybe we can access about 3%,” Musk said in a rare call with reporters prior to the first Starlink launch in 2019.

The second part of the appeal is usability. Starlink will never compete with terrestrial broadband in terms of speed; at best, it offers download speeds of a few hundred megabits per second, compared to gigabits on the ground,

▲ China in late 2024 launched two prototype satellites for the Guowang constellation. This is one of several broadband networks in development, all of which are to comprise thousands of satellites.

Hainan International Commercial Aerospace Launch Company Ltd



▲ Amazon has released very few images of the operational satellites for its Project Kuiper megaconstellation, of which 102 are on orbit. Pictured here is one of the prototypes launched in 2023, which Amazon deorbited last year.

Amazon

with far less total bandwidth. “No one is tearing fiber out to put satellite broadband in instead,” says Tim Farrar, a satellite communications consultant in California.

Instead, the value of satellite broadband is in the places fiber doesn’t reach: rural communities, ships, aircraft and conflict areas, among others. United Airlines, Qatar Airways and Air France have all signed on to equip their fleets with Starlink terminals to offer passengers faster WiFi than ever before. And the service has proven invaluable in war zones including Ukraine, where it has provided a resilient communications backbone.

“Starlink has been an extraordinary success,” says Farrar. “It has made a lot of difference to people’s capabilities to live their lives in remote areas. Six million subscribers is way beyond what anyone has achieved in the past or is likely to achieve in the next few years.”

Other countries have taken note. In addition to China, Russia has said it is developing its own satellite internet constellation, while the European Union has announced IRIS<sup>2</sup>, a secure constellation of about 290 satellites, to launch in the coming years.

“Having a sovereign space internet capability has been a big change,” says Weeden.

### Mega conflict

It is the U.S. and China, however, that are racing to develop the biggest constellations — a competition Starlink is dominating for the moment. But as competitors start to launch their spacecraft in earnest, on-orbit navigation will become increasingly challenging.

In the past, when satellites risked close approaches, known as conjunctions, operators phoned or emailed each other directly to decide who would maneuver. That is impossible at Starlink’s level.

“Email is not particularly scalable or responsive,”

notes Ian Christensen, director of private sector programs at the Secure World Foundation.

Instead, Starlink relies on automation. The satellites automatically fire their thrusters when collision risks exceed a certain threshold, according to SpaceX’s public filings. And the company has taken pains to note it has surpassed industry standards, initially tightening its trigger from the commonly used 1 in 10,000 chance of collision to 1 in 100,000. SpaceX has further increased that threshold, most recently to 3 in 10 million earlier this year, according to reports filed with the FCC.

“There’s no business case for it,” says Lewis, noting that more frequent maneuvers mean more fuel expended and potentially a shorter lifespan for the satellites. “The only thing I can guess is that it’s a safety issue, to maintain the safety of their constellation at a particular level.”

SpaceX did not respond to a request for comment.

Even so, risks remain. In a paper published last year in the *Journal of Space Safety Engineering*, Lewis estimated that even with safeguards, the cumulative chance that a constellation the size of Starlink experiences at least one collision per year is greater than 10%.

“It’s inevitable, I think, that we’ll see a collision involving an active satellite in a constellation,” he says.

Even a single collision can create thousands of new debris fragments. In 2009, the active American Iridium-33 satellite and the defunct Russian Kosmos-2251 collided over Siberia, generating 2,000 trackable pieces of debris bigger than a smartphone, about half of which remain in orbit. The fear is that more frequent collisions could generate enough debris to set off a chain reaction that eventually renders LEO unusable — the infamous Kessler Syndrome phenomenon.

Efforts to impose rules for collision avoidance have stalled, with regulators including FCC and the United



# The LEO leaders

Today, OneWeb and SpaceX operate a combined 9,000 satellites for their internet broadband constellations. As Amazon and a handful of Chinese operators continue building out their own networks, the total number of broadband satellites is poised to swell to 80,000 in the next decade.

Company	Megaconstellation name	Initial constellation size	Growth plan	First launch	Satellites in orbit as of September	Altitudes
<b>Amazon</b> Washington, U.S.	Project Kuiper	578	3,236	April 2025	129	590, 610 and 630 km
<b>China Satellite Network Group (China SatNet)</b> CASC subsidiary in Beijing	Guowang	6,080	12,992	December 2024	81	500 to 600 km, and 1,145 km
<b>Eutelsat OneWeb</b> London, U.K.	OneWeb	648	Declined to say	February 2019	648	1,200 km
<b>Geespace</b> Shanghai, China	Geely Satellite Communication Constellation	64	6,012	June 2022	41	600 km
<b>Shanghai Spacecom Satellite Technology</b> Shanghai, China	Qianfan	1,296	15,000	August 2024	90	1,160 km
<b>SpaceX</b> California, Texas and Washington, U.S.	Starlink	12,000	42,000	May 2019	8,300	340 to 610 km

Sources: Research by Jonathan O'Callaghan and Cat Höfacker; chart by THOR Design Studio

Nations yet to establish binding standards or rules of the road for safely operating large constellations, in part because of how rapidly the sector has grown.

"It's hard to have firm rules when you don't know what the best practices are," says Weeden.

In the U.S., NOAA's Office of Space Commerce is working on a possible solution with its TraCSS program. Short for Traffic Coordination System for Space, this surveillance network is intended to provide better data on potential conjunction events between civilian and commercial satellites to avoid collisions. The program, however, faces a somewhat uncertain future after a portion of its fiscal year 2025 budget was rescinded and the Trump administration proposed eliminating funding in its fiscal 2026 budget.

To illustrate the need for TraCSS, program manager Dmitry Poisk, points to the number of predicted conjunction events: "On a bad day, it's a million predicted just in the next week."

Some of those will resolve themselves, he notes,

meaning a satellite never has to move. But as the size and number of megaconstellations grow, the amount of possible conjunctions will increase.

"It will be exponential," Poisk says. "Automation is going to be key."

Neither Amazon nor the operators of the Qianfan and Guowang constellations has said whether they plan to maneuver their satellites via automated avoidance software, like SpaceX. Amazon and Shanghai Spacecom Satellite Technology did not respond to requests for comment, and contact information for the China Satellite Network Group couldn't be located.

In response to emailed questions, a spokesperson for Geespace said that while the company's avoidance technology is "not entirely automated," it has "established a high-precision collision warning and avoidance computation system" that's "capable of monitoring potential risks in real time and executing avoidance maneuvers via uplink commands."

As for communicating with other satellites, Geespace

“actively maintain[s] communication and information exchange with international space operators, including those in the United States, to jointly ensure orbital safety.”

### Mega challenge

The consequences of scaling up satellite numbers go beyond possible collisions. Since 2019, astronomers worldwide have reported that their observations of the night sky have been marred by the bright streaks of traversing Starlinks, especially at dusk and dawn. SpaceX has tried to dim the satellites, applying a darkened coating to some of them so they reflect less sunlight, but results are mixed. A paper published online as a preprint in June found that Starlinks still exceeded limits of acceptable brightness established by the International Astronomical Union.

“Starlink has done a lot of work to make their satellites fainter, and that’s fantastic,” says Samantha Lawler, an astronomer at the University of Regina in Canada, but she notes that the buses of the newer v2 variant are also bigger, “so they’re about the same brightness.”

The newly launched megaconstellations would worsen the issue, with some of the Chinese satellites already appearing particularly bright. The spokesperson for Geospace said its spacecraft “do not have any light-emitting devices and do not produce light themselves, so they will not affect astronomical observations,” but did not address the issue of the satellites reflecting sunlight.

And then there are the possible impacts to Earth’s atmosphere. The frequent rocket launches necessary to deploy and maintain megaconstellations could produce enough emissions to slow the recovery of the ozone layer, according to a Nature paper published in June.

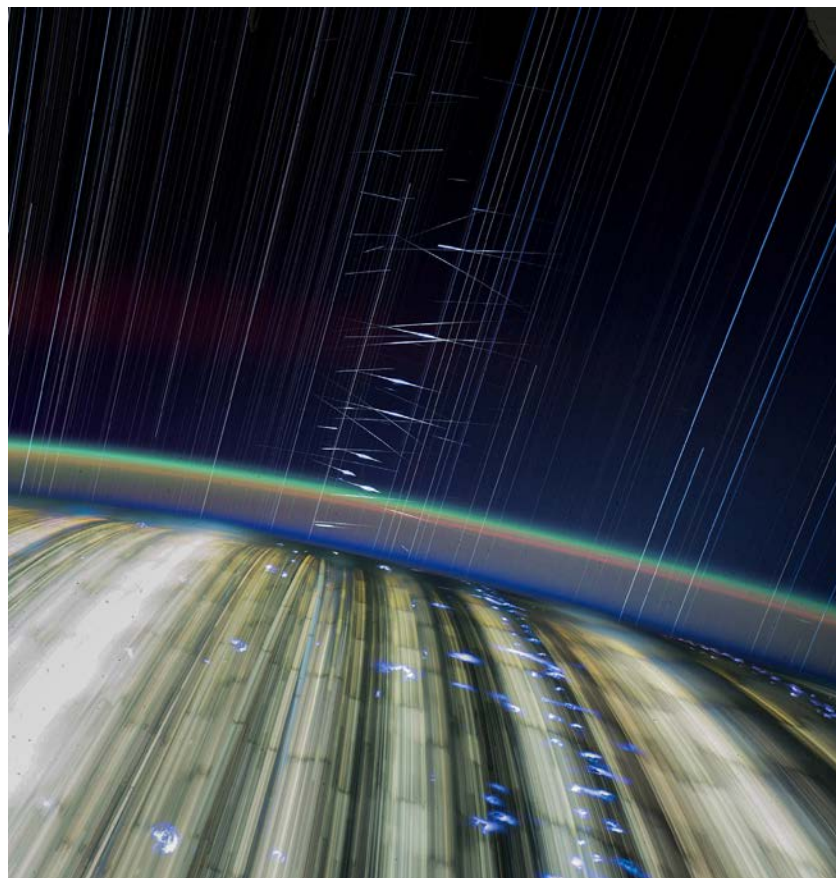
SpaceX estimates that four to five Starlinks reenter the atmosphere every day, and a 2024 study in the journal *Geophysical Research Letters* estimated that a typical 250-kilogram spacecraft during reentry generates about 30 kilograms of aluminum oxide particles, which may linger in the atmosphere for decades.

There are also concerns that not all these satellites will completely burn up on reentry. Last year, a piece of a Starlink was reported to have fallen on a farm in Canada, though that appears to be the only incident of its kind to date.

### Mega communication

The question now is how to operate multiple Starlink-size constellations at the same time over the coming years. While they all won’t be occupying the exact same altitudes and orbital shells, the different satellites will constantly be raising and lowering to reach their intended orbits, passing others on the way.

“Perhaps the satellites that are operating in a shell should remain stationary, and people orbit-raising or lowering should give way to those satellites and go around them,” says Miles Lifson, an expert in orbital carrying capacity at the Aerospace Corp. “One thing we’ve seen is



it’s really hard to get a single agreed set of rules that works for everyone.”

In August, the U.S. government issued an advisory on how operators should communicate with China in a conjunction event. It instructed operators to send an email to an address at the Beijing Institute of Telecommunications and Tracking Technology, which tracks satellites in China, that states whether they intend to maneuver, while not revealing any technical or mission-critical information.

“It’s a small step, but it is a step in the right direction,” says Samson, adding that there’s an understanding in the industry “that there needs to be communication between the U.S. and Chinese actors.”

How and whether such guidance will work for operators with thousands of satellites is unclear. Given the number of conjunction events that may occur, sending hundreds of emails a day is likely impractical.

McDowell, the astronomer, says one solution might be to allocate specific orbital slots to different countries, as well as have limits on the number of satellites allowed up to different altitudes, but he notes this is not an idea currently under discussion.

Whatever the chosen solutions, the clock is ticking. Given the current launch cadence, there could be tens of thousands of satellites in orbit within a decade.

“My concern has always been not at the 10,000 level, but at 50,000,” says McDowell. “We’ll find out whether that’s really doable.” ★

▲ SpaceX’s Starlink satellites are visible as white streaks in this long-exposure photograph by NASA astronaut Don Pettit, taken aboard the International Space Station last year. The “wonky streaks” are created by the “satellites reflecting pre-dusk or pre-dawn sunlight off their solar panels,” Pettit said on X.

NASA/Don Pettit



A full-page background image showing a rocket launch at night. The rocket is ascending vertically, leaving a massive, bright white and orange plume of fire and smoke that fills the right half of the frame. The launch pad structure is visible at the bottom, and a crane arm is on the left. The sky is dark.

# HYPERSONIC FLIGHT TESTING'S UNLIKELY RESCUER

## Companies developing Mach 5 passenger planes and capsules for on-orbit manufacturing could supply the Pentagon the extra hypersonic test platforms it has long been seeking.

**Keith Button** spoke to some of the aspiring providers about applications and the status of their technologies.

BY KEITH BUTTON | [buttonkeith@gmail.com](mailto:buttonkeith@gmail.com)

**T**he goal of Venus Aerospace's May flight test was straightforward: Propel a small rocket with a subscale version of the rotating detonation rocket engine the Houston startup is developing for its planned Mach 9 passenger plane and other hypersonic craft. But an off-hand comment by an unidentified observer suggested another possible market:

"We literally had a customer who watched our flight and says, 'Hey, on the next flight, could we talk about integrating something into this?'" says CEO Sassie Duggleby.

The interaction illustrates a potential opportunity for the U.S. Department of Defense to increase the number of hypersonic flight tests conducted each year from a handful to several dozen — and in doing so, finally have a shot at closing the technology gap with China and Russia.

Flight tests are the gold standard for proving hypersonic vehicles and components because it's tough, if not nearly impossible, to simulate the extreme heat and violent forces that would be exerted on a wing surface or the electronics of an aircraft.

"You've got to think about all the sensors and the cameras and the materials and all the different pieces that go into an integrated system: Each one of those individual components needs to be tested in order to be integrated into a full-out system," Duggleby says.

Wind tunnels might be fine for early tests on a prospective material for the exterior of a missile, for example, but not for proving the material will hold up during a Mach 5-plus flight, says Will Dickson, chief commercial officer at Colorado-based Canopy Aerospace.

"A lot of times they'll claim Mach 6, Mach 7, Mach 8, Mach 9, but it's just for 20 milliseconds. That's just not really helpful," says Dickson, whose company makes thermal protection materials for spacecraft and missiles. "Customers want to see the results of testing a material on an actual hypersonic flight. It's not an area where customers want to take a ton of risk."

Compounding the challenge is the very small number of flight test providers available today. Of the 500 or so hypersonic payloads that various customers want to test in the U.S. in 2025, only a handful will fly, according to Duggleby. And so, companies like Venus Aerospace that are developing craft for other high-speed flight applications have emerged as a potential solution: After all, the thinking goes, a hypersonic rocket test launch or a spacecraft designed to grow pharmaceutical crystals in orbit and then survive the searing conditions of atmospheric reentry could easily be adapted or repurposed to test components and materials for future hypersonic missiles.



### Keith Button

has written for C4ISR Journal and Hedge Fund Alert, where he broke news of the 2007 Bear Stearns hedge fund blowup that kicked off the global credit crisis. He is based in New York.

◀ Small launch provider Rocket Lab launched its second HASTE vehicle in November 2024.

Rocket Lab





The benefits aren't only on the government side. For a startup like Venus Aerospace, which is planning a hypersonic flight test in 2026 of the engine for its proposed Mach 9 airliner, DOD-funded research offers the promise of a welcome influx of cash.

"We're happy to have you come along for the ride and pay us for it. It's a faster way for us to get to some revenue as we're continuing to push things forward," says Dugleby. "If we're flying to learn more about our system, we might as well fly a payload for a customer and get paid for that."

### **Ramping up**

Until recently, the U.S. had conducted about one hypersonic flight test per year for about 20 years, says Iain Boyd, an aerospace professor at the University of Colorado. "That's absolutely not enough to actually make real progress," he says.

Over that same period, China is believed to have flown "multiples of 10" times the number of U.S. flights, he says. "It's generally known that they've been flying and flying and flying and flying."

Meanwhile, Russia has already begun fielding hypersonic missiles, firing air-launched Kinzhal missiles during its ongoing invasion of Ukraine.

"They've got deployed hypersonic weapons that the U.S. does not have yet, so regardless of what the test cadence is, they have managed to produce hypersonic weapons," says Doug Crowe, senior vice president of program management for NSTXL, the National Security Technology Accelerator, a DOD-funded nonprofit that fosters technology development.

The U.S. has responded by funneling hundreds of millions of dollars annually toward flight test activities to develop technologies for hypersonic missiles and for defenses against them. For the 2025 budget year, the



Varda Space Industries in December received a \$48 million contract from the Air Force Research Laboratory to test military payloads aboard its W-series capsules. The photo at left was taken by an onboard camera during W-3's atmospheric reentry in May. The W-4 capsule below was launched in June.

Varda Space Industries



Pentagon requested \$6.9 billion for hypersonics research overall, according to the Congressional Research Service, and \$3.9 billion for fiscal 2026. So far, that flight test money has flowed to a range of test beds, from plummeting space capsules, to rockets originally designed for launching small satellites, to drones launched from jet planes in flight.

Late last year, the U.S., Australia and the U.K. signed an agreement to spend \$252 million on joint hypersonic flight tests by 2028. In January, the Department of Defense's Multi-Service Advanced Capability Hypersonics Test Bed program — better known as MACH-TB — awarded a five-year, \$1.45 billion contract to Kratos Defense & Security Solutions, which will dole out the funding to other companies for flight tests. The sprawling reconciliation legislation that President Donald Trump signed into law in July includes \$400 million for expanding MACH-TB and \$2.7 billion for other hypersonic weapons

programs, plus \$24.4 billion to develop the proposed Golden Dome shield.

"There's a lot of money pouring in; there's a lot of technology pouring in," says Brian Rogers, vice president of global launch services at Rocket Lab, a California-based rocket launcher and subcontractor on the Kratos contract. "The world of geopolitics [is] in such a place that missile warning, missile track, missile defense is an important thing, and (so is) the commercial market for aerospace and space."

NSTXL has been helping attract potential subcontractors for MACH-TB, and Crowe says he expects the program will reach its goal of funding 50 hypersonic flights per year by 2027. With a flight every week or so, design cycles will shorten considerably.

"Right now, they do a design iteration; they may have to wait six months or more until they can actually get a flight test to validate it," he says. "If they've got corrective





actions, that goes online, so before you know it, you did two things and it's taken you a year to get that done."

Part of the reason why actual flights are so valuable is the lack of knowledge about the physics of flying at Mach 5 and above, says Zachary Krevor, CEO of Stratolaunch of Mojave, California. Another subcontractor on the Kratos contract, Stratolaunch, is in the process of building a fleet of reusable, air-launched testbeds that could eventually complete dozens of test flights per year for DOD and other customers. Temperatures on a hypersonic vehicle's surfaces rise above 1,100 degrees Celsius as it pushes through the air, then the air begins to ionize around the vehicle.

"Your control surfaces are either not as effective or actually potentially changing," Krevor says.

So far, Stratolaunch has conducted four flights with versions of its Talon-A autonomous aircraft, including two that reached hypersonic velocity.

### Learning on the fly

Another advantage of actual flights is that testers can see how their tech responds to "stacking" conditions, says Dickson of Canopy. That means vibrations from the flight, plus bow shock waves at certain velocities, plus sustained heat and pressure for minutes at a time, plus variations of heat and pressure at different altitudes and speeds, plus how the technology interacts with radios or sensors.

As these flights produce data about hypersonic aerodynamics, that information can also be fed into computational models. As those models improve, it will open up new design possibilities for space vehicles, says Dave McFarland, vice president of hypersonic and reentry test for Varda Space Industries of El Segundo, California. The company began flying space capsules for on-orbit manufacturing and research in 2023.

While Varda's main business model is focused on pharmaceutical customers and others that want to manufacture

substances in microgravity, McFarland says the latest reentry of its W-Series capsule in May illustrates that the design is ready-made for testing hypersonic technologies.

For each flight, a satellite connected to a capsule is lofted to orbit by a SpaceX Falcon 9. The capsule can spend days or weeks manufacturing the desired material or substance for a commercial customer. For its latest flight, which began in June, the plan is to make proprietary pharmaceutical crystals from a liquid solution. Once manufacturing is complete, the satellite ejects the capsule to return to Earth. During reentry, the capsule reaches speeds up to Mach 25 and is subjected to extreme vibrations and plasma-inducing heat — 17,700 C, hotter than the sun's surface.

"It seemed like a natural coupling of what DOD wanted to do," McFarland says.

So far, Varda has flown three capsules, each one carrying pharma materials and technology aboard for testing under hypersonic conditions: a plasma-measuring spectrometer for the U.S. Air Force Research Laboratory, an inertial measurement unit for the Air Force and thermal protection materials for NASA. Some prospective commercial customers, whom McFarland declined to name, have also inquired about testing their technology under the hypersonic reentry conditions.

Varda designed its capsules to reenter the atmosphere at a shallow angle to minimize the shock and vibrations for the pharma cargo, but if hypersonics customers wanted to pay to have some capsule flights all to themselves, McFarland says that trajectory could easily be altered to maximize vibration or other conditions.

"If we're going to make a business decision like that, it's going to have to be lucrative," he adds. "We are focusing on a firm fixed price, so you can get under \$10 million for a turnkey launch" that includes the launch, orbit, recovery of the capsule after a parachute landing, delivery of the cargo back to the customer and analysis of the flight.

▲ Stratolaunch of California is marketing itself as a provider of test services to the U.S. Department of Defense and other customers seeking a way to rapidly fly their hypersonic vehicles and components. The company is building a small fleet of autonomous Talon-A aircraft that would be flown over and over to keep costs down.

Stratolaunch

# “IF WE’RE FLYING TO LEARN MORE ABOUT OUR SYSTEM, WE MIGHT AS WELL FLY A PAYLOAD FOR A CUSTOMER AND GET PAID FOR THAT.”

— Sassie Duggleby, Venus Aerospace

That’s similar to the price that Rocket Lab is offering for flights aboard the suborbital version of its satellite-launching Electron rocket, says Rogers. It seems like a lot of money, but not in comparison to the \$100 million DOD was paying when it was conducting only one test per year.

Each HASTE — short for Hypersonic Accelerator Suborbital Test Electron — can launch and release a 700-kilogram payload from its nosecone fairing. This payload can be provided by a customer, or Rocket Lab can provide one that customers can bolt their test items to. HASTE’s liquid-fueled engines are throttleable and gimbaled, so the trajectory can be shaped, Rogers says — for instance, a parabola for an intercontinental ballistic missile-type trajectory, or a shallower angle better suited for releasing a winged, boost-glide vehicle.

Later this year, Rocket Lab plans to perform a “direct inject,” in which a HASTE will be launched and then commanded to turn horizontally and accelerate before releasing its hypersonic test payload, Rogers says. Three HASTEs have been flown so far, all in the last two years and each with expendable payloads that splashed into the ocean, but Rogers says the design is also capable of releasing reusable hypersonic vehicles that land on runways or parachute to land for recovery.

Rocket Lab builds an Electron rocket every 10 days and would like to launch at least one HASTE per month, he says. “There are a variety of payloads that have been waiting a long time to get a flight test, and now that the flood gates are open, I think you’ll see a higher cadence of tests.”

Krevor, the Stratolaunch CEO, hopes at least a handful of those will be aboard his company’s Talon-A vehicles. The goal is to conduct one hypersonic flight test per month by the end of 2025, and then increase that cadence to a flight every two or three weeks. One of the Talons has completed two flight tests for Virginia defense

contractor Leidos, under a MACH-TB contract. Stratolaunch plans to fly a second Talon-A by year-end and eventually have three in rotation, refurbishing them between flights by replacing the black thermal tiles on their leading-edge surfaces, if necessary, and their white insulation blankets.

So far, Krevor says that this reusability has already helped Stratolaunch drive down flight costs. A Talon-A test flight is about “two orders of magnitude” down from the \$106 million per flight that the Congressional Research Service once cited, Krevor says, which works out to \$3.2 million.

## Finding the market

For now, DOD and its contractors still constitute the majority of the demand — about 80% of the potential market versus 20% for commercial and civil uses, Krevor says — but he expects that ratio to shift to 65/35 as companies refine their concepts for hypersonic cargo and passenger planes.

In anticipation of this, Stratolaunch also plans to add a second carrier aircraft to its fleet: a Boeing 747 modified to carry a Talon-A on its belly that could potentially take off from runways near the test ranges of ally countries. The U.S. Missile Defense Agency is funding the modifications and one Talon-A test flight through a \$24.7 million contract.


Judging from U.S. budget figures, it appears that many more such contracts are on the way for other test flight providers as well. Funding for more and more test flights will drive down the cost of those flights, just as the government funding for SpaceX development and frequent flights drove down launch costs for the space industry, says Crowe of NSTXL. “It’s going to dramatically reduce the cost.”

“The technology is there; the funding is there,” says Rogers of Rocket Lab. “It’s a perfect match.” ★



A SpaceX Starship spacecraft is shown in orbit above the reddish, cratered surface of Mars. The ship is oriented vertically, with its nose pointing towards the top right. A bright, glowing blue-white light emanates from the base of the ship, suggesting engine activity or a landing burn. The background shows the dark, curved horizon of Mars against a deep black space.

# A closer look at SpaceX's Mars plan



# Despite meeting all objectives of the 10th Starship test in August, SpaceX's goal of sending the first Starships toward Mars this decade may still be out of reach. **Jon Kelvey** examines the proposed plan and the required technologies.

BY JON KELVEY | jonkelvey@gmail.com

**O**ver the years, Elon Musk has continually revised his aspirational targets for SpaceX landing an unoccupied craft on the surface of Mars. In a 2016 talk before the International Astronautical Congress, he proposed landing a variant of SpaceX's Dragon capsule by 2018, only to shift a year later and suggest the still-nascent Starship could touch down on the red planet in 2022.

"I feel fairly confident that we can complete the ship and be ready for a launch in about five years," he told 2017 IAC attendees, which could have paved the way for landing two crewed Starships on Mars by 2024.

He shifted that target yet again in May, during a talk at SpaceX's Starbase facility in Texas. But this time he gave more details, describing the broad outlines of a step-by-step approach for landing the first humans as soon as 2029.

Five uncrewed Starships would lift off in 2026, the next time the orbits of Earth and Mars are aligned. If all goes well, the craft would touch down on Mars in 2027, carrying an unspecified number of the bipedal Optimus robot made by Musk's electric car company, Tesla. Another 20 Starships would lift off during the next transfer window in 2028. Most of them would carry additional Optimuses to set up Martian ground infrastructure and survey for resources, such as water ice, but at least one of the Starships would carry an unspecified number of human passengers.

Plans then call for steadily increasing the number of flights every 26 months, in each subsequent launch opportunity: 100 Starships in 2031, 500 in 2033, working up to the eventual target of "1,000 or 2,000 ships per Mars rendezvous," Musk said, with each crewed Starship carrying 100 to 200 passengers.

The general plan is sound, according to the 10 experts I spoke with for this piece, several of whom were retired NASA employees who oversaw previous Mars missions and contributed to the agency's plans for sending its own astronauts to the red planet.

"I like it. I like it a lot," says Robert Moses, a retired aerospace engineer from NASA's Langley Research Center in Virginia. Like many I spoke with, Moses compared the SpaceX architecture favorably to NASA's latest reference

mission, though SpaceX's plan includes hundreds more spacecraft and crew. "He's checking all the boxes here that I would like to see checked."

What's less certain is whether SpaceX can stick to the launch targets. Even Musk acknowledges that 2026 is ambitious, tweeting in early August that it was "more likely" the first uncrewed Starships would launch "in ~3.5 years, next flight ~5.5 years with humans."

That might be OK, Moses says, since pushing the first uncrewed missions to 2028 "still gives him one more opportunity before 2033 to throw everything possible over to Mars."

But perhaps of greatest concern to Moses and the other experts are the numerous technical challenges SpaceX still needs to address — many of which have never been demonstrated by any organization — to ensure a successful Mars transit and surface operations, any of which could turn into a mission-swallowing morass. My emails to SpaceX requesting comment went unanswered, so for this report I drew on public documents and remarks by Musk and other executives describing the Mars plan.

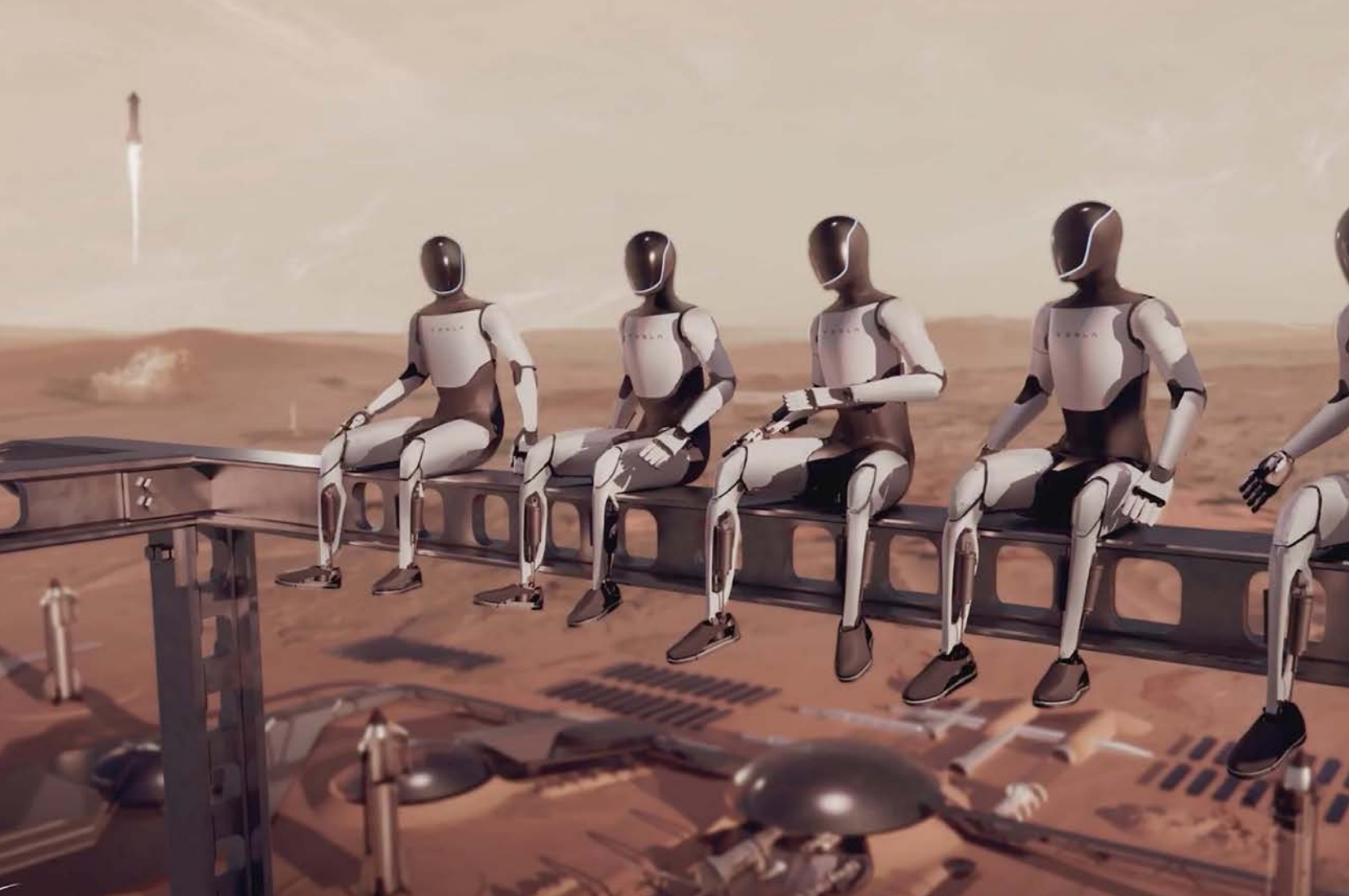
## Reaching orbit

For SpaceX's plan to work, the behemoth Starship-Super Heavy design must reach orbit as reliably as the company's Falcon 9 workhorse, which in July logged its 500th flight. For both vehicles, SpaceX has touted an iterative design approach in which the designs are incrementally refined between a series of rapid flight tests. But with Starship, SpaceX may have reached the limits of this "build a little, test a little, fail a little" strategy, says Scott Hubbard, former director of NASA's Ames Research Center and now director emeritus of the Stanford Center of Excellence for Commercial Space Transportation.

With Falcon, "there was a distinct improvement from flight to flight, until it's now 150 flights or something without a problem," he says. "Starship is nowhere near that at this point."

Starship has never reached orbit; instead, SpaceX has followed a suborbital trajectory for the 10 integrated flight tests conducted to date, in which the upper stages were sent toward controlled splashdowns in the Indian Ocean. The most recent Starship test, conducted in August, was





the first to survive the punishing trek through the atmosphere and splash down intact since late 2024, ending a streak of failures that included three Starships exploding in flight and another exploding on the ground during a June static fire test.

Once Starship reaches Earth orbit, the next challenge will be docking with multiple “tankers” to fill its tanks with the 933 metric tons of liquid oxygen and 267 metric tons of liquid methane required to reach Mars. A full load of propellant is essential for reducing the transit time to three to four months, according to Moses, so as to minimize how long the human crews are exposed to hazardous galactic cosmic radiation.

As necessary as it is, that refueling process involves a lot of logistics. “Starship needs 1,200 tons of propellant, and you’ve got a tanker that takes 100 tons at a time,” says Donald Rapp, a chemical engineer and consultant for NASA’s Jet Propulsion Laboratory for the Mars 2020 mission. That works out to 12 tanker launches to fuel each Mars-bound Starship.

By those calculations, the five Starships leaving Earth in 2026 would require 60 tanker launches, says Rapp — ample opportunity to test Murphy’s law, and an unprecedented stress test of ground infrastructure.

That refueling maneuver itself is sound in theory,

but there is scant evidence from practice. “There’s been a lot of models that have been developed,” says William Notardonato, a former NASA engineer and now CEO of Eta Space, a Rockledge, Florida, company developing spacecraft for small-scale cryogenic propellant transfers in Earth orbit. But “nobody’s really been able to accurately anchor those models in flight data using a real cryogenic fluid.”

SpaceX transferred an undisclosed amount of liquid oxygen between two internal tanks during a 2024 Starship test, but no one has yet attempted large transfer between two spacecraft. SpaceX plans to do so in 2026, per Musk, pitting SpaceX’s iterative design philosophy directly against his ambitious timeline.

Among the factors to be determined in these tests is how much of the cryogenic propellant will evaporate upon first contact with the relatively warm lines and empty tanks, according to Notardonato. These “parasitic” losses pose another challenge for SpaceX: Lose too much, and additional tanker launches could be required to fuel up each Starship.

“You might have to launch one or two more refueling missions,” Notardonato says, “and nobody really knows how many refueling missions they’re going to have to do yet.”

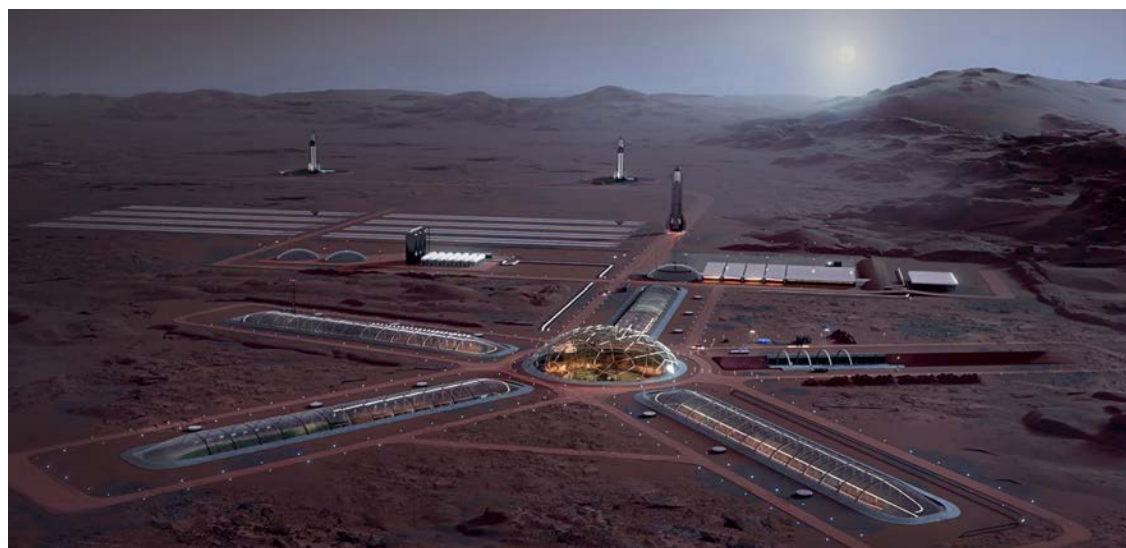
▲ For the inaugural Starship launches to Mars, the spacecraft will carry Optimus robots, like those shown in this illustration, to set up the infrastructure required for human astronauts to survive on the surface.

SpaceX



► Elon Musk's ultimate goal is to establish a "self-sustaining" city on Mars, which he predicts could be achieved in "20 to 30 years," according to an August post on X.

SpaceX



### Sticking the landing

Transit to Mars is just the first step of the journey. Once arriving in orbit, Starship must navigate entry, descent and landing. At 200 tons or more, depending on payload, each Starship will be 200 times more massive than any craft that's previously touched down, and therefore requires a different landing technique.

NASA spacecraft, including the Perseverance rover, relied on single-use, ablative heat shields to protect them during the searing journey to the surface. By contrast, each Starship will depend on a reusable heat shield made of hexagonal metallic-ceramic tiles for aerobraking in the Martian atmosphere, using friction to slow from 7.5 kilometers per second to around 1 kilometer per second.

"No one has ever developed a truly reusable orbital heat shield," Musk said in his May talk. He noted that the thin, carbon dioxide-rich atmosphere of Mars, when ionized by the heat of entry, generates more free oxygen than Earth's, which will eat away at shield tiles.

For Flight 10, SpaceX technicians installed tiles of various compositions on different parts of the Starship upper stage, and the vehicle's reentry trajectory was "designed to intentionally stress the structural limits of the rear flaps" that would steer the vehicle through the atmosphere, SpaceX said on its website.

Then there's the landing itself, which Hubbard predicts could pose an even greater challenge due to Starship's height of 52 meters. There's a reason, he says, that NASA utilized parachutes and airbag-cushioned landings for many of its landers and rovers, which were relatively squat vehicles with low centers of gravity.

"Landing vertically looks very slick," Hubbard says, "but look at the failures to land on the moon with a tall, slender vehicle." He pointed to the Odysseus lander built by Intuitive Machines that "tipped right over" in early 2024 after a laser altimeter failure led it to land faster and on a steeper slope on the lunar surface than anticipated.

"A lower center of gravity would always add stability,"

Hubbard told me in a follow-up email, noting that there are no flat, well-prepared landing pads awaiting the first Starships landing on the moon or Mars.

### Establishing the Mars city

Once the first Starships reach Mars, the job of setting up camp for human astronauts will fall to Optimus. The bipedal humanoids are to install power plants and other infrastructure, as well as scout for resources such as water ice. In May, Musk showed an image of Optimus ironworkers building the Empire State Building, sitting on a girder eating lunch.

Hubbard, who in 2000 became NASA's first Mars Program director, has doubts Optimus can do the job. He notes that many of the demonstration videos show the robots in well-prepared environments — a sharp contrast to the barren Martian surface. Tesla has also been criticized over videos it's shared of Optimuses seemingly cooking or interacting with people at events, where it later turned out the robots were at least partially remote controlled.

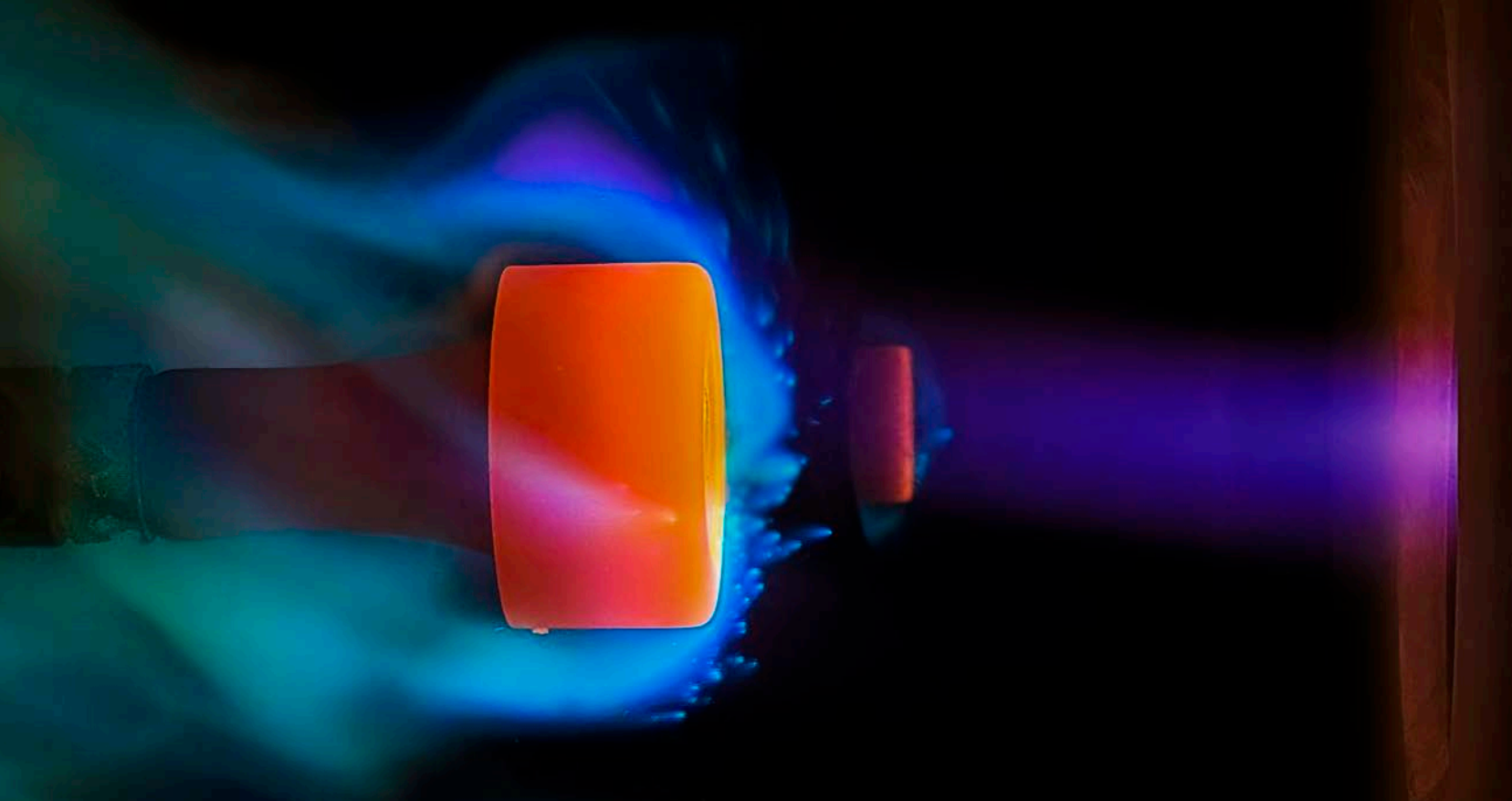
Instead, "Why not take a whole bunch of rovers of a design you're pretty sure will work?" Hubbard asks. The six-wheel design used for Perseverance and Curiosity has proven "capable of adapting to almost any kind of surface with enough clearance."

Another option is to take to the air. Optimus is "inferior as an exploration platform to a scaled-up Ingenuity helicopter, which can fly," says Robert Zubrin, an aerospace engineer and longtime Mars mission optimist, referring to the small rotorcraft that rode along with Perseverance and completed 72 flights in three years.

Given Starship's touted 100-metric-ton payload capacity, Zubrin believes that SpaceX could deliver an army of rovers and rotorcraft, "like the troops coming off the landing craft at Normandy Beach," he says, and conduct more Mars science in two years than NASA has been able to in decades.

Neither Musk's remarks nor SpaceX's public materials





indicate to what extent science factors into the objectives for the early Mars landings. But Zubrin and other experts agree that if Musk is to achieve the self-sustaining city of his dreams, some form of robotic automation will be essential.

NASA's planning has long assumed in situ resource utilization will be key to human Mars missions. The latest concept, Design Reference Architecture 5 (DRA-5), calls for pre-positioning solid oxide electrolysis cells on Mars ahead of astronauts' arrival. Essentially a fuel cell run in reverse, solid oxide electrolysis cells would split atmospheric carbon dioxide into carbon monoxide and oxygen via electric current.

Operating over 16 months, the electrolysis unit would produce 25 tons of liquid oxygen to power the Mars Ascent Vehicle, along with 6 tons of liquid methane propellant that the astronauts would have brought from Earth. Once fueled, this rocket would return astronauts to Earth at the end of their mission.

NASA in 2021 proved this general concept with the MOXIE experiment aboard the Perseverance rover, which produced 122 grams of oxygen over 30 months. Scaling MOXIE up to make tons of liquid oxygen would not be difficult, according to Michael Hecht, the experiment's principal investigator, but it wouldn't come free.

"It takes a lot of energy to pull a carbon dioxide molecule apart," he says — about a kilowatt per kilogram of oxygen produced.

In NASA's plan, a nuclear fission reactor would be required to produce the 25 kilowatts of power necessary



to create 25 tons of liquid oxygen. By Hecht's calculations, Starship would need more: roughly 600 kW to produce 600 tons of liquid oxygen for each vehicle returning to Earth, if filled to capacity.

Unlike NASA, SpaceX plans to rely on solar power — "a lot of solar power," Musk has said, though he hasn't elaborated on the mechanism for collecting and storing that energy.

The technique could work, Hecht says, but again, at a cost: "The solar arrays are going to be more massive, certainly, than the reactors would be," Hecht says. NASA's DRA-5 estimated that producing 25 tons of liquid oxygen would require around 1,450 square meters of solar panels, putting the potential SpaceX equivalent at 38,400 square meters — about seven American football fields.

That's a lot of infrastructure for Optimus to set up and maintain ahead of human crews. But the alternative — sending humans to set things up without already having

▲ SpaceX in November 2024 shared these photos of a ground test in which Starship heat shield materials were subjected to conditions similar to those the craft would encounter as it plunges through the Martian atmosphere toward the surface. Surviving entry, descent and landing will be a key milestone of the first Starship Mars flight, which SpaceX could conduct as soon as 2026.

SpaceX

◀ Among the techniques SpaceX has yet to demonstrate is refueling a Starship in Earth orbit. This illustration depicts a lunar lander variant of Starship (left) docking with a "tanker" version carrying liquid oxygen and liquid methane.

SpaceX

propellant stored and ready for a return mission — “strikes me as dangerous beyond belief,” Hubbard says.

And unless SpaceX also wants to fly a lot of extra liquid methane to Mars, it will need to utilize a different process than MOXIE to create that methane on Mars, according to Rapp: the Sabatier reaction, which uses electricity and carbon dioxide, but also requires water. The basic premise is to run an electric current through the water to split it into oxygen and hydrogen. Take the hydrogen and react it with carbon dioxide at around 300 degrees Celsius to obtain methane and more water, with the water fed back into the loop.

“It’s a very simple process,” Rapp says, “It’s almost risk free.”

But SpaceX would need to find a lot of water on Mars, he notes, and while orbital data suggests abundant subsurface water may exist, there’s no concrete evidence yet. But let’s assume there is 15% water in Martian regolith, he says, based on a February paper in the journal *IgMin Research*. That means to create 5 tons of propellants per day, Optimus or some other machinery would need to process 33 tons of surface material.

#### The road ahead

All that taken together, the odds that a Starship will launch to Mars in 2026 is nearly impossible, Zubrin says.

“The notion they’re going to land a Starship on Mars that they launch next year is not true. If you disagree, I’ll bet you \$1,000.”

He agrees with Moses that 2028 seems more feasible, but he also warned against waiting too long, lest the Trump administration or Congress change its priorities, causing SpaceX to lose momentum.

“I don’t think Apollo could have been accomplished in a 20-year schedule,” he says. “It had to be accomplished on an eight-year schedule,” or else the political and economic conditions that led then-President Richard Nixon to cancel the program after the Apollo 17 landing could have overtaken the program sooner.

Politics may be the biggest unknown of all when it comes to SpaceX’s plans. Between Musk’s public falling-out with President Donald Trump and the proposed cuts to NASA funding, it’s not clear there’s government support for the public-private, NASA-SpaceX partnership that most experts I spoke with believe is necessary to achieve a human Mars mission.

“A lot of people take it as a given that it will work, and there’s really no guarantee,” says Casey Dreier, chief of space policy at the Planetary Society, about SpaceX, Starship and Mars. But “you never want to bet against SpaceX as a company, because they are, frankly, incredibly capable.” ★

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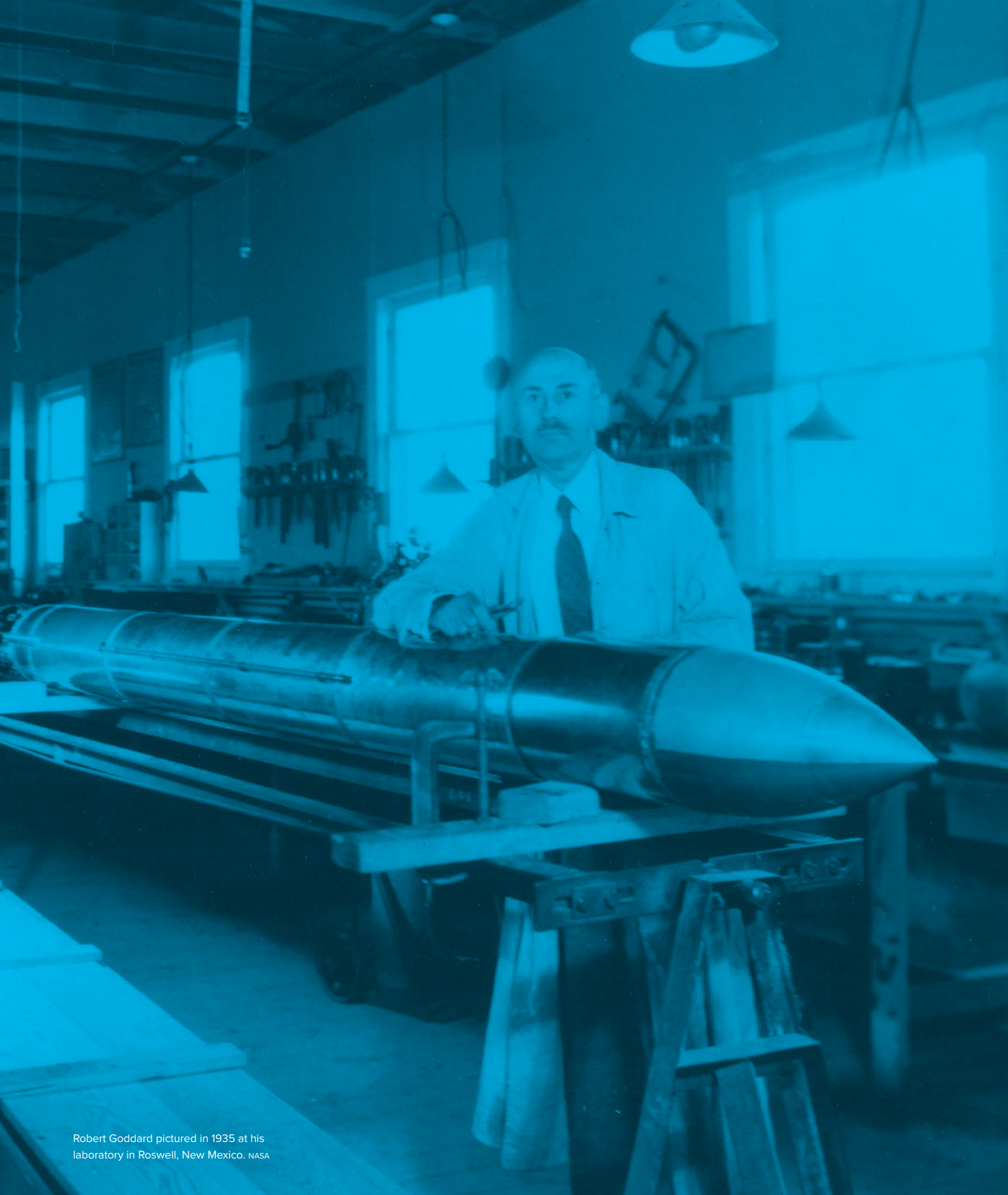
*This is the second in a three-part series commemorating the 100th anniversary of the launch of the first liquid-propellant rocket on March 16, 1926.*

# Goddard and the 1920s space craze

**While today's aerospace professionals and the general public laud Robert Goddard as a technical genius and visionary, that wasn't always the case. His early studies received negative reactions in the press that prompted Goddard to become protective — verging on secretive — when it came to his research, even as the technical community began to enthusiastically embrace his ideas. Roger D. Launius and Jonathan C. Coopersmith explore how this approach affected the pace of innovation.**

BY ROGER D. LAUNIUS AND JONATHAN C. COOPERSMITH





Robert Goddard pictured in 1935 at his laboratory in Roswell, New Mexico. NASA



William Harvey, Gregor Mendel, Galileo — history is rife with inventors and innovators who were mocked or dismissed by their contemporaries, only to have their ideas embraced and

heralded by later generations. While that wasn't quite the case for Robert Goddard, the father of liquid rocketry experienced his fair share of skepticism and ridicule from the general public, even as his research began to slowly but surely reshape the way the aerospace industry regarded orbital spaceflight.

Goddard's first broad public attention came six years before his famous 1926 launch, when the Smithsonian published "A Method of Reaching Extreme Altitudes." This report and accompanying press release described Goddard's Smithsonian-funded work on liquid-fueled rockets and the ultimate potential they offered for propelling vehicles, even with humans aboard, to the moon. It was a remarkably academic study, however, containing all the staid language and cautious prose typical of such writing.

The report — but especially the press release — generated hundreds of newspaper articles that ranged from dismissing Goddard as an impractical academic dreamer to hailing him as potentially turning the 1865 Jules Verne novel, "From the Earth to the Moon," into reality. Most well-known is a New York Times editorial that called Goddard "a savant who isn't writing a novel of adventure" whose ideas were certainly impractical, perhaps impossible. Titled "A Severe Strain on Credulity," the editorial questioned Goddard's credentials as a scientist, made fun of him operating from "his 'chair' in Clark College" and questioned the Smithsonian Institution's rationale for supporting his research. The writer concluded that Goddard "seems to lack the knowledge ladled out daily in high schools."

Not everyone agreed. Among them was Rear Adm. William Sims, the commander of U.S. naval forces for Europe in World War I, who sent a letter to the Times objecting to this assessment. Based on an experiment conducted during one of his classes at the Naval Academy, Sims wrote, he was convinced the newspaper was in error and Jules Verne was right.

Sims' professor suspended "from the ceiling of the lecture room a large water bottle in a horizontal position. Upon his removing the cork the bottle [recoiled] several inches," Sims wrote. "In conclusion, he stated that a rocket would ascend in a vacuum for the same reason that a gun would 'kick if fired in vacuum; that the propelling force of a rocket was nothing but a continuous 'kick.'"

Over the next few years, liquid-fueled rockets emerged as the fundamental technology by which humans would reach orbit and access realms beyond Earth. Goddard's 1920 study and subsequent experiments contributed to a flowering of broad theoretical and experimental work for this purpose, the organization of rocket societies in several countries, and the proliferation of writings on this

"It's impossible to know for certain how [Goddard's attitude toward collaboration] impacted the pace of rocketry innovation, or what might have happened differently had Goddard promoted rocketry with the enthusiasm, effectiveness, and networking of someone like von Braun."



**Roger Launius** is a former chief historian of NASA and associate director for collections and curatorial affairs at the Smithsonian National Air and Space Museum in Washington, D.C.



**Jonathan Coopsmith** is an historian of technology and former professor at Texas A&M University in College Station who has written about 20th century space commercialization.

subject. It inspired theoreticians including Germany's Hermann Oberth and Wernher von Braun; Robert Esnault-Pelterie of France; and Frank Malina, a young engineering student at Caltech — all of whom pursued sophisticated rocket research thereafter.

In many ways, Goddard brought "the seeds of the idea of the space rocket into the public consciousness," Frank H. Winter, a former Smithsonian curator who has long studied Goddard's work, said in 2011.

Still, Goddard personally disliked this public attention — including that of the 21 people who volunteered by late 1921 to go into space on his theoretical rocket. At first, he tried to correct errors and misperceptions by participating in several interviews. Later in 1920, he clarified his

position in an article published in Scientific American; however, that journal had neither the same audience nor the influence of The New York Times and the other large-circulation publications that wrote about his 1920 study.

Unable to withstand the ridicule, by 1930 Goddard retreated into isolation in Roswell, New Mexico, becoming even more selective about who he shared information with. For instance, when Malina visited the New Mexico laboratory in 1936, Goddard was polite but showed Malina only some hardware.

"I naturally cannot turn over the results of many years of investigation, still incomplete, for use as a student's thesis," Goddard wrote in a letter to Caltech President Robert Millikin about the encounter.

Malina's adviser, Theodore von Kármán, disagreed with Goddard's insularity: "Naturally we at Caltech wanted as much information as we could get from Goddard for our mutual benefit. But Goddard believed in secrecy," he told William Burrows for his 1999 book, "This New Ocean: The Story of the First Space Age." "The trouble with secrecy is that one can easily go in the wrong direction and never know it."

Goddard's management style also wasn't conducive to cooperative research. He always had to be in charge and only worked with assistants, not collaborators or

co-principal investigators. It's impossible to know for certain how this impacted the pace of rocketry innovation, or what might have happened differently had Goddard promoted rocketry with the enthusiasm, effectiveness, and networking of someone like von Braun. What is certain is that much of Goddard's knowledge died with him in 1945, only partially preserved in patent applications, two Smithsonian reports and his personal papers.

But even with these isolationist tendencies, Goddard made profound contributions to rocketry in the 1920s-1930s, aided by Charles Lindbergh. Concerned about the future of flight technology, the famous aviator in 1930 convinced the Guggenheim Foundation to support Goddard's research. Armed with that \$183,500 grant, Goddard moved his rocket research to New Mexico and helped pioneer designs including rotor motor vanes and gyro controls for guidance.

Under Lindbergh's prodding, Goddard even donated one of his rockets to the Smithsonian in 1935, the first liquid-fueled rocket in its collection. In 1936, the Smithsonian published Goddard's second report on his research, "Liquid Propellant Rocket Development." Despite Goddard's fame, that report received virtually no press coverage or public attention — a fact that was surely of huge relief to him. ★



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# ABOVE + BEYOND

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The YFQ-42A Collaborative Combat Aircraft, designed and developed by General Atomics Aeronautical Systems, Inc. (GA-ASI), is conducting flight testing in coordination with the U.S. Air Force. This historic achievement continues the company's rapid creation of new, jet-powered uncrewed platforms chartered by the U.S. Air Force (USAF) to achieve air dominance while being designed for rapid production, in large quantities, at an affordable price.

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# ABOVE + BEYOND

Starship's tenth flight test lifted off on 26 August 2025, at 6:30 p.m. CT from Starbase, Texas, taking a significant step forward in developing the world's first fully reusable launch vehicle. Every major objective was met, providing critical data to inform designs of the next generation Starship and Super Heavy. View of Starship landing burn and splashdown on Flight 10, made possible by SpaceX's recovery team.

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DATE	MEETING	LOCATION	ABSTRACT DEADLINE
2025			
25–26 Oct	SmallSat Education Conference	Cape Canaveral, FL	1 Aug 25
28 Oct–20 Nov	V/STOL Aircraft Design Conderations Course	ONLINE ( <a href="https://learning.aiaa.org">learning.aiaa.org</a> )	
3–6 Nov	Foundations of CFD with OpenFOAM® Course	ONLINE ( <a href="https://learning.aiaa.org">learning.aiaa.org</a> )	
3–7 Nov*	COSPAR 2025 Symposium	Nicosia, Cyprus ( <a href="mailto:cospar@cosparhq.cnes.fr">cospar@cosparhq.cnes.fr</a> )	4 Apr 25
4–6 Nov	Launch Vehicle Coupled Loads Analysis Course	ONLINE ( <a href="https://learning.aiaa.org">learning.aiaa.org</a> )	
5–6 Nov	Fundamentals of Space Domain Awareness Course	ONLINE ( <a href="https://learning.aiaa.org">learning.aiaa.org</a> )	
10–19 Nov	Technical Writing Essentials for Engineers Course	ONLINE ( <a href="https://learning.aiaa.org">learning.aiaa.org</a> )	
12–14 Nov*	High Speed Aerospace Transportation (HSAT) Workshop	Midland, Texas ( <a href="https://hsat.highspeedflight.com/">https://hsat.highspeedflight.com/</a> )	
17–20 Nov	Applied Model-Based Systems Engineering Course	ONLINE ( <a href="https://learning.aiaa.org">learning.aiaa.org</a> )	
1–2 Dec	AIAA Region VII Student Conference	Sydney, Australia	22 Sep 25
2–5 Dec	Space Systems Verification and Validation Course	ONLINE ( <a href="https://learning.aiaa.org">learning.aiaa.org</a> )	
8–11 Dec	Aircraft & Rotorcraft System Identification Engineering Methods Course	ONLINE ( <a href="https://learning.aiaa.org">learning.aiaa.org</a> )	
2026			
11 Jan	7th AIAA Propulsion Aerodynamics Workshop	Orlando, FL ( <a href="https://aiaa.org/courses/aiaa-propulsion-aerodynamics-workshop-paw/">aiaa.org/courses/aiaa-propulsion-aerodynamics-workshop-paw/</a> )	

DATE	MEETING	LOCATION	ABSTRACT DEADLINE
<b>2026</b>			
12–16 Jan	AIAA SciTech Forum	Orlando, FL	22 May 25
9 Feb–25 Mar	Design of Space Launch Vehicles Course	ONLINE (learning.aiaa.org)	
17 Feb–12 Mar	Verification & Validation for High Temperature Material Modeling & Applications Course	ONLINE (learning.aiaa.org)	
24 Feb–2 Apr	Aircraft Performance for Advanced Air Mobility: A Path to Certification Course	ONLINE (learning.aiaa.org)	
25–26 Feb	ASCENDxTexas	Houston, TX	
2 Mar–1 Apr	Spacecraft Lithium-Ion Battery Power Systems Course	ONLINE (learning.aiaa.org)	
7–14 Mar*	IEEE Aerospace Conference	Big Sky, MT (www.aeroconf.org)	
17–20 Mar	AIAA DEFENSE Forum	Laurel, MD	14 Aug 25
21–22 Mar	AIAA Region VI Student Conference	San Luis Obispo, CA	23 Jan 26
26–27 Mar	AIAA Region II Student Conference	Columbia, SC	Jan 26
26–27 Mar	AIAA Region V Student Conference	Ames, IA	31 Jan 26
27–29 Mar	AIAA Region IV Student Conference	Houston, TX	30 Jan 26
10–11 Apr	AIAA Region III Student Conference	Ann Arbor, MI	6 Feb 26
12–13 Apr	AIAA Region I Student Conference	College Park, MD	2 Feb 26
16–19 Apr	30th Annual Design/Build/Fly Competition	Wichita, KS (USA)	
18 May	2026 AIAA Fellows Induction Ceremony and Dinner	Washington, DC	
19–21 May	ASCEND 2026 Powered by AIAA	Washington, DC	18 Sep 25
8–12 Jun	AIAA AVIATION Forum	San Diego, CA	13 Nov 25
15–20 Jun*	2026 International Rocket Engineering Competition (IREC)	Midland, TX	
1–9 Aug*	46th Scientific Assembly of the Committee on Space Research (COSPAR 2026) & Associated Events	Florence, Italy (cospar2026.org)	
5–9 Oct	76th International Astronautical Congress	Antalya, Turkey	

\*Meetings cosponsored by AIAA. Cosponsorship forms can be found at [aiaa.org/events-learning/exhibit-sponsorship/co-sponsorship-opportunities](https://aiaa.org/events-learning/exhibit-sponsorship/co-sponsorship-opportunities).

 AIAA Continuing Education offerings



**FOR MORE INFORMATION** on meetings listed below, visit our website at [aiaa.org/events](https://aiaa.org/events) or call 800.639.AIAA or 703.264.7500 (outside U.S.).



# RECOGNIZING TOP ACHIEVEMENTS AN AIAA TRADITION

AIAA is committed to ensuring that aerospace professionals are recognized and celebrated for their achievements, innovations, and discoveries that make the world safer, more connected, more accessible, and more prosperous. From the major missions that reimagine how our nation utilizes air and space to the inventive new applications that enhance everyday living, aerospace professionals leverage their knowledge for the benefit of society. AIAA continues to celebrate that pioneering spirit showcasing the very best in the aerospace industry.

AIAA acknowledges the following individuals who were recognized between March 2025 and September 2025.

## AAAE/ACC Airport Planning, Design, and Construction Symposium

12–14 March 2025  
San Antonio, TX

## PARTNER AWARD AIAA/AE/ACC Jay Hollingsworth Speas Airport Award

This award is to recognize those who have contributed most significantly in recent years to the enhancement of relationships between airports and/or heliports and their adjacent environments via exemplary innovation that might be replicated elsewhere



## Boston Logan International Airport

“For developing, validating and implementing novel noise abatement procedures at Boston Logan International Airport that reduced community noise impacts as well as flight distance and fuel burn.”

**2025 AIAA DEFENSE Forum**  
14–18 April 2025  
Laurel, MD

## TECHNICAL EXCELLENCE AWARD

### 2025 AIAA Missile Systems Award

This award is presented for excellence in developing or implementing missile systems

technology. It can be presented for a significant accomplishment in developing or implementing technology that is required for missile systems or for inspired leadership of missile systems programs.



**Gary Sullins**  
Johns Hopkins University  
Applied Physics Laboratory  
(retired)

“For over 35 years of contributions to the development of multiple variants of the U.S. Navy Standard Missile.”

## 2025 International Conference on Environmental Systems

13–17 July 2025  
Prague, Czechia

## TECHNICAL EXCELLENCE AWARD

### 2025 AIAA Jeffries Aerospace Medicine and Life Sciences Research Award

The award is presented for outstanding research accomplishments in aerospace medicine and space life sciences.



**Christophe Lasseur**  
European Space Agency (retired)

“For leadership of international advanced life support research toward development of safe and reliable closed loop regenerative systems for sustained human presence in space.”

## 2025 AIAA AVIATION Forum and 2025 ASCEND

21–25 July 2025  
Las Vegas, Nevada

## PREMIER LECTURES 2025 AIAA David W. Thompson Lecture in Space Commerce Award

This premier lecture recognizes a prominent industry leader or senior management team (up to three individuals) who have created or grown a space-related business and generated substantial economic benefits and market value.



**Jamie M. Morin**  
Vice President of Defense Strategic Space and Executive Director of the Center for Space Policy and Strategy  
The Aerospace Corporation

Lecture: “Accelerating Space and Defense Innovation Through Savvy Policy”

## 2025 AIAA Wright Brothers Lecture in Aeronautics

The Wright Brothers Lecture in Aeronautics commemorates the accomplishment of the Wright Brothers in creating the first practical airplane and also recognizes the success of their approach to problem solving - beginning with study of the literature, and including innovative thinking, constructive debate, systematic testing, and teamwork. In particular, the Wright Brothers Lecture-ship is awarded for the recent accomplishment of a significant “First in Aeronautical Engineering”. The lecture will highlight the details of the accomplishment and the approaches to meeting both the technical

and programmatic challenges involved.



**Susan Ying**  
CEO, AMP2FLY

Lecture: “Emergence of Hybrid Electric Aircraft”

## PREMIER AWARD

### 2025 AIAA Aerospace / Excellence Award

This award honors a unique achievement by a group or team in the aerospace community that is shaping the future of aerospace and inspiring the next generation to pursue careers in aerospace.



**SpaceX**  
“For demonstrating controlled landings of the Starship Super Heavy booster by catching it with arms on the launch tower and accelerating the development of the space economy through this fully reusable launch vehicle.”

## MANAGEMENT AWARDS 2025 AIAA Hap Arnold Award for Excellence in Aeronautical Program Management

This award is presented to an individual for outstanding contributions in the management of a significant aeronautical or aeronautical-related program or project.



**Richard A. Rezabek**  
Lockheed Martin (retired)

“For outstanding leadership and management of the X-35 throughout the technically innovative, challenging,

safe, and successful design, development, and flight test.”

## 2025 AIAA von Braun Award for Excellence in Space Program Management

This award gives national recognition to an individual(s) for outstanding contributions in the management of a significant space or space-related program or project.



**Thomas H. Zurbuchen**  
ETH Zurich

“For exemplary leadership of

NASA’s science program and its successful civilization-scale science missions, including the James Webb Space Telescope, Mars 2020, and Parker Solar Probe.”

## TECHNICAL EXCELLENCE AWARDS

### 2025 AIAA Aeroacoustics Award

This award is presented for an outstanding technical or scientific achievement resulting from an individual’s contribution to the field of aircraft community noise reduction.



**Anastasios “Tasos” Lyrantzis**  
Embry-Riddle Aeronautical University

“For seminal contributions to aeroacoustics including the introduction of surface integral methods for the extension of CFD results to the far-field.”

### 2025 AIAA Aerodynamics Award

This award is presented for meritorious achievement in the field of applied aerodynamics, recognizing notable contributions in the development, application, and evaluation of aerodynamic concepts and method.



**Richard A. Wahls**  
NASA Headquarters

"For outstanding leadership and technical contribu-

tions advancing high-confidence computational and experimental aerodynamic tools for prediction and analysis of airplane configurations and technologies."

### 2025 AIAA Aircraft Design Award

This award is presented to an individual or team for an original concept or career contributions leading to a significant advancement in aircraft design or design technology.



**Isabelle Bloy**  
Airbus A321XLR Team



**Thierry Diez**  
Airbus A321XLR Team



**Ahmet Kiryaman**  
Airbus A321XLR Team

"For contributions to the Airbus A321XLR,

a narrowbody aircraft opening long-haul services to airlines, successfully launched in 2019 with an entry into service in 2024."

### 2025 AIAA Fluid Dynamics Award

This award is presented for outstanding contributions to the understanding of the behavior of liquids and gases in motion as related to need in aeronautics and astronautics.



**Ari Glezer**  
Georgia Institute of Technology

"For groundbreaking contributions to

fundamental understanding, application, and invention of actuation strategies for active flow control."

### 2025 AIAA Ground Testing Award

This award is presented for outstanding achievement in the development or effective utilization of technology, procedures, facilities, or modeling techniques for flight simulation, space simulation, propulsion testing, aerodynamic testing, or other ground testing associated with aeronautics and astronautics.



**Nicole L. Key**  
Purdue University

"For outstanding contributions to the rigorous testing of

advanced high-speed compressor and fan technologies, with application of state-of-the-art diagnostic methods."

### 2025 AIAA Losey Atmospheric Sciences Award

This award is presented in recognition of outstanding contributions to the atmospheric sciences as applied to the advancement of aeronautics and astronautics.



**Philippe Villedieu**  
ONERA

"For distinguished contributions to the advancement

of aeronautics through research, leadership, and teaching in the atmospheric science of ice crystal and supercooled liquid icing."

### 2025 AIAA Plasmadynamics and Lasers Award

This award is presented to an individual who has made outstanding contributions to the understanding of the physical properties and dynamical behavior of matter in the plasma state and lasers as related to aeronautics and astronautics.



**Mark A. Cappell**  
Stanford University

"For impactful computational and experimental

research in plasma flow control, plasma assisted combustion, spacecraft electric propulsion, laser diagnostics, and the mentoring of future aerospace leaders."

### 2025 AIAA Thermophysics Award

This award is presented for an outstanding singular or sustained technical or scientific contribution by an individual in thermophysics, specifically as related to the study and application of the properties and mechanisms involved in ther-

mal energy transfer and the study of environmental effects on such properties and mechanisms.



**Deborah Ann Levin**  
University of Illinois at Urbana-Champaign

"In recognition of her pioneering work

into deriving new thermo-physical insights into complex, multiscale high-speed flows using particle kinetic simulation approaches."

### 30th Ka and Broadband Space Communications Conference (KaBSC) and the 42nd International Communications Satellite Systems Conference (ICSSC) and Colloquium

24 September 2025  
Barcelona Spain

### 2024 AIAA Aerospace Communications Award

This award is presented for an outstanding contribution in the field of aerospace communications.



**Rod G. Fleck**  
Amazon (retired); Consultant

"For outstanding technical

contributions, innovation, and leadership; revolutionizing LEO broadband communications architectures with the development of SpaceX Starlink and then Amazon Kuiper communications systems solutions."

### 2025 Digital Avionics Systems Conference

14–18 September 2025  
Montreal Canada

### 2025 AIAA Dr. John C. Ruth Digital Avionics Award

The award is presented to recognize outstanding achievement in technical management and/or implementation of digital avionics in space or aeronautical systems, including system analysis, design, development or application



**Carlo L M Tiana**  
Collins Aerospace

"For being a globally recognized expert in the field of airborne

vision systems that enable commercial and military platforms to operate in extremely low visibility."

## DIRECTORY

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# Ascendant Alumni – Their Journey & Where They Are Today

Anne Wainscott-Sargent

Since the inception of ASCEND in 2020, a global community of emerging space trailblazers has taken the stage to pitch their vision for “Space for All.” In five years, the community has grown to 60 thought leaders. Their ideas are published in Op-Eds at [ascend.events/outcomes/ascendants](https://ascend.events/outcomes/ascendants).

Program creator Moriba Jah, in an interview before this year’s final cohort, said, “What they share is a fire and a passion to be agents of change,” and to advocate for “regenerative, restorative, and just human space activity.”

The Ascendants profiled below share how the program inspired their journey as space stewardship advocates.

## 2020 Cohort



**Ruvimbo Samanga,**  
Zimbabwe 

**Then:** Research Fellow, Open Lunar Foundation

**Now:** Space Policy Analyst, Mandela Washington Fellow, Mandela Rhodes Scholar, and Ban Ki-moon Global Citizen, representing Africa’s emerging space voice across 20+ countries, delivering keynote lectures, writing widely published work, and contributing to international dialogues on space governance.

**Inspiration:** This was my first introduction to the world of effective stewardship of the space environment. I am inspired continuously by Moriba who has long advocated for traditional ecological knowledge. Knowledge that comes from indigenous communities holds unique value, as it is sustainable and adaptive in nature.

**After ASCEND:** I’ve contributed through thought leadership...to ensure that space remains coordinated and safe, through technical and policy rules alike. I had the honor of presenting novel research toward filling the current gaps in multilateral rules, including some definitional aspects like what space debris entails, and how this has an impact on collision avoidance and our ability to keep our space “highways” clean. In my role as a space policy analyst, I advocate for robust laws to serve multiple stakeholders...to make efficient and effective use of outer space and its benefits.

**Final Word:** Through science communication, we can...get more brilliant minds to work together through space to create a better world. We have the great responsibility of communicating the benefits of space to our communities, in a way that should inspire and evoke a desire to be a part of something that is truly bigger than us all.

## 2021 Cohort



**Emma Cain Loudon,**  
USA 

**Then:** Yale doctoral student coming out of the isolation of a global pandemic

**Now:** Astrophysicist, strategist and speaker / President, Slooh, bringing Earth and space to all ages through its network of telescopes and a gamified learning platform

**Inspiration:** To solve the problem of space sustainability, you must bring the right people together and make them care about the issue. To do that you have to create empathy about the problem and the way that you do that is through storytelling.

**After ASCEND:** I began public speaking again, starting at the Jasper Dark Side Festival and including the TEDx talk. I created ASCEND’s Astrodebates with Rob Meyerson, now in its fourth year. More recently,

I co-authored a children’s book called *Mia and the Martians*, a story about science that also teaches emotional resilience and emotional intelligence.

**Final Word:** I used to think we had to solve all of our problems, including sustainability on Earth first. In the last decade I realized that space can be a place to try new things, to learn from our past mistakes, and to evolve our understanding of how we live and work sustainably. There’s a real opportunity for the industry to say, “Here’s a really powerful place to be to learn how do we live more sustainably and learn from our mistakes to do better.”

## 2022 Cohort



**Uma Shangery Aruldass,**  
Malaysia 

**Then:** Member, Space Generation Advisory Council, and Revenue Management Specialist, global airline in Malaysia

**Now:** Continuing Airworthiness Manager, Asia Jet / in-demand speaker traveling to 16 countries talking on space debris and sustainability.

**Inspiration:** I studied aerospace engineering and completed my master's in aviation management then landed a job in an international airline in Malaysia. I really wanted to be a part of a space program, but I didn't know how. During COVID, I came across the Space Generation Advisory Council and became a member. I met like-minded people including Moriba Jah. His style completely blew me away. I read about space sustainability. Realizing that something I had always aspired to do was real—people were working on it—made me very excited.

**After ASCEND:** The [Ascendant] program was a life-changing moment. During COVID, I had shifted to work for the food and beverage industry. My employer's parent company had a private jet business. I wrote about my Op-Ed on LinkedIn, and when my post went viral, the organization saw it and offered me a position there. For a woman in Malaysia to become an engineering manager was a big deal. I'm the only woman in my department and also the youngest on my team. I'm also working on my pilot project with one of the Malaysian universities on a mathematical model that can predict the probability of objects in space colliding.

**Final Word:** You don't need to be an aerospace engineer to be a part of the space community or to contribute to space sustainability. I know Syahirah, a space artist and educator, who uses art to raise awareness about light pollution and advocates for protecting our

dark skies, linking it to the wider challenges posed by space debris. She does it perfectly.

## 2023 Cohort



Yumna Majeed,  
Pakistan 🇵🇰

**Then:** Founder, Exploration — Cosmos to Classroom, a Pakistan-based STEAM Education organization focused on outer space, astronomy, and space technology awareness

**Now:** Leading a K-12 STEAM Education Program at Pakistan's largest aerospace technology park (NASTP)

**Inspiration:** My first exposure to space traffic management was during IAC 2021 in Dubai, in a working group led by ESA. I was deeply inspired by Moriba Jah and his vision of space environmentalism, which emphasizes unity and shared responsibility in space. Coming from a non-technical background, I initially felt intimidated by the idea of presenting on a complex topic like space sustainability—but that challenge became my motivation. His work showed me that space isn't just for engineers; it's for everyone committed to a more sustainable and inclusive future. My essay focused on how to communicate the urgency of space debris to children, and in the process, I developed a deep appreciation for the broader implications of orbital debris, policy, and long-term space stewardship.

**After ASCEND:** This experience shifted my perspective. I began to see the strategic, policy-level changes needed to secure a sustainable space future. Since

returning home, I've intentionally woven these insights into my talks and outreach. Today, I lead the K–12 STEAM Education Program at Pakistan Air Force's NASTP—a platform that enables me to scale this mission nationally. It's a responsibility I carry with pride. I'm designing programs that not only inspire curiosity, but also embed space policy, sustainability and systems thinking into early education. I've also set my sights on bringing AIAA to Pakistan—starting a chapter and exploring how Pakistani students can participate in AIAA's Design/Built/Fly competitions.

**Final Word:** I'm proud to have helped build a space education ecosystem in Pakistan—one that will inspire young people to pursue technical space careers and contribute to our aerospace future. ASCEND gave me the confidence to explore what once felt out of reach. Now, I'm better equipped to shape Pakistan's space future—by sparking ambition in classrooms and guiding decisions in education, policy and sustainability.

## 2024 Cohort



Salman Ali Thepdawala,  
Pakistan 🇵🇰

**Then & Now:** Doctoral candidate & Munich Aerospace Scholar, University of Bundeswehr's Department of Aerospace Engineering, focused on AI-based collision avoidance and satellite constellation management

**Inspiration:** What really struck me during the experience was

the diversity of perspectives. My background primarily is engineering and at most policy, but the perspectives of the cohort ranged from arts and policy to engineering and geopolitics and all approaching the same challenge of space stewardship, which reminded me that no single discipline or nation can solve this problem alone.

**After ASCEND:** I have been actively building on that momentum. I was honored to moderate the Space Generation Congress 2024 working group with the UK Space Agency before IAC in Milan. More recently, I co-moderated a roundtable at SG-Germany 2025 focused on the downstream market of satellite data and AI use cases. In parallel, I remain active in the Space Generation Advisory Council as partnerships lead in the Space Safety and Sustainability Project Group, as well as in the International Astronautical Federation and the Moon Village Association.

Building on ASCEND and the experiences since, I have gained a renewed purpose and motivation to continue to be a voice for sustainability. More importantly, seeing the incredible work that other fellow cohorts are doing only drives home that true stewardship in space can only be achieved collectively across disciplines and nations.

Looking ahead, post-doctorate, I plan to transition fully into the space industry and make a meaningful impact on responsible space development.

**Final Word:** Space must be sustainable, inclusive and managed for the benefit of all humanity — not just a few powerful players.



# MAKING AN IMPACT

The AIAA Foundation has announced the winners of its 2025 undergraduate scholarships and graduate awards. Through its Foundation and supported by nearly 30,000 members, AIAA awards over \$225,000 in academic scholarships and STEM educational grants to support the next generation of aerospace professionals.

## 2025 Graduate Award Winners

### Neil Armstrong Graduate Award

#### Patrick Bailey

Pursuing M.S. in Mechanical Engineering

University of South Carolina

Amount of Award: \$10,000



My goal in life is to help others realize their potential while pushing beyond my own limits. This generous scholarship provides me the ability to pursue this goal for years to come and pay forward the opportunity I have been given.

### Orville and Wilbur Wright Graduate Award

#### Veera Venkata Ram Murali Krishna Rao Muvva

Ph.D. candidate

University of Nebraska, Lincoln

Amount of Award: \$10,000



My inspiration comes from birds, which gracefully navigate complex environments despite numerous challenges. I aspire for our UAVs to achieve that same elegance in flight. On my desk, I keep a reminder of this vision: 'May our UAVs soar with Avian Grace.'

### Dr. Hassan A. Hassan Graduate Award in Aerospace Engineering

#### Stephen West

Ph.D. candidate

North Carolina State University

Amount of Award: \$8,000



The Dr. Hassan A. Hassan Graduate Award is enabling me to freely explore and define my research area during the first year of my doctoral program. This award is personally significant to me as I was introduced to the study of orbital mechanics by Dr. Hassan at NC State, sparking an interest that shaped my academic and professional pursuits. I am thankful to the AIAA Foundation and the Hassan family for their generous support.

#### Andrew Strawn

First-year graduate student, Aerospace Engineering  
North Carolina State University  
Amount of Award: \$8,000



Being selected for the Hassan Fellowship is an incredible honor. Dr. Hassan's legacy at NC State and within AIAA set a high standard in aerospace research, and this award will support me as I continue advancing my work in hypersonic flow and experimental design.

### Guidance, Navigation, and Control Graduate Award

#### Akshaj "Akku" Kumar

Current M.S. Aerospace Engineering Student

Texas A&M University

Amount of Award: \$3,500



People have often asked me, 'Why work on research? Why start a company? Why not just get a job like everyone else?' The simplest

answer I can give is that I know my heart, and it would never let me focus on anything but the most cutting-edge, riskiest work, and I'm happier every day for it. I think we should all listen to our hearts just a bit more.

### Liquid Propulsion TC Graduate Award

#### Cole Nielsen

Ph.D. candidate, Aeronautical and Astronautical Engineering  
Purdue University

Amount of Award: \$2,500



I am honored to receive this graduate award as a way to fuel the final stretch of my degree. I hope to continue the path of rocket propulsion research started at Purdue University over 75 years ago.

### Martin Summerfield Propellants and Combustion Graduate Award

#### Ari Jain

Ph.D. student studying aerospace engineering

Georgia Institute of Technology

Amount of Award: \$1,500



Receiving the Martin Summerfield Award is both an honor and a reminder of the collaborative spirit that drives combustion research. It inspires me to push the boundaries of fuel-flexible, sustainable propulsion systems that will power the future of flight.

### John Leland Atwood Graduate Award

#### Marwa Yacouti

Ph.D. student, Aerospace Engineering Sciences  
University of Colorado Boulder  
Amount of Award: \$1,250



I am honored to receive the John Leland Atwood Graduate Award. This recognition encourages me to continue advancing aerospace materials through innovative computational methods and motivates me to carry forward the spirit of excellence that Atwood exemplified.

### Gordon C. Dates Air Breathing Propulsion Graduate Award

#### Kaurab Gautam

Fourth-year Ph.D. student, Department of Aerospace Engineering and Engineering Mechanics

University of Cincinnati

Amount of Award: \$1,000



I am honored to receive this recognition. It motivates me to keep on pushing the boundary of the propulsion research and to contribute innovations that make the supersonic flight quieter and more efficient.

### William T. Piper Sr. General Aviation Systems Graduate Award

#### Rayush Bhattarai

Ph.D. candidate, Aerospace Engineering

Auburn University

Amount of Award: \$1,000



The future of aerospace lies in bridging gaps between cutting-edge technology and its practical,

life-saving application, particularly in resource constrained environments. AIAA helps cultivate the pioneering spirit and collaborative platforms essential for developing these impactful solutions, ensuring that advancement in aerospace elevate safety and opportunity across the globe.

## 2025 AIAA Undergraduate Scholarship Winners

### David and Catherine Thompson Space Technology Scholarship

#### Paige Rust

Senior, Aerospace Engineering and Electrical & Computer Engineering  
Worcester Polytechnic Institute  
Amount of Award: \$10,000



I'm forever grateful to AIAA; it's through their support that I found the aerospace topics that spark my curiosity and shaped my college journey!

### Daedalus 88 Scholarship

#### Abigail Frank

Senior, Aeronautical and Astronautical Engineering  
Purdue University  
Amount of Award: \$10,000



I'm incredibly honored to be recognized with this scholarship, particularly one that focuses on project work. I have loved and am very proud of my role as Project Manager of High Altitude, and receiving this award is amazing! Additionally, this award makes a significant difference for me financially as I work to fund both an undergraduate and a graduate degree. This helps me continue my education and I'm immensely grateful!

### Mary W. Jackson Scholarship

#### Joshua Kassel

Aerospace Engineering  
University of Colorado Boulder  
Amount of Award: \$10,000



This scholarship is more than financial support — it is a profound validation of the path I've chosen. It allows me to continue pursuing ambitious research in rocketry and aerospace while inspiring others along the way. With this support, I am one step closer to achieving my goal of contributing to cutting-edge propulsion research and the future of space exploration. I am deeply grateful to AIAA for investing in students like myself, whose dedication and passion will help shape the aeronautical and astronautical industries in the decades to come.

### Vicki and George Mueller Scholarship for Aerospace Engineering

#### Ishaan Kalanadha Bhatta

Sophomore, Aeronautical and Astronautical Engineering  
Purdue University  
Amount of Award: \$5,000



This scholarship has strengthened my resolve to keep learning and growing as I pursue every opportunity to expand my knowledge. It inspires me to work with the aspiration of leaving a lasting, positive mark on the future of aerospace.

### Cary Spitzer Digital Avionics Scholarship

#### Geenadie Rathnayake

Senior, Aeronautical and Astronautical Engineering  
University of Washington  
Amount of Award: \$3,000



I am deeply honored and grateful to be chosen as a recipient for this AIAA scholarship. This not only relieves the financial burden but

also motivates me to continue my journey towards becoming an aerospace engineer.

### Ellis F. Hitt Digital Avionics Scholarship

#### Karsten Caillet

Senior, Aerospace Engineering  
Georgia Institute of Technology  
Amount of Award: \$3,000



Advancing GNC means advancing humanity's ability to navigate the unknown, whether paving the way in space or improving how we move on Earth.

### Dr. Amy R. Pritchett Digital Avionics Scholarship

#### Karson Schaefer

Aerospace Engineering  
University of Colorado, Colorado Springs  
Amount of Award: \$3,000



Thanks to AIAA, I have had the amazing opportunity to meet industry leaders, develop lifelong skills, and explore new technologies. Now, AIAA is equipping me to continue my education through my scholarship. As I approach graduation, I cannot thank AIAA enough. I am truly honored and blessed to have been selected. With this scholarship, I plan to help humanity reach for the stars as I pursue a career in propulsion technology.

### Dr. James Rankin Digital Avionics Scholarship

#### Julianna Schneider

Senior, AI & Decision-Making and Mathematics  
Massachusetts Institute of Technology  
Amount of Award: \$3,000



I am humbled to receive the Dr. James Rankin Digital Avionics Scholarship which not only highlights my academic success, but the vital role of interdisciplinary research in AI, robotics, and aerospace.

This award allows me to pursue innovative solutions at the intersection of these fields, bringing my goals within closer reach.

### Space Transportation Scholarship

#### Avah Cherry

Senior, Aerospace Engineering  
University of Tennessee, Knoxville  
Amount of Award: \$1,500



This scholarship will enable me to pursue my goals of contributing to impactful space exploration research, shaping my experience as an Aerospace Engineering student.

### Rocky Mountain Section Scholarship

#### Titus Smith

Mechanical Engineering  
Colorado School of Mines  
Amount of Award: \$500



As the first of five siblings to begin college, I have worked hard to maintain a high GPA in the hopes of receiving scholarships to aid in college expenses. The funds I have received through this AIAA scholarship will help me to pay for my education and realize my goals of working in aerospace without being a financial burden on my family. Additionally, these funds will allow me to dedicate more time toward pursuing my passion for aerospace through related projects and more fully leveraging my AIAA local section to gain invaluable insights and industry connections.

**Applications for the 2026 scholarships and graduate awards are being accepted from 15 October to 31 January.**

Please visit the AIAA Foundation's Scholarship and Graduate Awards website (<https://aiaa.org/get-involved/university-students/undergraduate-scholarships-graduate-awards/>) for more information.



# AIAA Establishes Steve L. Karman Jr. Aerospace Engineering Scholarship

Rebecca Gray, AIAA Communications

AIAA is proud to announce the Steve L. Karman Jr. Aerospace Engineering Scholarship to support aspiring aerospace professionals while honoring the legacy of a remarkable individual who made significant contributions to the aerospace industry. Steve was an AIAA Associate Fellow who advanced the state of the art in computational fluid dynamics (CFD) and mesh generation through his 40+-year career.

Steve's family is pleased to see such a meaningful tribute to their beloved father and husband that celebrates him as an engineer and a family man.

"Memorializing my dad with a scholarship is kind of perfect," Steve's daughter, Kristen Karman-Shoemake, added. "My dad was a nerd before it was cool. He watched Star Trek with us, insisted we know the science behind everything, and we celebrated Pi Day every March 14. Education and knowledge were very important to him."

The scholarship was made possible through the generous funding provided to the AIAA Foundation by AIAA Fellow John Chawner, a colleague and friend of Steve.

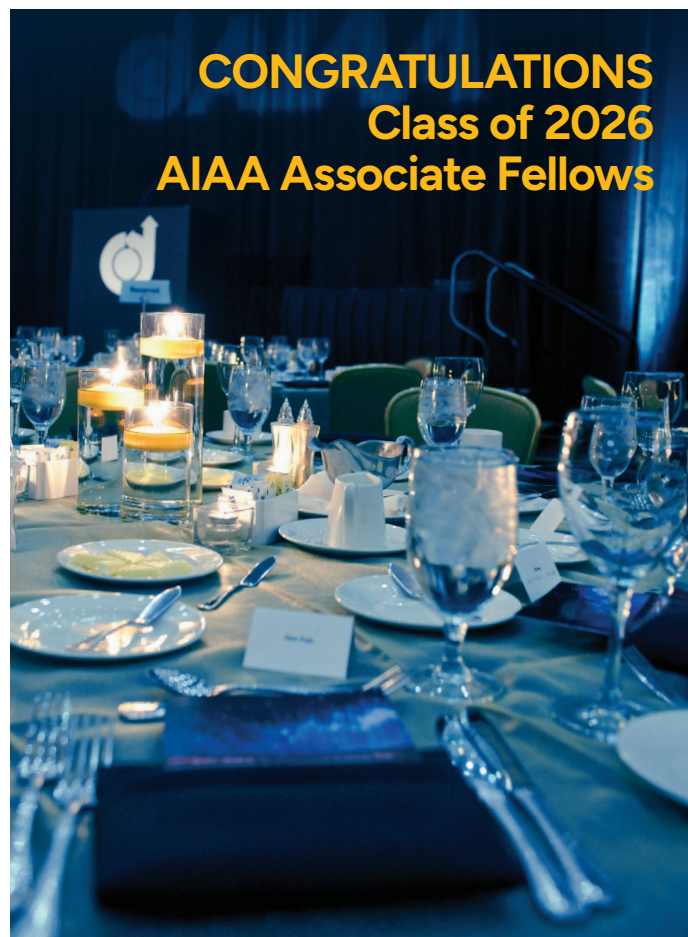
"Steve was a prodigious programmer. He had an ability to get things working faster than just about anyone I knew. I believe it's important to

perpetuate his impact on aerospace into future generations of aerospace engineers and scientists," John said.

In the past 25 years, the AIAA Foundation has provided over 1,400 scholarships and graduate awards to students at more than 150 colleges and universities worldwide.

The application for the scholarship will be open 15 October to 31 January. Find out how to apply at: <https://aiaa.org/get-involved/university-students/undergraduate-scholarships-graduate-awards>.

Read more about Steve's impact on aerospace in the extended story online at [aerospaceamerica.aiaa.org](https://aerospaceamerica.aiaa.org).



## AIAA Associate Fellows Induction Ceremony and Dinner

Wednesday, 14 January 2026

Hyatt Regency Orlando  
Orlando, Florida

The Class of 2026 AIAA Associate Fellows will be officially recognized for their accomplishments in engineering or scientific work, outstanding merit, and contributions to the art, science, or technology of aeronautics or astronautics.

Purchase Tickets at

[aiaa.org/SciTech/registration](https://aiaa.org/SciTech/registration)

You do not have to register for AIAA SciTech Forum to register for this event.



## AIAA Announces Winners of Prestigious Zarem Graduate Student Awards for Distinguished Achievement in Aeronautics and Astronautics

AIAA is pleased to announce the winners of the 2025 Zarem Graduate Student Awards for Distinguished Achievement

The winners will receive their awards at the 2026 AIAA SciTech Forum, Orlando, Florida, 12–16 January 2026. This award was established by AIAA Honorary Fellow Abe Zarem, founder and managing director of Frontier Associates, to annually recognize graduate students in aeronautics and astronautics who have demonstrated outstanding scholarship in their field.

**Patrick Eid, Auburn University**, won the astronautics award for his paper, “Evolution of the Bidirectional Vortex in a Capped Ellipsoidal Cyclonic Rocket Engine.” Eid will present his paper at the 76th International Astronautical Congress (IAC) in Sydney, Australia, 29 September–3 October 2025.



**Patrick Eid** is a Graduate Teaching and Research Assistant in the Department of Aerospace Engineering at Auburn University. He is a member of the Advanced Propulsion Research Lab directed by Professor Joseph Majdalani. Eid holds a Bachelor of Engineering in Mechanical Engineering from Notre Dame University (NDU). He has distinguished himself through leadership roles as Secretary of the ASME Student Chapter, Treasurer of the Astronomy Club, and Deputy Secretary General of the Model United Nations Program. His prior accolades include global honors at NASA's International Space Apps Challenge and top distinctions in the ASME EFX Oral Presentation Competition at NDU and the 2025 AIAA Region II Student Conference.

Eid's faculty advisor, Joseph Majdalani, is the Francis Chair of Excellence in Aerospace Engineering at Auburn University. An AIAA Fellow, he is recognized for pioneering work in acoustic instability and cyclonic-engine technology. With over 350 publications and 21,000 citations, he ranks in the top 0.8% of aerospace researchers globally. His breakthroughs include new cyclonic, vorticoacoustic, asymptotic, computational, similarity, stability, boundary-layer, and high-speed flow formulations. He is known for coauthoring *Viscous Fluid Flow* with Frank White while cracking the Pohlhausen paradox on its centennial anniversary. Besides 27 Best Papers, his main accolades include the Walker Teaching, Spencer Mentorship, Wyld Propulsion, Von Kármán Lectureship, Research Excellence, Abe Zarem Educator (4 times), Book Author, Outstanding Graduate Mentor, Leland Atwood Educator, Sustained Service, Foundation Faculty Advisor, Dannenberg Educator, Hap Arnold, Ralph Teetor Educator, Marquette Outstanding Teacher (twice), and CAREER Awards.

**Luke Busse, University of Cincinnati**, won the aeronautics award for his paper, “Multi-Sensor Based Adaptive Fusion Scheme for Position Estimation of Multirotor UAV Systems in GPS-Denied Environments.” Busse will present his paper at the 35th Congress of the International Council of the Aeronautical Sciences (ICAS) in Sydney, Australia, 13–18 September 2026.



**Luke Busse** received Bachelor of Science degrees in Mechanical Engineering Technology and Engineering Management from Bluefield State University, WV, in 2022, and a Master of Science in Mechanical Engineering from the University of Cincinnati in 2025. He is currently a doctoral student in the Department of Mechanical Engineering at the University of Cincinnati under the supervision of Manish Kumar. Busse's research interests include autonomous navigation and control of uncrewed aerial vehicles, machine learning, and multi-sensor fusion. His research is focused on hardware and software development of UAV systems capable of navigating in previously unknown environments where GPS is unreliable or unavailable while processing real-time data for mission-critical applications to achieve autonomous operation.

His faculty advisor, Manish Kumar, received his bachelor's degree in mechanical engineering from the Indian Institute of Technology, Kharagpur, India, and his M.S. and Ph.D. degrees in Mechanical Engineering from Duke University. After serving as a postdoctoral researcher at Duke University, the U.S. Army Research Office, and University of Pennsylvania, he started his career as a faculty member at University of Cincinnati (UC) in the Department of Mechanical and Materials Engineering where he currently serves as a Professor and the Graduate Program Director. At UC, he directs Cooperative Distributed Systems (CDS) Laboratory, co-directs Industry 4.0/5.0 Institute, and co-directs Applied Autonomy Lab. His research interests include unmanned aerial vehicles, robotics, decision making and control in complex systems, AI, multi-sensor data fusion, swarm systems, and multiple robot control.

### AIAA Announces 2025–2026 Design/Build/Fly Draft Rules and Mission

In April 2026, AIAA DBF will celebrate its 30th anniversary fly-off in Wichita, Kansas, hosted by Textron Aviation. The objective for this year is to design, build, and test a banner-towing bush plane, conduct charter flights to pay for the airplane, and start a banner-towing business. The mission balances performance with practicality, pushing students to innovate while staying grounded in real-world design constraints. The 2025–2026 rules document can be found at [aiaa.org/dbf](http://aiaa.org/dbf).

**Proposal submissions will be accepted from 8 a.m. ET, 15 October 2025 until 5 p.m. ET, 31 October 2025.**





# AIAA Designates Hammondsport, New York, as Historic Site

By Audrey Muendel, AIAA Social Media Intern

Glenn Curtiss' pioneering early flights were honored by AIAA in a ceremony designating Hammondsport, New York, as a Historic Aerospace Site on 28 June. The ceremony included AIAA members, local community members, and representatives from the Hammondsport area.

**T**he Institute is committed to recognizing the daring people and memorable places throughout history that have led to modern flight — both in the atmosphere and beyond the Kármán line into space,” said AIAA Senior Director of Aeronautics Jim Sherman during the event. “Glenn Curtiss’ breakthroughs laid the critical groundwork for powered heavier-than-air flight. His work was directly inspired by the Wright Brothers and shaped the future of aviation.”

Among Curtiss’ achievements at this site was the first U.S. vertical takeoff and landing flight – or VTOL – on 22 May 1908. The experimental helicopter of John Newton Williams was powered by an engine designed and built by Glenn Curtiss. The flying machine hovered about two meters off the ground before landing.

Curtiss made Hammondsport a center of aviation advancement.

Working with the Aerial Experiment Association, he created revolutionary aircraft like the June Bug, the Silver Dart, and the Reims Racer—with which Curtiss won the Gordon Bennett Cup in France in 1909. Curtiss also produced the mass-produced Model D Pusher and Models G and J that led to the famous JN-4 Jenny that trained over 10,000 American pilots to fly during World War I.

The recognition of Hammondsport as an AIAA Historic Aerospace Site reflects the Institute’s ongoing commitment to preserving aviation history. Curtiss’ legacy in Hammondsport reflects the remarkable efforts he made to advance the aerospace industry—efforts rooted in the kind of breakthrough thinking that continues to define AIAA’s mission today. The dedication plaque will remain at the Curtiss Museum until Curtiss Park opens in downtown Hammondsport.

## Yvonne C. Brill Lectureship in Aerospace Engineering

This premier lecture emphasizes research or engineering issues for space travel and exploration, aerospace education of students and the public, and other aerospace issues such as ensuring a diverse and robust engineering community.

Candidates should have a distinguished career involving significant contributions in aerospace research and/or engineering and will be selected based on technical experience, originality, and influence on other important aerospace issues such as ensuring a diverse and robust engineering community.

The award includes a **\$1,000** cash prize and a **\$1,000** travel stipend.

The lecture will be held at the National Academy of Engineering building in Washington, DC, in October 2026.



Yvonne Brill receiving the National Medal of Technology and Innovation from President Obama at the White House in 2011.

**NOMINATIONS OPEN: 10 NOVEMBER 2025**  
**NOMINATIONS CLOSE: 15 JANUARY 2026**

For more details and nomination form, please visit

**[aiaa.org/brill](http://aiaa.org/brill)**



Sponsored by AIAA with the participation and support of the National Academy of Engineering



# Obituaries

## AIAA Honorary Fellow Casani Died in June 2025

**John R. Casani**, an engineer who served a central role in many of NASA's deep space missions, died on 19 June. He was 92 years old.

Casani studied electrical engineering at the University of Pennsylvania. After briefly working at an Air Force research lab, he was hired to work at Jet Propulsion Laboratory in 1956. His initial focus was on the guidance system for the U.S. Army Ballistic Missile Agency's Jupiter-C and Sergeant missile programs.

Casani went on to become an engineer on some of the earliest spacecraft. He was payload engineer on Pioneer 3 and 4, NASA's first missions to the moon. He then served as spacecraft systems engineer for the two Ranger missions to the moon, before joining the Mariner project in 1965.

He took on the role of project manager for NASA's Voyager mission, and he was the first to envision attaching a message representing humanity to any alien civilization that might encounter humanity's first interstellar emissaries.

After Voyager 1 and 2 launched in 1977, JPL focused on the Galileo mission and Casani was the project manager for 11 years, leading the effort from inception to assembly.

In 1988, he became deputy assistant laboratory director for flight projects, before serving as project manager of the Cassini mission to Saturn

from 1990 to 1991. Casani became JPL's first chief engineer in 1994, temporarily retiring in 1999, and then served on several nationally prominent committees.

In 2003, Casani returned to JPL to serve as project manager for NASA's Project Prometheus. In 2005, he became manager of the Institutional Special Projects Office at JPL, a position he held until retiring again in 2012. His work helped advance NASA spacecraft in areas including mechanical technology, system design and integration, software, and deep space communications.

Casani volunteered on the AIAA Management Technical Committee and the Institute Development Committee (1996–2000); he also served as Board of Directors Vice President of Standards (1997–2000). A Class of 2009 Honorary Fellow, Casani also was honored with the 1979 AIAA Space Systems Award, the 1991 AIAA von Kármán Lectureship in Astronautics, and the 2005 AIAA Goddard Astronautics Award.



JPL's John Casani receives the National Air & Space Museum's Lifetime Achievement Award.  
CAROLYN RUSSO/INASM, SMITHSONIAN INSTITUTION



## AIAA Senior Member Wendl Died in May 2025

**Michael J. Wendl**, AIAA Senior Member Emeritus, died 22 May 2025 in St. Louis.

Wendl started his career with McDonnell Aircraft Company (McAir) after graduating from Washington University in 1958 with a degree in electrical engineering, working initially in missile controls and inertial navigation systems. He simultaneously continued his graduate education at Washington University under the tutelage of Professor John Zaborsky, who was also a McAir consultant. These studies culminated three years later in a thesis on the mathematical theory of electro-mechanical controls of the type applicable to aircraft and missiles.

Wendl worked briefly on Project Mercury, before relocating to Houston in 1963 to work on Project Gemini at Manned Spacecraft Center (now NASA Johnson Space Center). Upon returning to St. Louis, he transitioned to fighter aircraft research and development. Wendl was part of Project 666A, a joint effort among McAir, Texas Instruments, and General Electric, that culminated in one of the first practical demonstrations of terrain following, in which the aircraft flies close to the ground to avoid anti-aircraft fire. He also worked on the fly-by-wire transition away from purely mechanical controls that the newer, higher-performing generation of jet fighters would require. This research was part of the U.S. Air Force Survivable Flight Control System (SFCS) program conducted through the Flight Dynamics Laboratory at Wright-Patterson AFB. With Robert Kisslinger, Wendl wrote the "control laws supplement" of the SFCS program report TR-71-20. Incidentally, the F-4E Phantom II airframe, serial number 62-12200, that had been used extensively for testing in these and several related programs was later

donated by McDonnell-Douglas to the National Museum of the U.S. Air Force in Dayton, Ohio, where it is currently undergoing restoration.

In the late 1960s, McDonnell-Douglas was chosen by the U.S. Air Force to develop what would become the F-15 Eagle to counter the Soviet Mig-25. Wendl would work both on this program and on the F-18 Hornet program for the U.S. Navy over much of the rest of his career and this included frequent journeys to Edwards Air Force Base for flight tests. He ultimately rose through the McDonnell-Douglas ranks to Branch Chief, being responsible for ongoing F-15 flight controls development and the F-15 Keep Eagle program, which sought to perfect recoveries from high angle-of-attack departures. He also was called upon as part of the engineering contingent involved in the Japanese Self Defense Force's adoption of the F-15, with flight evaluations at Kadena Air Force Base on Okinawa.

Over the years Wendl garnered many technical awards, including the SAE Wright Brothers Medal in 1974, the McDonnell-Douglas Engineering and Research Fellow's Medal in 1992, and several Air Force Commendations, including one for Keep Eagle from program commander USAF General Richard Scofield. Although he retired shortly after the McDonnell-Douglas merger with Boeing in 1997, Wendl continued to stay abreast of aeronautical progress and government and military policy developments and enjoyed attending the McDonnell-Douglas retiree "fighter mafia" luncheon reunions.



[View more Obituaries](#)





## SIMPSON'S VIEW

# U.S. air traffic control doesn't just need to modernize — it must transform

BY AMANDA SIMPSON | [simpson.amanda.r@gmail.com](mailto:simpson.amanda.r@gmail.com)

Even for casual readers of the news, the last few years point to a troubling trend for U.S. aviation safety. Outdated hardware, troublesome software, and a continued shortage of trained air traffic controllers has meant reduced staffing levels resulting in periods of ATC Zero, in which there are no controllers at a facility. All this has led to more near misses, runway incursions, communication equipment failures and, most seriously, the first major airline midair collision in decades.

It was no surprise, then, that the modernization plan announced in May by Transportation Secretary Sean Duffy is focused on replacing outdated equipment, upgrading technology and resolving the staffing shortages.

To be sure, these are all serious problems that must be addressed. The ATC system is already stretching its capacity limits as it handles some 45,000 flights each day. Advanced air mobility companies are on the verge of beginning passenger service, which will add tens of thousands of air vehicles. Commercial space launches and recoveries are now occurring in untraditional locations, shutting down swaths of airspace for hours. While the pace continues to increase, each places a high burden on the ATC system — and that's exactly why Duffy's plan doesn't go far enough.

The current process for ATC modernization is to slowly and appropriately make small improvements that can be incorporated into the airspace system — effectively, attempting to patch problems as they emerge over time. There is nothing wrong with that approach per se, but what's missing is the overall vision for something new that will not only accommodate the future of air travel we see coming, but also be able to adapt beyond that.

My vision? A future in which ATC stands for Automated Traffic Control. In this reality, air traffic management will be based upon aircraft talking to each other — without someone on the ground controlling them. When we get down into the urban environment with advanced air mobility vehicles and drones, where line-of-sight communication is restricted, this will be the only solution. Here, interactions are happening too close,



**Amanda Simpson** is a consultant, a former U.S. deputy assistant secretary of defense for operational energy, and a former head of research and technology at Airbus Americas, where she led sustainability efforts. An AIAA fellow, she's a licensed pilot and certified flight instructor.

too quickly, for there to be a human in the loop. Certainly, human oversight of the operating picture should be part of the system, but real-time separation and sequencing could be done by onboard electronics directly.

This may seem a daunting task, but ATC has remade itself before. After World War II, ATC consisted of towers at selected airports that sequenced airplanes for takeoff and landings and air route centers that monitored aircraft as they radioed in positions along their filed flight plans. These plans were tracked on strips of paper that included their filed flight plan information and expected time to the next reporting point. The strips were passed from controller to controller as each flight progressed.

In 1956, two airliners departing Los Angeles minutes apart on their way to different Midwest airports collided over the Grand Canyon, even though they had filed different routes and different initial altitudes. In response to this tragedy, Congress created the FAA and put it in charge of establishing an effective ATC system. Leveraging technology from WWII, the agency installed radar tracking to monitor aircraft and expanded communication to cover the entire country.

In the 1960s, aircraft were equipped with transponders and computers were introduced with traffic monitoring. Jet aircraft flew faster and higher than before, and ATC handled 13,000 flights per day. The paper strips remained but were now typed on computers rather than being handwritten.

As traffic increased, the U.S. introduced new aircraft equipment to assist in avoiding collisions. In the 1980s, the government mandated the Traffic alert and Collision Avoidance System (TCAS) in larger aircraft. Upgraded computers and advanced software were installed at ATC en-route centers and later at ATC approach control facilities. The paper strip data was now displayed electronically on controllers' screens.

As of 2020, the majority of aircraft were required to be equipped with Automatic Dependent Surveillance–Broadcast Out transmitters, so their GPS position could be viewed by surrounding aircraft. A bill introduced in Congress in response to the January collision of a Black Hawk helicopter and regional jet over the Potomac River near Washington, D.C., will mandate ADS-B In (Automatic Dependent Surveillance–Broadcast In) for airspace where ADS-B Out was mandated.

Yet even as air traffic increased, qualified air traffic controllers remained in short supply. The 1981 Professional Air Traffic Controllers Organization strike and decertification resulted in the firing of over 11,000 controllers. COVID-19 shut down the FAA's Training Academy in Oklahoma City for four months in 2020, before instruction was able to resume at half capacity to comply with exposure restrictions. In 2024, there were 1,100 fewer controllers than in 2021, and hiring is barely outpacing retirements. My local airport has gone ATC Zero for five days over the last month, downgrading the facility to "uncontrolled."

Balanced against these concerns and equipment

"In the future, air traffic management will be based upon aircraft talking to each other — without someone on the ground controlling them."

upgrades is the continued growth of air travel. Following the COVID-19 downturn, airline travel quickly rebounded and exceeded pre-COVID levels. Anticipated growth at an annual rate of about 3.4% will result in a doubling by the early 2040s to over 400,000 aircraft movements per day globally. The rise of advanced air mobility could add 200,000 eVTOLs to the global fleet by 2040.

So we need a transition plan, sooner rather than later. Whatever it consists of, having such a plan defined would allow the FAA and industry to begin developing the technology to solve the missing pieces that are currently unavailable to reach deployable milestones.

Here are some of those needed technologies: A secure upgrade to ADS-B could include position data even in GPS-denied areas, along with planned flight paths and aircraft classification. Advanced algorithms could use this data to make adjustments in each aircraft to ensure appropriate safety clearances are met. Advancements in flight deck displays could advise human pilots of potential conflicts and suggest corrective action. Machine learning could be employed to ensure arrival gates will be available before takeoff. Those iconic paper strips would only be seen in museums.

There are teams and organizations working to define what ATC could look like in 2050, but they must coalesce on a concept soon so there can be global agreement on the transition path that will drive the technology development and international deployment. Further postponement of determining a suitable and reasonable future ATC scheme only supports maintenance investments that are random versus purpose-driven to back the coming aviation evolution. ★

Aerospace America publishes a rich variety of opinions relevant to the future of aerospace. The views expressed are those of the author(s) and do not necessarily reflect those of our publisher, AIAA.



## How the Artemis program got its name

BY CHRISTIAN DAVENPORT

*The following is an excerpt from Davenport's book, "Rocket Dreams: Musk, Bezos and the Inside Story of the New, Trillion-Dollar Space Race," released by Crown Currency on Sept. 16.*

In May 2019, NASA Administrator Jim Bridenstine convened a meeting with his top communications aides. Just a couple months earlier, Vice President Mike Pence had sent shockwaves through the space industry by proclaiming American astronauts would return to the moon by 2024, and a woman would be among them. But it was bothering Bridenstine that the first, uncrewed flight in the program was known clunkily as Exploration Mission-1. There was nothing lofty, like Mercury, Gemini, or Apollo.

"There's no cohesive story," he told his staff. "I'm trying to mobilize people, but we don't have a program. We have parts and pieces." He paused for a moment. "We need to name it. We need a brand for this."

Some on the team were against naming the program. Give it a name and Congress can kill it, longtime NASA staffers warned him. That's what happened to the Constellation program, which was canceled during the Obama administration. But Bridenstine didn't want to hear it. The right name, he believed, would bring national pride and support. China knew the power of a good name. Its moon program, Chang'e, was named for the moon goddess celebrated in Chinese folklore and culture. Its Long March rocket program got its name from the historic six-thousand-mile trek by Chinese communists in the 1930s that led to the emergence of Mao Zedong.

Suddenly, Bridenstine popped out of his chair and left the room, telling his puzzled team, "I'll be back." He started roaming the hallways of NASA, asking everyone

he ran into if they had any ideas for what to call the moon program. He poked his head into offices and cubicles. Finally, a few days later, he ran into Alex MacDonald in a snack area. MacDonald was NASA's chief economist and the author of "The Long Space Age: The Economic Origins of Space Exploration from Colonial America to the Cold War." He was also something of a Renaissance man — a historian and academic, with an appreciation for modern art. His father had been a fan of the classics, and when MacDonald was a child, he recounted the Iliad and the Odyssey from memory as bedtime stories.

"We could always go back to Artemis," MacDonald told Bridenstine.

"Artemis?" Bridenstine said, looking curious but also a bit confused. He was aware that Andy Weir had just published a novel with that title, but he couldn't quite place the name.

Artemis was the twin sister of Apollo, MacDonald explained, and also the goddess of the moon. The only problem was that NASA had already used the name for a mission years earlier, involving a pair of spacecraft used to study the moon and solar wind.

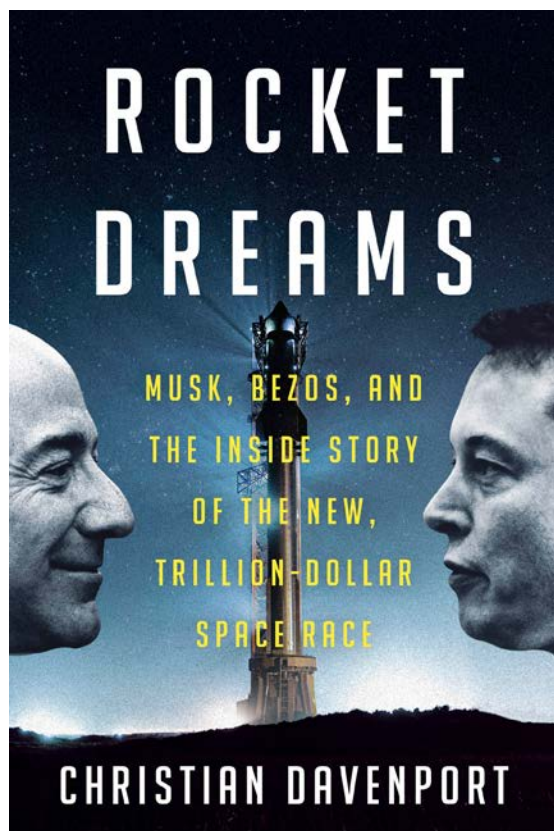
No one had ever heard of the earlier mission, Bridenstine thought. And no one outside of the scientific community cared. "Artemis" was perfect.

"That's it," Bridenstine said. "That's the name."

Bridenstine was in love with Artemis and wanted to announce it as soon as possible. Normally, such a decision would need sign-off from the White House and the National Space Council. NASA's Capitol Hill liaisons



**Christian Davenport** has been a staff writer at The Washington Post since 2000, covering space since 2014. He is the author of three books and a producer of the documentary, "Space: The Private Frontier."



“It was an attempt to demonstrate momentum, that NASA did in fact have a plan — and the money, or at least the first deposit — to meet Pence’s 2024 deadline.”

would be dispatched to give a heads-up to the appropriate congressional committees and make them feel like they were part of the plan. But Bridenstine didn’t have time for a bunch of meet-

ings on the subject. That would only delay the inevitable.

That same month, he decided to hold a press conference, ostensibly to announce that the White House had agreed to boost NASA’s budget by \$1.6 billion. But he also wanted to drop the Artemis name. Late in the day, as his team scrambled to prepare for the teleconference, which was to start at 7 p.m., Bridenstine called Gabe Sherman, his chief of staff, who was already headed for his train ride home, for a gut check. Sherman didn’t answer, so Bridenstine went running after him and was out of breath by the time he caught up to him.

Was he making a mistake to name the program? Bridenstine wanted to know. Or should he go for it? “Let’s do it,” Sherman said.

Shortly before the teleconference started, President Trump scooped Bridenstine in part by crowing on Twitter: “Under my administration, we are restoring @NASA to greatness and we are going back to the Moon, and then Mars. I am updating my budget to include an additional \$1.6 billion so that we can return to Space in a BIG WAY!”

On the media call, Bridenstine said the funds would

“accelerate our return to the lunar surface.” It was an attempt to demonstrate momentum, that NASA did in fact have a plan — and the money, or at least the first deposit — to meet Pence’s 2024 deadline. But he also sought to manage expectations, acknowledging that “in the coming years, we will need additional funds.”

At the end of the call, after fielding questions from reporters skeptical about the timeline and whether Congress would really pay up, Bridenstine said he had some closing remarks. It was time for his own surprise announcement.

“The first time humanity went to the Moon, it was under the name Apollo,” he said. “The Apollo program forever changed history, and I know all of us here in this room and on the phone are very proud of the Apollo program. It turns out that Apollo had a twin sister, Artemis. She happens to be the goddess of the moon. Our astronaut office is very diverse and highly qualified. I think it is very beautiful that 50 years after Apollo, the Artemis program will carry the next man and the first woman to the moon. I have a daughter who is 11 years old, and I want her to be able to see herself in the same role that the next women that go to the moon see themselves in today. This is really a beautiful moment in American history, and I’m very proud to be a part of it.”

The White House was not happy with the breach of protocol and let Bridenstine and his staff know they should have given them a heads-up. But it was too late. The name was out there. There was no taking it back now. ★



# LOOKING BACK

100, 75, 50, 25 YEARS AGO IN OCTOBER–DECEMBER

COMPILED BY FRANK H. WINTER AND ROBERT VAN DER LINDEN



## 1925

**1 Oct. 3** The aircraft carrier USS Lexington is launched at Quincy, Massachusetts. This converted battlecruiser enters service in late 1927 and operates until 1942, when it is sunk at the Battle of the Coral Sea. **Aircraft Year Book, 1925**, p. 120.

**Nov. 7** The Marquis de Pinedo and his mechanic arrive in Rome after a 201-day round trip to Tokyo via Australia. The 56,300-kilometer (35,000-mile) flight in their Savoia S16 flying boat is the longest airplane journey yet made. **Flight**, Nov. 12, 1925, p. 756.

**Dec. 12** A handful of New York investors establish Colonial Air Transport to fly the first contract air mail route. CAM-1 — contract air mail route number 1 — will connect New York and Boston, with service to begin in 1926. Colonial in 1930 is absorbed with several other carriers to form American Airways, the predecessor to American Airlines. R.E.G. Davies, **Airlines of the United States Since 1914**, pp. 49-50.

**Dec. 15** U.S. Sen. Hiram Bingham (R-Conn.) introduces a bill to establish national air laws and a bureau of civil aviation in the Department of Commerce. Later renamed the Air Commerce Act of 1926, the bill attempts to regulate commercial interstate flying, leaving the control of pilots and aircraft engaging in air work within the confines of a single state to local laws or voluntary submission to federal control. **Aviation**, Jan. 4, 1926, p. 7; **Aircraft Year Book, 1926**, p. 122.

**Dec. 27** Daniel Guggenheim establishes the Daniel Guggenheim Foundation for the Promotion of Aeronautics. This organization supports the technical advancement of aviation by sponsoring the Model Airline of Western Air Express and funding various ventures: aeronautical research at numerous universities, the Full Flight Laboratory at Mitchel Field that led to the first successful

“blind flight,” and Lindbergh’s tour around the United States following his trans-Atlantic flight, among others. Richard Hallion, **Legacy of Flight: The Guggenheim Contribution to American Aviation**.

## 1950

**2 Oct. 10** The Boulton Paul P.111 research airplane completes its first test flight at the Aeroplane and Armament Experimental Establishment in Boscombe Down, Wiltshire. A single Rolls-Royce Nene turbojet powers this delta wing design, and its leading edge has detachable tips for comparing the effectiveness of blunt and pointed tips. In 1953, the P.111 is modified and redesignated the P.111A. **The Aeroplane**, Nov. 10, 1950, p. 400; William Green and Roy Cross, **The Jet Aircraft of the World**, p. 118.

**Nov. 8** The first jet-versus-jet dogfight takes place near the Chinese-Korean border. Four U.S. Air Force F-80C Shooting Stars encounter a handful of Soviet-built MiG-15s crossing from China., and U.S. Air Force Lt. Russell Brown Jr. shoots down a Soviet-built MiG-15 fighter carrying a North Korean pilot. The entrance of MiG-15s into the Korean War prompts the U.S. Air Force to send North American F-86 Sabres to augment its fleet. In December, Lt. Col. Bruce Hinton in his F-86 shoots down a MiG-15 in the first swept wing combat of the war. C.V. Glines, **The Compact History of the USAF**, p. 303. Ray Wagner, **The North American Sabre**, pp. 46-37, 78.

**3 Dec. 6** NACA scientists at the Langley Aeronautical Laboratory in Virginia achieve a continuous transonic airflow in the Langley 8-foot high-speed tunnel with a newly installed slotted-throat test section. Lead scientist John Stack and the NACA team responsible for this development are later awarded the 1951 Collier Trophy. NASA, **Aeronautics and Astronautics, 1915-1960**, p. 213.

## 1975

**Oct. 16** NOAA’s first Geostationary Operational Environmental Satellite is launched aboard a Delta rocket from NASA’s Kennedy Space Center in Florida. Designated GOES 1 once on orbit, the satellite provides NOAA scientists with images of a quarter of Earth’s surface at 30-minute intervals, day and night. GOES also collects and relays non-visual environmental data transmitted from thousands of remote-sensing facilities on land and sea. **NOAA Release 75-188**.

**4 Oct. 22-25** The Soviet Union becomes the first country to land a spacecraft on Venus, where temperatures reach 500 degrees Celsius and pressures are up to 100 times that of Earth’s atmosphere. Upon arriving in orbit, the Venera 9 and 10 probes release their landers. After slow descent through the dense atmosphere, each craft functions for roughly an hour, capturing the first pictures of the planet’s surface. **New York Times**, Oct. 23, 1975, p. 1, and Oct. 26, 1975, p. A3.

**Nov. 14** Pan American World Airways announces the industry’s first nonstop flight, a New York to Tokyo route scheduled to commence early next year. The announcement comes a day after a new Boeing 747SP jetliner completes a demonstration flight from New York to Tokyo in 13 hours and 33 minutes, the fastest time to date for this route. **Baltimore Sun**, Nov. 15, 1975, p. A9.

**Nov. 17** Leading Soviet geochemist Alexander Vinogradov dies in Moscow at 80. He identified 40 chemical elements in Earth’s soil zones and also developed the field of cosmochemistry, the chemical analysis of lunar and planetary bodies. A mountain on the moon’s near side and a Mars crater bear his name. **New York Times**, Nov. 19, 1975, p. 38.

**Dec. 3** The People’s Republic of China announces its first recovery of a retrievable satellite, Fanhui Shi Weixing. This imagery reconnaissance craft was

launched in late November and reentered days later, touching down in the Guizhou Province in southwest China. **Baltimore Sun**, Dec. 4, 1975, p. A4.

## 2000

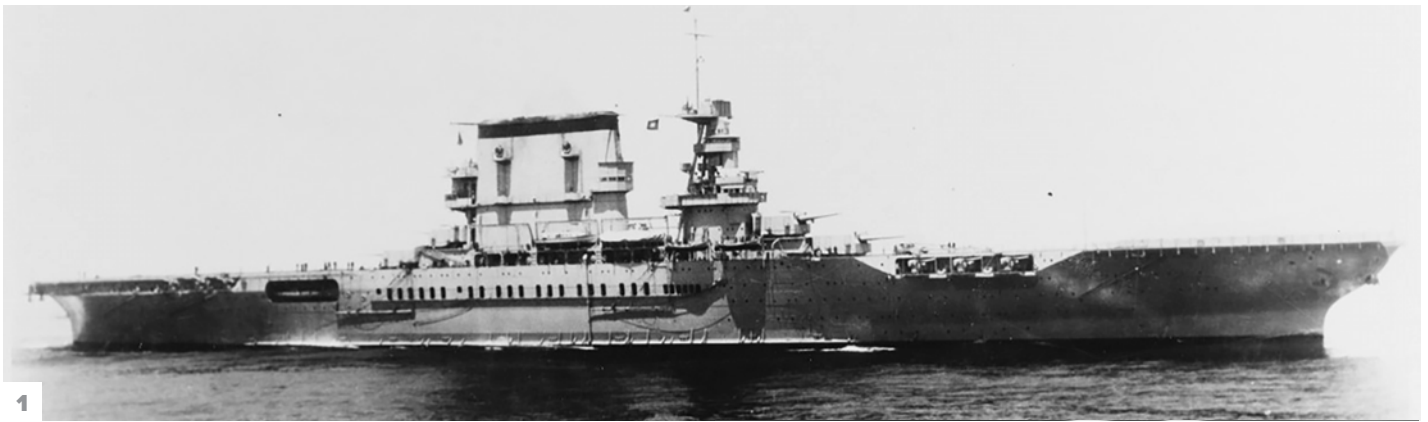
**Oct. 11** The space shuttle Discovery launches from NASA’s Kennedy Space Center in Florida on the 100th shuttle flight, carrying the Z-1 truss and a new docking port for the International Space Station. The STS-97 crew will dock at that port in December to install the truss and the first pair of solar arrays on the U.S. Unity module. **Flight International**, Oct. 24-30, 2000, p. 32.

**5 Oct. 24** The Lockheed Martin X-35A Joint Strike Fighter makes its inaugural flight. After taking off from the 600-meter (2,000-foot) runway in Palmdale, California, the aircraft climbs to an altitude of 10,000 feet without the use of an afterburner. **Flight International**, Oct. 31-Nov. 6, 2000, p. 6.

**Oct. 31** China’s first navigation satellite, BNTS-1, launches aboard a Long March 3A. This is the first satellite in China’s planned Beidou Navigation System for highway, rail and sea-going traffic, as well as for military operations. **Flight International**, Nov. 7-13, 2000, p. 32.

**Nov. 2** The Soyuz TM-31 capsule docks with the International Space Station, carrying the first long-duration crew. NASA astronaut Bill Shepherd, cosmonaut Yuri Gidzenko and cosmonaut Sergei Krikalev stay aboard for 115 days, installing equipment, conducting biomedical experiments and welcoming multiple cargo and crew vehicles, among other tasks. **Flight International**, Nov. 7-13, 2000, p. 32.

**Dec. 6** Four Russian airlines — Domodedovo Airlines, KrasAir, Chelyabinsk Airlines and Aviaskpresskruiz — form the country’s first interline civil aviation alliance. In this arrangement, intended to boost revenue and improve market share, the carriers are authorized to sell tickets on one another’s flights. **Flight International**, Dec. 12-18, 2000, p. 10.



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ВЕНЕРА-9 22.10.1975 ОБРАБОТКА ИППИ АН СССР 28.2.1976  
ЧЕРА-10 25.10.1975 ОБРАБОТКА ИППИ АН СССР 28.2.1976



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6



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# TRAJECTORIES

Young professionals shaping the future of aerospace

## Eugene Hoffman, 31

From Ghana to San Antonio, Texas, Eugene Hoffman's career journey has been a "winding path" in search of ever greater technical challenges and problems to solve. That's brought him to Southwest Research Institute, where he researches and conducts experiments related to fluid and thermal management for a variety of clients — a role that requires the occasional parabolic flight.

**What's your aerospace origin story?** ▶ In grade school, I had aspirations of being an astronaut but never knew how to physically get there. Engineering seemed to mesh with my natural inquisitive nature, then I decided to go back to grad school for a greater challenge. That's how I ended up at UTSA (University of Texas at San Antonio) building the hypersonic wind tunnel facility, funded by NASA, UTSA and the Dee Howard Foundation. It's one of a handful in the world that can simulate reentry conditions for high-speed vehicles.

**Favorite thing about your job?** ▶ The ability to meet cool people doing really cool things and contribute to a wide variety of technology. At SwRI, we assist our clients and our partners to take their technology from TRL [Technology Readiness Level] 2 all the way to about TRL 6 or 7. This is in the valley of death, because the tech is not really academic research, but it's not also at the shop level, ready to be manufactured.

**What motivates you?** ▶ I look forward to the difficult questions, the difficult tasks. In aerospace particularly, there's no shortage of those. Take the difficult problems we have here on Earth — they amplify by a factor of 10 when you're out in space. That's a nice thing about the spot I'm in right now. I can still do work in hypersonics, in ISRU [in situ resource utilization], in surface power, lots of topics.

**What tech outside your field fascinates you?** ▶ Small, modular nuclear reactors for surface power, both on Earth and other planetary bodies. On Earth, the biggest bottleneck for our AI data centers is finding a clean, sustainable way to power them. On the flip side, if you're looking at sustained human presence on the moon or Mars, sunlight isn't reliable enough to rely on solar power. And so that aspect of having a nuclear reactor that is modular and can be easily set up and transported becomes very, very enticing.

**What will the world look like in 2050?** ▶ There'll be more space travel. We'll begin space manufacturing, space mining. The use of AI is going to become even more prevalent in general, but there's still going to be human interaction. It'll be a more automated world with more tools than we have right now, but we'll have even more difficult problems than we do have right now. ★



### MORE ABOUT EUGENE

**CAREER HIGHLIGHTS:** 2019-2023, graduate assistant at the University of Texas at San Antonio, where he helped set up the Mach 7 wind tunnel. At Southwest Research Institute, completed a parabolic flight in 2024 for a NASA-funded study about how liquids boil in reduced gravity. "It's one of the coolest experiences I've ever had. My younger self would be very excited, very proud."

**AIAA CONNECTION:** "One of my advisers says that people that can design wind tunnels and do high-speed aerodynamics are like the eighth wonder of the world because there aren't many left. AIAA served as a huge bedrock when we were setting up the Mach 7 tunnel. Through the conferences and papers, we met a ton of people and learned a lot about how these tunnels function and how they're run."

**EDUCATION:** Ph.D. in mechanical engineering (2023) and Master of Science in mechanical engineering (2021), both from the University of Texas at San Antonio. Bachelor of Science in mechanical engineering from the University of Evansville in Indiana (2016).

**FUTURE FLIGHTS:** NASA is funding another parabolic flight in 2026, in which Hoffman and his SwRI colleagues will test the ability of an electrolysis device to produce hydrocarbons from Martian regolith simulant.

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