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JULY–SEPTEMBER 2026

AEROSPACE AMERICA

Rise of the orbital data centers

What it would take to move computing to space. PAGE 28

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AEROSPACE AMERICA

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FEATURES | JULY-SEPTEMBER 2026

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DEPARTMENTS

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.

EDITOR'S NOTEBOOK

From moon missions to morphing wings

▲ Earthset photographed through the window of the Artemis II Orion capsule, during the crew's April 6 lunar flyby.

NASA

By the time this magazine comes out, it will have been nearly three months since Artemis II concluded. Yet the mission's effects continue to reverberate.

Anecdotally, at least, the nearly 10-day flight seemed to capture public attention in a way I haven't seen in years. Tens of millions tuned in to watch the crew's splashdown off the coast of California on April 10.

At the Space Symposium in Colorado Springs the following week, the tone was extremely positive, perhaps even jubilant. And in May at AIAA's ASCEND event in Washington, D.C., NASA Administrator Jared Isaacman promised to keep the agency's foot on the pedal.

Now, NASA is gearing up for Artemis III in 2027 and beyond.

In parallel, the U.S. Space Force is bracing for major growth. The White House's fiscal year 2027 budget requests just over $71 billion for the service, up from the $31.6 billion it received in fiscal 2026.

Whether civil or military, it seems space is readying for a major buildup. In our print magazines and on our website, you can expect plenty of coverage of both.

What's inside

Our cover story (page 28) takes a look at another area that's seen a dramatic increase in interest: orbital data centers. In less than a year, the conversation around this potential market has surged, even drawing commentary from Amazon and Blue Origin founder Jeff Bezos. The growing adoption of artificial intelligence is creating a nearly insatiable demand for energy, pushing companies to consider new ideas that could reduce the demands on Earth's resources.

For our story, Jonathan O'Callaghan takes a closer look at exactly how this could work — and what the potential pitfalls are.

Switching gears to a longer-term project, Adam Hadhazy looks at NASA's planned Habitable Worlds Observatory (page 38). The telescope requires a slew of technological advancements if it is to achieve its goal of imaging Earth-like exoplanets, which could provide new insight into whether life exists elsewhere in the universe.

And don't miss The Big Question (page 22) about the future of the International Space Station. The ISS is slated for retirement in 2030, but some of our experts say operations should be extended, while others say more study is warranted.

Plus, we have a Q&A with Arun Seraphin (page 10), who runs the National Defense Industrial Association's Emerging Technologies Institute, and a closer look at DLR's effort to develop an aircraft wing with a morphing trailing edge (page 18). ★

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Aerospace on America's 250th Birthday

Clay Mowry
AIAA CEO

In 1976, when America celebrated its 200th birthday, the Apollo program was in the rearview mirror. The Space Shuttle was still on the drawing board. Reusable launch was a plan to recover solid rocket boosters from the ocean at enormous expense. Autonomous vertical flight, beyond the iterations of the helicopter Sikorsky first fielded in 1939, remained speculative. The Concorde – supersonic commercial service launched that January – was the era's boldest ambition. Had you stood at that bicentennial and described today's aerospace landscape to the engineers gathered there, it would have defied imagination.

Fifty years later, at America's 250th birthday, the distance our industry has traveled is extraordinary. Reusable rockets routinely return to landing pads under their own guidance and propulsion. Electric air taxis are on the verge of commercial certification. And private jets can travel point-to-point anywhere in the world.

We've seen machine learning and additive manufacturing fundamentally alter how flight hardware is designed and produced. And the power of artificial intelligence (AI) is quickly reshaping the engineering process from concept development through testing and fielding.

That transformation did not happen by accident. Private capital has entered the sector in historically significant volumes. Digital engineering matured. Computational power expanded dramatically, enabling high-fidelity modeling and simulation that didn't exist a generation ago.

These tools did not displace engineers – they amplified what engineers could accomplish, compressing design cycles and enabling rapid iteration. That pattern is both consistent and instructive as the industry now confronts the promise and complexity of AI.

Over the course of this year – from SciTech to DEFENSE Forum to ASCEND to AVIATION Forum – one theme surfaced consistently: AI is a powerful tool, and its value is determined by how rigorously it is applied.

At AIAA SciTech, Lockheed Martin CTO Craig Martell defined AI in precise terms: pattern recognition applied to quality data, used to model future outcomes from past inputs. He was equally direct about what it is not – a substitute for domain expertise or human accountability. "The onus of the output is still our responsibility," he said. That framing resonated at every gathering that followed. It is not a limitation on AI's potential; it is the governing principle for deploying it effectively.

AIAA's "Technologies Transforming Aerospace" report, released earlier this year, reaches the same conclusion. Across propulsion, autonomy, materials science, and digital engineering, emerging technologies consistently function as force multipliers – compressing what is possible within a given time frame, not eliminating the judgment required to get there. AI adoption in mission-critical systems remains uneven precisely because the workforce capable of directing, validating, and owning AI outputs is still being built. That is the central challenge ahead of us.

The historical record, however, is encouraging. When CAD/CAM became standard, engineering productivity accelerated. When additive manufacturing scaled, production organizations grew and qualified personnel were needed to manage workflows, certify parts, and integrate new processes. Each technological transition has followed the same trajectory: new tools raised the ceiling on what practitioners could achieve, and the workforce evolved accordingly.

AI will follow that arc. The roles that transform will not disappear; they will demand new and more sophisticated competencies. Aerospace will need professionals who can formulate the right questions, interpret outputs with genuine domain knowledge, and maintain rigorous ownership of the validation process. Martell's counsel is practical and principled: approach AI as a good engineer approaches any system – with clear objectives, defined measures of success, and full accountability for results. Data hygiene, appropriate guardrails, and human review will provide solid results that crush the process from months to days.

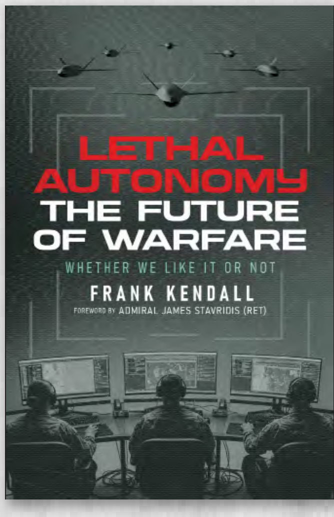
The technologies being refined through these tools will reach well beyond aerospace itself. Electric vertical takeoff and landing aircraft (eVTOL) have the potential to restructure urban transportation – connecting city centers to airports, reducing surface congestion, and generating infrastructure that does not yet exist. The next generation of aviation is contributing to a broader redesign of how people and goods move, with implications extending into urban planning, energy systems, and economic development.

As this nation marks 250 years, AIAA's mission has never been more consequential. Convening the brightest minds across industry, government, and academia is one part of that work. Equally vital is what those gatherings make possible: the exchange of knowledge that advances the state of the art, informs the next generation of professionals, and ensures aerospace remains the world's most significant technical enterprise.

The AIAA community has always stood at the leading edge of what aerospace can become. That position was earned by the professionals who came before us and broke the barriers of air and space. The next fifty years will belong to those who bring the same discipline to what is available now. ★

BOOK SPOTLIGHT

A SELECTION OF RECENTLY PUBLISHED AND UPCOMING TITLES



Lethal Autonomy: The Future of Warfare Whether We Like it or Not

RELEASING JULY 7, 2026
(Knox Press)

Former U.S. Air Force Secretary Frank Kendall describes "how lethal autonomous platforms will transform warfare," according to the publisher.

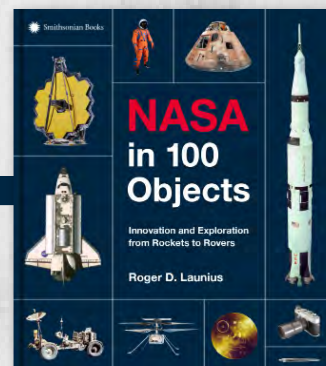
Kendall, also a previous Pentagon acquisition chief, offers "compelling descriptions of how artificial intelligence and autonomous weaponry are going to transform conventional warfare, rendering current militaries almost entirely obsolete," it adds. The book weighs the future of warfare across all military domains — including space and cyberspace, the publisher notes.

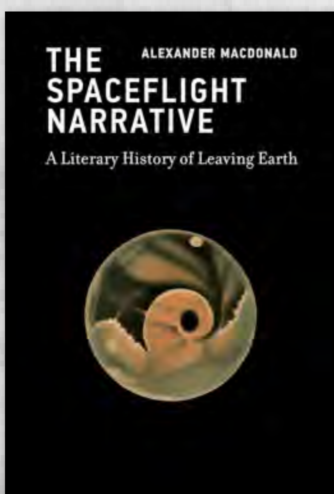
NASA in 100 Objects: Innovation and Exploration from Rockets to Rovers

RELEASING SEPT. 15, 2026
(Penguin Random House)

Former NASA Chief Historian Roger D. Launius has put together what the publisher calls a "space coffee table book," featuring 100 influential objects.

"NASA in 100 Objects begins with the agency's origin as the National Advisory Committee for Aeronautics and moves through the space race, Apollo era, rise of Earth orbital activities, International Space Station, and present-day commercial spaceflight," the publisher writes, calling it "an accessible reference guide to the nation's amazing history of space exploration."





The Spaceflight Narrative: A Literary History of Leaving Earth

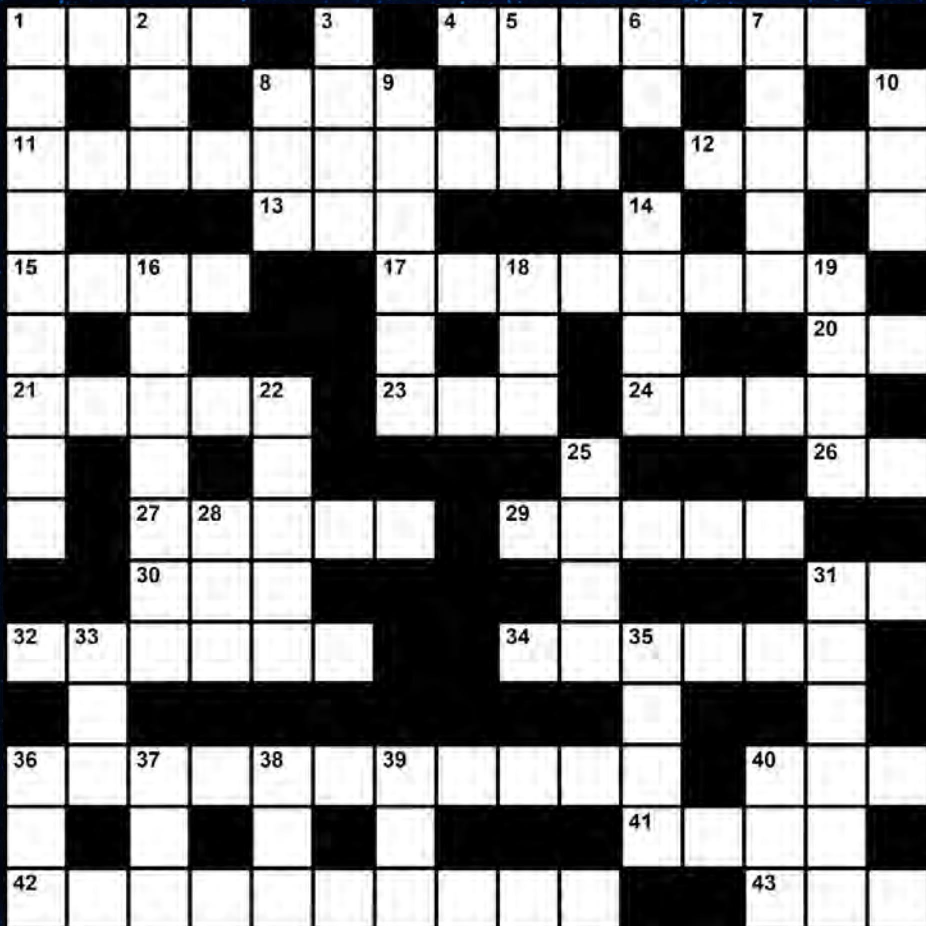
RELEASING OCT. 13, 2026
(The MIT Press)

NASA's first chief economist, Alexander MacDonald, "explores the earliest origins of spaceflight as it emerged through storytelling in works of literature and commentary dating back over three hundred years," the publisher writes.

The book "covers the history of the conceptual development of spaceflight from the first story, written in the 1620s, of a person building a machine that goes to the Moon, all the way through to the 1890s when visions of spacefaring adventures across the solar system had become common," it adds.

Titles are meant to reflect a broad range of topics and are not reviewed or endorsed by *Aerospace America* or AIAA.

CROSSWORD



Test your knowledge then find the answers online.

Across

1 This inflatable module arrived at ISS 10 years ago in April

4 Drone operators are usually concerned with the ____ to weight ratio

8 Initial Operational Capability, abbr.

11 Mercury is the only planet in our solar system without this

12 Apollo 11 was a giant leap for mankind, but a small one of these for Neil Armstrong

13 This feature is called a mare on other celestial bodies, but is known by another name on Earth

15 U.S. military missile testing frequently involves this remote atoll in the Pacific (abbr.)

17 How cargo spacecraft are berthed to ISS (2 words)

20 Jupiter's most explosive moon

21 Not inner but ______

23 One proposed method for capturing space junk

24 Cosmic and gamma, for instance

26 Chemical symbol of a metal commonly used in aircraft and spacecraft construction

27 This orbiter's mission formally ended in June, but NASA lost contact with it in December

29 Often the first big deployment after a spacecraft launch

30 What NASA's VIPER rover will hunt for

31 Logarithmic unit used to measure the intensity or loudness of sound (abbr.)

32 The U.S. military has increasingly used these in recent months to shoot down drones

34 This colorful substance is a distinctive feature of Starship flight tests

36 JetZero and Natilus want to build these

40 Young Anakin's favorite kind of racer

41 NASA describes this cloud as a "thick bubble around our solar system"

42 U.S. President Donald Trump wants this operational by the end of his term

43 Host of the annual air show in Wisconsin (abbr.)

Down

1 Get caught in this cosmic feature, and you'll never escape (2 words)

2 Common shorthand for electric air taxis

3 This orbiter arrived at Mars in early 2021

5 The next step in DARPA's development of AI-piloted aircraft technologies

6 Pound (abbr.)

7 Not before but _____

8 Some members of Congress want to extend this

9 Pluto's largest moon

10 Rank below sergeant (abbr.)

14 Polaris or Alpha Centauri, for instance

16 This NASA program had a big launch in April

18 When you don't feel like saying robot

19 Thin fog

22 NASA has a few of these traversing Mars

25 Spoken, not written

28 DARPA pitted AI-piloted aircraft against human-piloted ones in this program (abbr.)

31 War of the Worlds star, ______ Fanning

33 Shorthand for the Maryland laboratory that's building NASA's Dragonfly

35 One of Ptolemy's 48 constellations that are now a grouping of three IAU constellations

36 Not small but ___

37 A more technical name for the 7 minutes of terror Mars spacecraft undergo (abbr.)

38 NASA is working with this agency to establish a nuclear reactor on the moon

39 Item that fails to function

40 ___flight checklist

If you build it, they will soar

Eastern Iowa Airport Director Marty Lenss reflects on Iowa's aerospace & defense industry and the future of the state's aerospace cluster

From the moment 13-year-old Marty Lenss set foot in an airport, it was love at first flight.

"I remember how fascinating the commotion and chaos of the airport was, and of course, actually flying for the first time was incredible," said Marty, recounting that first voyage to visit his sister in Canada. That love of flight was instrumental in leading him to become director of the Eastern Iowa Airport (CID). "That experience lit the fuse," he said.

Years later, after securing his pilot's license and earning dual degrees in airport and business administration, Marty began a career in aviation that spanned multiple states and positions before being named CID's director in 2014. During his tenure, Marty has become a central figure in Iowa's burgeoning aerospace and defense industry, using his extensive aviation business background to help the state modernize and innovate into a new stratosphere among its regional competitors.

Building the foundation for regional aerospace leadership

Marty and the team at CID represent just some of the many Iowa-based aerospace and defense industry veterans leading this effort — a fundamental piece of which ensured that Iowa's reputation for ease of doing business and lower-than-average operating costs aligned with how the state incentivizes aerospace-related businesses.

"About five years ago, we worked with state airport operators and aviation businesses to support the state legislature's passage of the sales tax exemption bill on aircraft parts and labor," said Marty. "For where we wanted to go, if you lack that sort of exemption, you're dead in the water. So, enacting that was an important first step that's helped supercharge our industry."

While tax credits and needle-moving incentives are key for growth, workforce readiness is paramount for business leaders as well — especially in the midst of an industry-wide strain on talent. Fortunately, Iowa's ecosystem of universities, apprenticeships and collegiate training programs aim to close this skills gap and ensure the state offers a deep pipeline of aerospace talent. CID itself is home to the Aviation Workforce Development Campus where students from Coe College and Kirkwood Community College train to meet the industry's ongoing need for pilots and maintenance personnel. Programs such as these also give seasoned professionals like Marty an opportunity to share their knowledge with up-and-coming aviation professionals — a nod to the spirit of collaboration and mentorship that's a consistent through-line among each of Iowa's key industries.

"There's a depth to this talent pipeline that I think is unmatched," said Marty. "The quality of Iowa's workforce speaks for itself, and legacy employers like Collins [Aerospace] and BAE [Systems] can tell you that firsthand."

Another important building block for any aerospace and defense cluster is shovel-ready land and room to scale, both of which Iowa has in spades. Through Iowa's very own Certified Sites program, developers were able to speed up selection of the 500-acre plot adjacent to CID as the future home of a SuperPark that will serve as the centerpiece of Iowa's revamped aerospace and defense cluster for generations to come.

"Through the SuperPark, we want to create real opportunities for legacy aerospace companies operating here to drive deeper roots into Iowa, while also making Iowa even more attractive for companies considering expansion," said Marty.

A legacy of excellence

The excitement for the forthcoming SuperPark and the cluster at large aside, Marty understands that it takes more than just talent, incentives and shovel-ready land to cement Iowa as a regional aerospace and defense hub: It requires a spirit of collaboration and support.

"There's been this willingness from the state and other partners to identify the challenges we have collectively and come together to solve them," said Marty. "That collaboration is part of what I think is going to help us really attract broad attention in the years ahead."

With the building blocks in place and SuperPark construction slated to begin in 2026, Marty and state leaders are excited for the possibilities and ready to shine an even bigger spotlight on all that Iowa has to offer.

"Iowa's legacy in aerospace is also a legacy of manufacturing, and our history in both is part of why Iowa sells itself," said Marty. "We have the sites, we have the incentives, we have the workforce, we have the innovation. Here, you're just a connection away from your next big thing."

Get a closer look at the present and future of Iowa's aerospace and defense industry during the 2026 Farnborough International Airshow (July 20-24) at booth #2428.

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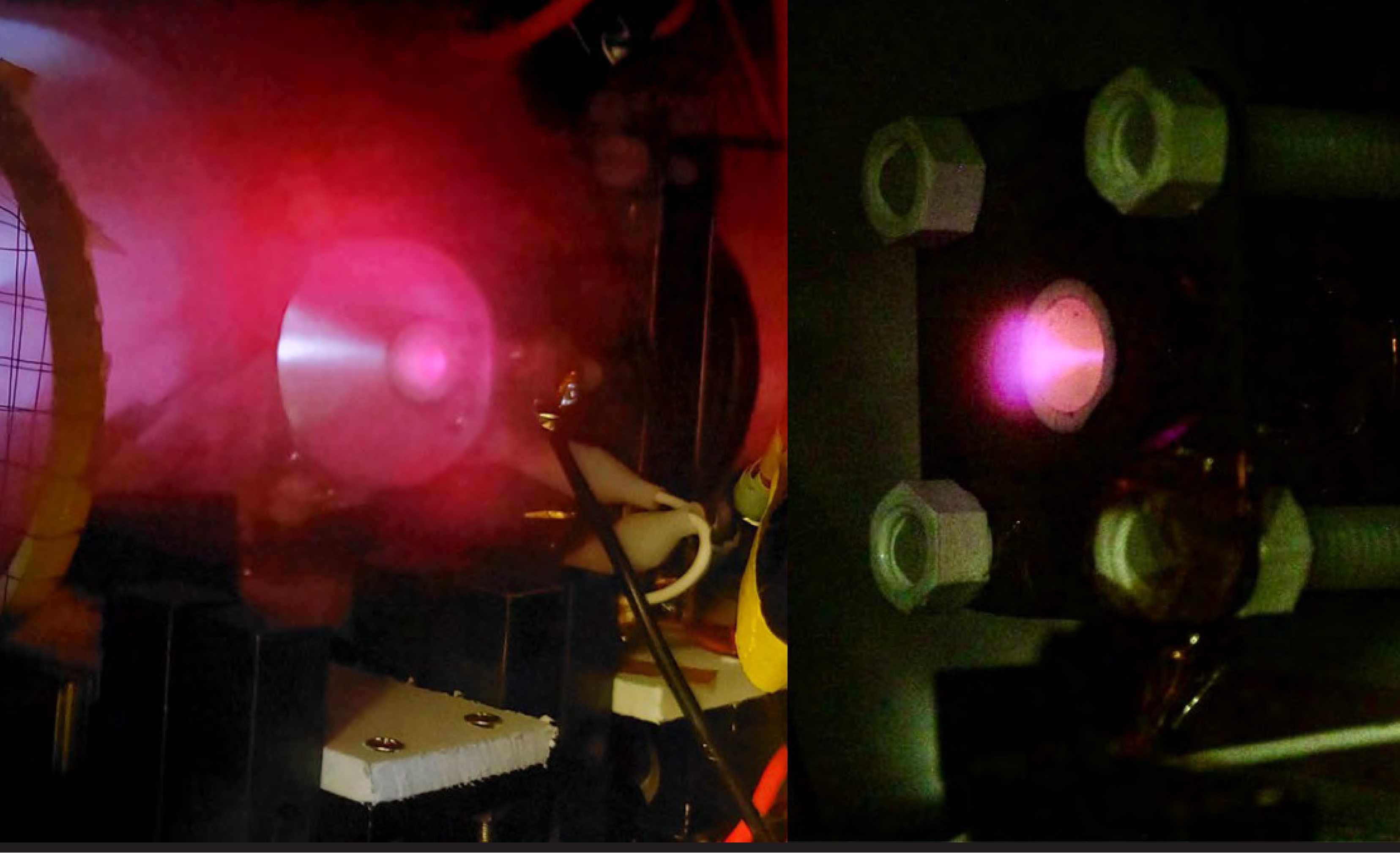


R&D

Spacecraft without gas tanks

Startup readies for plasma thruster tests

BY ASPEN PFLUGHOEFT | aspenp@aiaa.org

In the coming months, a cubesat is slated to arrive at the International Space Station equipped with a novel kind of thruster: Unlike today's liquid- or gas-propelled designs that require fuel tanks, it will rely on plasma.

This thruster is the work of JivaJet, a Washington, D.C., startup that stemmed from the doctoral research of former George Washington University students. For the ISS demo, the thruster will be tested at an altitude of 415 kilometers, but the company's long-term goal is for its plasma propulsion to enable satellites to operate for extended periods at altitudes below 200 km — dubbed very low-Earth orbit, or vLEO.

This orbital regime offers a range of potential benefits, including reduced communications delays and quicker revisit times, but also requires constant propulsion for spacecraft to overcome gravity's pull. With conventional liquid-based thrusters, the size, weight and power equation does not balance out, says Anmol Taploo, one of JivaJet's three founders and its chief technology officer. Satellites require a large fuel supply, which adds to overall weight, which increases the necessary thrust to stay in orbit, which requires more fuel in an ever-increasing loop.

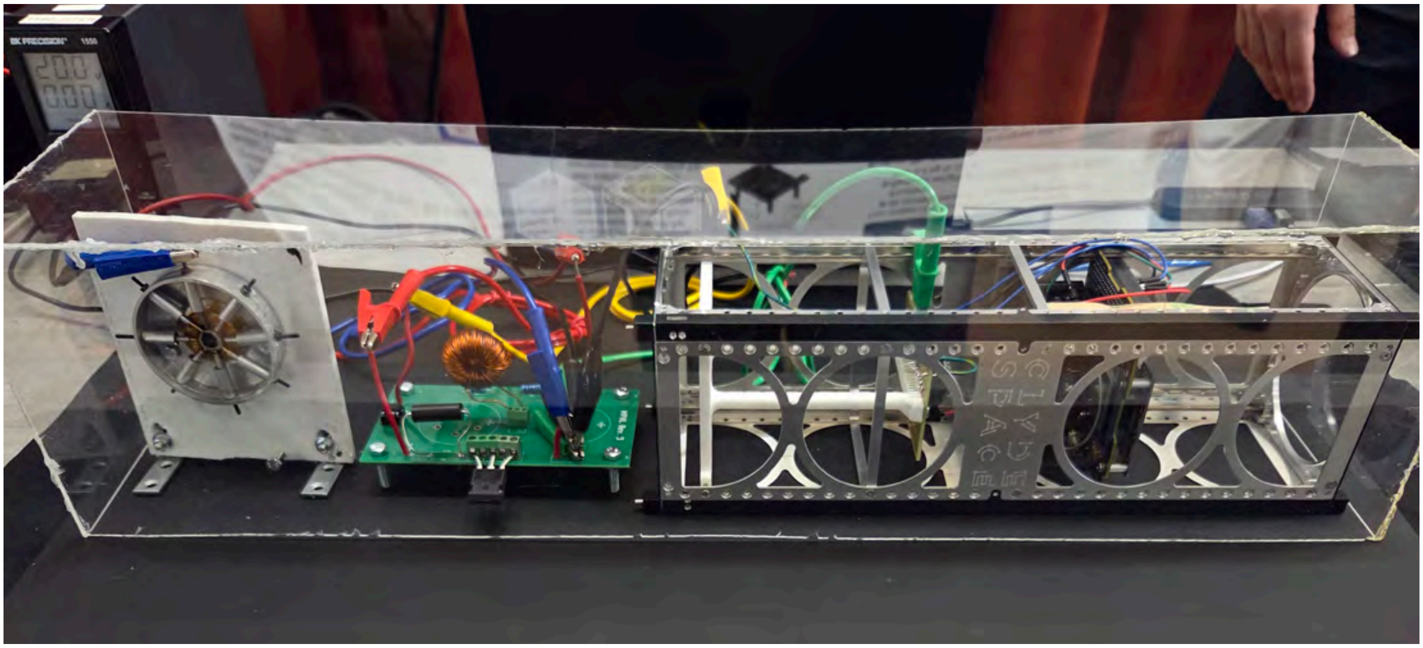
JivaJet's solution is to rely on air-breathing plasma propulsion and operate in the "sweet spot" of 80–110 km, as identified by simulations in GWU's electric propulsion laboratory under professor Michael Keidar, an adviser to JivaJet. At these altitudes, air does not need to be compressed or slowed to power a thruster but can directly feed into the system.

As a result, the thruster "actually takes hypersonic air and just slightly accelerates it," says Keidar.

"If we can manage all of the odds, then we can do miracles operating the thruster at the lower altitudes," says Guru Duppada, a GWU doctoral candidate researching plasma propulsion and a subcontractor to JivaJet.

▲ JivaJet's plasma thrusters undergo laboratory testing.

JivaJet



▲ A functional test article of JivaJet's thruster (far left) beside flight hardware for the cubesat slated to be launched to the International Space Station in the coming months.

Aspen Pflughoeft

The fourth state of matter

Plasma is a lesser-understood state of matter, occurring when another state — typically a gas — is ionized to a certain degree. Unlike solids, liquids and gases, plasma is not a resting state.

JivaJet is developing two variants of its thrusters: a metal-based one for satellites orbiting 200 km and above, and an air-breathing one for those operating between 80–150 km. Both use the same multi-stage hardware to create and accelerate plasma but differ in fuel source and operational dynamics.

The thruster's first stage resembles a thick disk, says Duppada, and either takes in passing air or relies on a built-in metal feeding system for fuel. The fuel enters and is hit with electricity, ionizing it and creating plasma. The plasma naturally begins moving through a funnel to the second stage, a self-extraction process aided by a magnet.

The second stage looks like a cone and has a series of electromagnets to accelerate the newly created plasma. These electromagnets operate in pulses with a higher charge than any magnets in the first stage, pulling the plasma forward at an increasing rate for added thrust.

The accelerated plasma exits the thruster and soon changes to a gas. The resulting plume automatically maintains a neutral electric charge, so the thruster has no charge neutralization component.

In this, JivaJet's designs differ from comparable ion propulsion systems, such as Hall thrusters, which require electron neutralization devices to keep positively charged exhaust plumes from forming. Those thrusters split the incoming fuel particles to ionize just positive ions. This makes the electrical charge of the exhaust plume positive, requiring electrons to be discharged nearby to return to a neutral charge. JivaJet's thrusters instead ionize full particles, resulting in neutrally charged plasma and plasma plumes.

The air-breathing variant also relies on a "natural phenomenon" to maintain a neutral charge, says Taploo. In his doctoral research, he discovered that below 100 km, "whatever is happening inside the [ion] engine also starts happening outside." This leads to an "ion cloud" forming in the air around the engine, attracting electrons toward it and self-neutralizing.

Proving it on orbit

For the ISS demo, JivaJet is sponsoring a GWU student team participating in NASA's CubeSat Launch Initiative to build a satellite with its metal-based plasma thrusters. The three-unit cubesat is slated to launch aboard a Northrop Grumman Cygnus no earlier than "Fall/Winter," NASA told me.

Once aboard the station, the cubesat will be deployed and spend six months testing the thrusters at 415 km before deorbiting. Because this orbit will not have as much atmospheric drag as vLEO, the primary goal "is to test the tumbling and satellite rotation," as well as "the thrust it's producing and also any wobbling," says Sarah Levine, the team member assembling the thrusters.

In preparation, she is working with Duppada to extend the system's run time by adjusting how the metal fuel feeds into the thruster.

If this demo goes well, "it just opens the door for this new kind of innovation," says Marc-Andre Berthin, another team member. "Looking back, I'd be very proud if we did something that is kind of like the first step."

Building on the ISS mission, JivaJet is targeting 2027 for the first on-orbit test of the air-breathing thrusters. For this test, a custom-designed satellite will be deployed to 80–150 km for similar maneuvering experiments.

If successful, "we'll be the first in the world to do that," says Taploo. ★

The future of defense innovation

For more than 20 years, Arun Seraphin worked in Congress and at the White House, focusing on how changing legal processes and structures can help national security efforts better leverage science and technology. Now, as director of the National Defense Industrial Association's Emerging Technologies Institute, he spends his time assessing how artificial intelligence will affect the defense sector, facilitating conversations among the increasingly diverse actors of the sector and evaluating whether today's research investments will be sufficient to meet tomorrow's challenges. NDIA's membership comprises 1,700 defense and national security companies, as well as 66,500 individuals.

"NDIA brings together government, industry, small businesses, academia and new commercial companies and tries to discuss how to improve partnerships between the public and private sector to deliver the best product for national defense," he told me in an April interview. "Our mission is the same thing as applied to emerging technologies."

Our conversation about the state of the defense innovation ecosystem has been condensed and lightly edited for space and clarity. — *Aspen Pflughoeft*

ARUN SERAPHIN, DIRECTOR OF NDIA'S EMERGING TECHNOLOGIES INSTITUTE

KEY POSITIONS:
- Since 2023, director of NDIA's Emerging Technologies Institute.
- 2014–2022, a professional staff member on the Senate Armed Services Committee for Sen. Jack Reed (D-R.I.).
- 2010–2014, held several assistant director positions within the White House Office of Science and Technology Policy and was special assistant for policy initiatives with DARPA.
- 2001–2010, a professional staff member on the Senate Armed Services Committee for Sen. Carl Levin (D-Mich.).
- 1996–2001, a research staff member at the Institute for Defense Analyses.

NOTABLES:
- Beginning in the late 1990s, helped create and expand the legal authority for the government to offer prizes in technology competitions, a mainstay in today's innovation ecosystem.
- Helped expand the use of Other Transaction Authority, an acquisition approach meant to simplify the process. Also helped establish Commercial Solutions Openings as a way for the government to solicit ideas from industry, a key tool for responding to the COVID-19 pandemic.
- Wrote a number of authorities aimed at improving the way the federal science workforce is hired, paid and retained.

RESIDES: Centreville, Virginia

AGE: 56

EDUCATION: Bachelor's degree in engineering science and American government, Stony Brook University, 1991; Ph.D. in electronic materials and nanotechnology, MIT, 1996.

Q: What drives ETI's research, and how do you determine what to focus on?

A: Some of it is signals that we get from our membership. We also get signals from the Pentagon, like when the Pentagon told us they'd love for us to start figuring out how to bridge what they're doing and what venture capital and private equity want to do. We're the perfect place to do that.

The Pentagon did not issue a formal request to ETI; Seraphin said he was referring to "informal feedback and themes" coming from the department. — AP

Sometimes we get signals from the Hill, when they say, 'We'd love for someone to think about a particular issue.' ETI can start to put together events or papers on that. The signals come from all over and, truthfully, from ourselves as well.

Q: What are your current focus areas?

A: The use of advanced software, artificial intelligence and digital engineering to improve the way the Defense Department buys is one big focus area. Another focus area right now is that question of how private capital is influencing the shape of the defense sector and how the Pentagon should best position itself in a world of billions of dollars of private capital. We've got another set of research going on trying to track how basic research investments of the past are now manifested in operational capabilities. We're kind of uniquely positioned to draw the line between the academic research and the defense contractor that's creating and selling those systems to the Pentagon.

Q: You have a long background working in the Senate and the White House. How does watching what comes out of Capitol Hill and the White House influence ETI and your work?

A: You have to get signals for a couple of things. One is, what are their priority areas? The Pentagon, for example, has listed six areas that they feel are the highest priority for their research and engineering portfolios.

That list comprises applied artificial intelligence, biomanufacturing, contested logistics technologies, quantum and battlefield information dominance, scaled hypersonics and scaled directed energy. — AP

When they signal something like that, the industry and academic world is going to vector toward them, and then that's going to drive what we think is useful to stimulate a conversation between those two groups.

Another thing is the messaging they want. For example, speeding up acquisition. That's a signal coming from both them and our industry members, and so we can contribute to that through our work.

Q: Are there ways you think Congress or the White House could better support industry research?

A: I think both Congress and the White House, working with the Pentagon, can do more to send out market signals as to what they're going to buy because then that helps drive where industry needs to position itself and where [the] private sector should be making investments.

Another end of the spectrum is that we have to get from the Congress and the White House and the Pentagon strong and stable funding for the research community. Making sure that those funding levels are adequate for the number of good ideas that we want generated to create the capabilities of the future and adequate to maintain that important part of our industrial base, which is that innovation base that resides at government laboratories and research universities. That's an important part of the

> "My attitude would be: The government should try to send the right signals to attract as much private capital as it can, but when those private sector market failures occur, it's the government's duty to step in and make those investments."

industrial base that we can't forget. Of course, things like passing appropriations bills and keeping the government open always help.

Q: What's the right balance of private investment and public investment? And how has that balance shifted over time?

A: I think everybody understands that, on the development of technology side, the balance has swung far over from government to the private sector, and that's pretty healthy and good. On the other hand, on the basic research side, the balance is going to forever be on the government. A private-sector-style of expectation of return and a private-sector-style of risk tolerance is never going to let them invest in the people, in the long-term research and in the infrastructure required to have that science base needed for military development and procurement. You're going to have to see the government investing in those kinds of systems that have no commercial alternative, like hypersonic weapons or tactical vehicles for combat. A bunch of other things, or even subsystems for those larger systems, could be over on the commercial side.

My attitude would be: The government should try to send the right signals to attract as much private capital as it can, but when those private sector market failures occur, it's the government's duty to step in and make those investments.

Q: What emerging technologies do you think will be most impactful for defense within the next decade?

A: No. 1 is easy: artificial intelligence. It's going to be the way that the Department of Defense sorts through tactical data and makes decisions on the battlefield. It's going to be the way it runs its back office. It's going to be the way it does everything.

The other thing that will drive everything is biotechnology, whether we're talking about the food side of it or whether we're talking about the chemical and biological defense world that the military has traditionally been in, whether we're talking about the medical side or even the new areas like using biomaterials for structural things, like building runways or for information processing.

I'll just pick one more: additive manufacturing. The spread of parts which can be built using additive manufacturing methodologies of all different types is reshaping the way we build our military, we repair our military, we resupply our military.

Q: Let's talk AI more specifically. What do you think the impact will be on defense technology?

A: There is a possibility that AI can create situations where you're able to project power using autonomous systems that can learn in ways we've never imagined before. The ability to create deterrence through the use of unmanned systems or automated systems, the ability to process threat information so quickly and be able to deter adversaries as a result is going to be a huge change.

At the same time, AI could create all kinds of new threats because of its ability to process information. Those threats can be in the physical world or on the virtual side. Think AI-based cyberattacks against AI-based cyber defenses.

This ability to sift through data and learn and then control things at incredible speed will absolutely change the shape of warfare in the future, which then all leads to the issue of regulation. This is yet another technology that is evolving really fast, but the regulatory regime surrounding it is not evolving very fast.

▲ The U.S. Army and Navy conducted a joint test of a long-range hypersonic missile in March. Scaled hypersonics is one of the six "critical technology areas" the Pentagon unveiled in late 2025.

U.S. Defense Department

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Q: Do you see any potential risks in embracing AI in this realm? And if so, what safeguards are needed to address those risks?

A: AI could create the ultimate autonomous systems, and any time you take people out of the loop in combat military situations, it creates concern. The idea would be to put together the right groups of people, hopefully internationally, that can address: What are the potential uses of AI in these military kinds of situations? And what are we comfortable with and not comfortable with?

That kind of discussion needs to be a four-sided table. You need a person who knows how to write treaties and regulations and laws — a lawyer type. You need an actual user of the technology; in this context, it's the military user. You also need somebody who would build and sell the AI capability — that business viewpoint with a sense of what the markets are and what the regulatory environment has to be in order to keep those businesses alive. Then the last side of the table is someone who actually knows how the technology works. That often is missing in these conversations, that person with the technical knowledge who can balance what the policy maker or the user who just wants it or the guy who just wants to sell it is saying.

We've lived in this world in previous technology areas. For example, landmines are a form of primitive autonomy used on the battlefield that have some regulatory structure around it. There are models for how we develop that regulatory structure, and maybe those could be used again.

Q: What do you think are the current weak points or challenges for the Pentagon's innovation ecosystem?

A: Right now, the Pentagon is doing a really good job in trying to embrace the ability for technology to move rapidly and change the way our forces can fight, and they're doing a really good job in adjusting their buying and management practices to keep up with the speed of technology. There's really healthy outreach to a larger set of the industrial base.

My concerns are: first, the [White House] budget request that we just saw. I don't think it prioritizes science and technology investment as much as it should in order to drive all the innovation that we seek to keep up with our peer adversaries and to just keep up with technology. We need to think about a healthier investment in basic research and applied research.

Second, I worry about are we investing in research infrastructure and people — whether they're inside the government or in the university community — enough. Our innovation system has been built off of these universities and government labs, and we can't forget about them as we're investing in the future.

Q: Given your experience on Capitol Hill, what are you watching in the fiscal year 2027 defense budget request?

A: I'm watching that issue of science and technology spending. I'm also interested to see whether the appropriations committees will go along with what the Pentagon is requesting and completely endorse it — which has never happened, so I doubt that will happen. Then, if they make adjustments, what are they going to adjust to? What I'll be watching, basically, [is] are the appropriators going to play a big role in reshaping this request and strengthening the science, technology, emerging technology pipeline that leads to the good and necessary procurement of these technologies? ★

ENGINEERING NOTEBOOK

DODGING DEAD ZONES

▲ During a 2024 demonstration at Hickam Air Force Base in Hawaii, engineers used radios equipped with Saltenna's plasmonic antennas to communicate from inside a C-17 Globemaster (above) with personnel out on the tarmac.

U.S. Air Force photo/
Tech. Sgt. Shane A. Cuomo

The U.S. Air Force has awarded millions to a Virginia startup to develop a means of communicating through dense jungles, fortified bases and other environments where radio-based communications are inaccessible. Keith Button explores the concept and the testing ahead.

BY KEITH BUTTON | buttonkeith@gmail.com

If you've ever lost your cell phone signal in an elevator or while driving through a tunnel, you're familiar with the problems Igor Smolyaninov and his Virginia startup are trying to solve.

The physicist and his team of engineers are developing wireless communication devices for the U.S. Air Force to reach where typical handheld radios can't, such as radio-signal dead zones in and around hangars; bunkers and tunnels on air bases; and in areas of dense foliage. The devices transmit via plasmons: electromagnetic waves that can travel along and through metal or concrete structures, bodies of water, the ground and even forest canopies.

"We don't want to replace anybody's radios. We just want to augment the conventional radios and antennas with this, so that it makes communication more resilient and reliable," says Smolyaninov, who co-founded the company, Saltenna, with investor Dendy Young in 2017.

Saltenna has received $3.4 million under two separate Air Force projects to develop radio antennas and hockey-puck-like devices for two slightly different scenarios. The company's Plasmonix Pucks project is aimed at extending ground-to-ground radio communications in challenging areas for traditional radio signals, like dense jungles or steep valleys. Under the second project, Plasmonix SignalStorm, Saltenna is developing antennas for handheld tactical radios to allow communications into and through radio-obstructed buildings and other structures on air bases.

Plasmonic potential

Saltenna introduced its plasmonic technology to Air Force officials during a 2024 demonstration with a parked C-17 cargo plane at Hickam Air Force Base in Hawaii. With

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.

▲ Saltenna utilizes commercial off-the-shelf radios for some demonstrations of its antennas, housed inside tubes in this photo. Saltenna

Inside the contracts

Saltenna has a combined $3.4 million in Air Force research and development contracts to develop its surface wave communications technology. They include:

- $2 million for the Plasmonix Pucks project, which wraps up in July 2027.
- $1.25 million for the Plasmonix SignalStorm air base communications project, which ends June 2027, and related preliminary research that concluded last year.

In addition to the Air Force funding, Saltenna has received:

- $1.3 million in R&D funding from the U.S. Defense Threat Reduction Agency for developing underground communication devices for missions to counter weapons of mass destruction.
- $140,000 from the U.S. Navy for preliminary research into plasmonic Wi-Fi aboard aircraft carriers.

conventional handheld tactical radios, a pilot inside the airplane tried to communicate with Saltenna executives on the tarmac, who were playing the roles of ground crew. The ground crew during normal operations would communicate with the cockpit via a cable plugged into their headsets and the fuselage.

The conventional radios didn't work, says Ashley Johnston, Saltenna's chief operating officer, because the metal skin of the aircraft acted as a Faraday cage, an enclosure typically made of metal designed to block radio waves.

Then they switched out the radios' antennas for Saltenna's plasmonic antennas — and the radios worked.

"We had Air Force people out there watching us going: 'How did you do that, please?'" he says. "Our ability to sit inside a C-17A and communicate clearly to not only just to the outside, to some distance from the aircraft, was eye-opening to the folks that saw us demonstrate that."

Saltenna showed the radios with the plasmonic antennas could communicate through the skin of the aircraft, past two other aircraft on the tarmac and through a metal warehouse and to the other side, Johnston says. "Our only limitation in that example was the fact that we ran into the edge of the airfield and couldn't go any further."

Because the surface waves utilized for plasmonic communication can transmit at higher frequencies than radio waves, they have the potential to carry more information than even cell phone frequencies, says Anatoly Zayats, a physics professor and plasmonic researcher at King's College London who is not associated with Saltenna.

"The higher frequency, the more information you can encode," he says.

As for the potential limitations, the distance a surface wave's signal will carry depends on the type of surface, Zayats notes. Surfaces with greater electric conductivity, such as materials containing conductive metals or water, will perform better. "Depending on how many electrons there are in the material — the more electrons, the easier it will be to communicate," he says. For instance, a hard metal pipe surface will have less signal loss than a jungle canopy surface of leaves and branches: "With lower losses, you can communicate over longer distances."

The testing ahead

For both the Plasmonix Pucks and Plasmonix SignalStorm projects, the goal is to demonstrate how the technology works under a list of scenarios requested by the Air Force, Johnston says. These include tests in dense jungle scenarios, conducted earlier this year in Puerto Rico, and tests slated for later this year at an Air Force base or bases yet to be determined.

For those, the aim is to demonstrate the ability of the pucks and antennas to communicate through structural obstructions. For both scenarios, Saltenna engineers carry tactical radios equipped with plasmonic antennas and evaluate how well they can communicate with other radios with the antennas or via the pucks.

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The pucks are designed to serve like Wi-Fi extenders for radio communication in environments where tactical radio signals don't travel far or don't work at all, Johnston says, such as the ground in a dense forest where vegetation absorbs radio signals in the air.

On a jungle island, for example, "rather than sticking up great big antennas all over the island and making yourself known to people you don't want to be made known to, you have these little pucks around the place, or you just have radios with our antennas where you don't need to put up big radio masts."

Radios with plasmonic antennas can use the vegetation to propagate the signal. "It uses the leaves and the foliage as the transmission medium." Johnston says.

For plasmonic antenna transmissions through air base structures, the goal is to avoid needing to place a large number of expensive, networked ground antennas around a facility to make sure everyone can get a signal with no dead zones, he says.

"They have hangers that are made of steel; they're basic Faraday cages. They want a way to make sure that their tactical radios function no matter where people are," he says.

The air base tests will be similar to the 2024 Hickam demonstration — but more difficult, Johnston says. For some of the planned scenarios, the Air Force will be looking for certain percentage gains in signal resiliency or signal distance over previous benchmarks.

The Air Force declined to make its managers for the Saltenna projects available for comment, and Saltenna declined to provide further details about testing and development for the projects.

But for the dense vegetation and air base scenarios, the general engineering goals are similar: Develop prototypes that are more compact, can transmit farther with less power, and can be tuned quicker, Johnston says.

"How do we squeeze another milliwatt of power out of this antenna and make it go this much further? This is the sort of thing we spend a lot of time doing," he says.

The engineers are also learning about how certain frequencies of plasmonic waves work better with certain surfaces, Johnston says. Instead of using third-party electronics, they want to build their own software-defined radio. In the future, that may include software that constantly retunes the plasmonics, similar to how current home Wi-Fi systems constantly search the spectrum to identify the best channel.

Saltenna is also developing and considering applications of its plasmonic technology for other environments. Within a few months, it plans to begin marketing devices for divers to communicate with one another while underwater.

Engineers and founder Smolyaninov have also considered plasmonic communication concepts for the surface of the moon and spacecraft reentering Earth's atmosphere, but so far have not developed those.

On the moon, where the absence of an ionosphere makes beyond-the-horizon radio communication difficult, plasmonic communication could be possible if the lunar soil is conductive enough, says Zayats of King College.

"It'll work," Johnston says. "But could I write you a quick spec sheet, 'what will work on the lunar surface'? Don't hold me to that, please."

The reentry scenario looks similarly promising, Zayats says. Today, mission controllers lose contact with reentering spacecraft for several minutes because plasma buildup on the vehicle's exterior blocks conventional radio signals. The challenge for plasmonic communications, he predicts, would be converting the signal at the edge of the plasma to a radio or optical signal to reach the ground, but it could probably be done.

Smolyaninov agrees. "We haven't done it yet, but it's a clear technical possibility," he says. "Any time you are inside a conductive kind of enclosure, it can be a space vehicle or whatever, whenever you see metal everywhere around, it will help you." ★

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ENGINEERING NOTEBOOK

Shape-shifting aircraft wings

The German Aerospace Center in April concluded the first phase of its effort to develop an aircraft wing with a morphing trailing edge. Designers believe the concept shows promise for increased control-surface fault tolerance and enhanced drag reduction capabilities. Paul Marks spoke to the project leader about the lessons learned so far and the work ahead.

BY PAUL MARKS | paulmarksnews@protonmail.com

To most of us, the word "airplane" conjures a very specific mental picture: a rigid tube-and-wing airframe peppered with familiar components like ailerons, flaps and elevators, whose roles in flight are pretty much set in stone. But talk to Martin Radestock, a senior adaptive systems engineer at the German Aerospace Center (DLR), and you may come away with a different view.

Radestock and his colleagues in DLR's Institute of Lightweight Systems in Braunschweig, Lower Saxony, believe aircraft could be capable of adopting far more fluid and adaptive structures, ones in which the shape of flight control surfaces can morph into smoother profiles that reduce drag and increase fuel efficiency. Ultimately, Radestock envisions a future in which aircraft fuselage surfaces are capable of morphing too, he told me in a May video call.

All these ideas stem from a DLR project called Morphing Technologies and Artificial Intelligence Research — morphAIR for short. Under this €1 million ($1.16 million) initiative, engineers fitted a 70-kilogram drone with a morphing trailing edge that spans the full length of its 3-meter wings. That drone, called Proteus, in April finished a series of seven remotely piloted flight tests at DLR's National Experimental Test Center for Unmanned Aircraft Systems in Cochstedt, Saxony-Anhalt.

Based on those initial flights, Radestock and colleagues believe the concept shows promise for a range of novel capabilities, such as combining and replacing some of today's aircraft control surfaces. For instance, because the morphable trailing edge spans the full length of the wing, an inboard section of the edge can provide a flap function, and an outboard section the aileron. And by ganging the flap and aileron together into an adaptive elevator of sorts, this morphing wing could take on major tailplane functions like elevator pitch control, allowing the tailplane and tailfin structures of drones and light aircraft to be shrunk — reducing drag. Also, that smaller tail could have a morphing rudder, says Radestock.

The shape of wings to come

Underlying this morphing technology are some innovations by DLR at the wing level — harnessing novel, flexible, actuated materials —and in the computerized control of the morphing profile.

Engineers created a reinforcement learning algorithm to operate the trailing edge's shape-shifting motorized actuators in an efficient way for a given flight, says Radestock. Both the morphing surface and AI-based control algorithm were completed between 2022 to 2025, with the April flight tests marking the official conclusion of morphAIR.

Now, DLR's three-person morphing team is moving into a two-year follow-up phase, UAdapt, short for Unmanned Aircraft Wing Adaption. They will investigate how the morphing trailing edge "can transfer some functionalities of the tail's horizontal and vertical stabilizer, like the rudder or elevator, to the wing to make the tail structure smaller, to reduce the drag and fuel consumption of the overall aircraft," says Radestock.

But why morph the wing in the first place? "Currently, aircraft are flying with turbulent flow over their wings, because they have steps and gaps between their control surfaces," says Radestock.

By "steps," he means areas where an aileron or flap, for instance, is not perfectly flush with the wing, leaving gaps behind and between these hinged surfaces and the wing.

"They also have screws on top of the slats and the flaps, and with these generous steps and gaps, normal airflow produces turbulence," he says — and with it, increased fuel burn.

By contrast, a surface that smoothly changes shape while leaving no gaps or steps, no screws or rivets interfering with the airflow, could reduce wing friction by 95%, Radestock estimates. "So morphing aircraft aim to fly with natural laminar flow that's completely attached to the wing and not creating any turbulence.

It's not a new concept. In 2015, FlexSys of Michigan

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In 2015 trials for NASA and the U.S. Air Force Research Laboratory, FlexSys flew this modified Gulfstream II with a morphing flap that spanned the middle portion of one of the wings.

NASA/Jim Ross

flew a Grumman Gulfstream II business jet fitted with morphing flaps for NASA and the U.S. Air Force Research Laboratory. Since then, FlexSys has been supplying retrofit and other morphing structures in applications such as defense and drones, CEO Sridhar Kota told me by email. He gave an update on the company's progress in February on an Emerging Technologies Institute podcast.

In the FlexSys tests, the flap spanned only a portion of the wing, Radestock notes, so he and his colleagues wondered what advantages could be gained from having an entirely morphable trailing edge.

"What we wanted to try was not to have a single flap, but have multiple flaps at certain stations on the wing that can smoothly transition on that continuously variable, gapless surface," he says.

This is what they set out to flight test on a drone, specifically looking for one with wing loading strong enough to make their results applicable to future morphing research on general aviation light aircraft like a Cessna 172 or Beechcraft G58. They bought a 3-m-long radio-controlled sports jet from Tomahawk Aviation, called a Futura Jet 2, and built two sets of wings: one a conventional two-flap-and-one-aileron per wing version, using carbon-fiber reinforced plastic; the other with the morphing trailing edges.

The conventional wing contains just three rotary actuators — motorized aluminum rods that raise and lower the two flaps and the aileron — but the morphing version contains 10 identical actuators across each wing, spaced 15 centimeters apart. The morphing trailing edge's flexible skin is made from glass-fiber reinforced plastic because it's "slightly more flexible than carbon fiber," says Radestock.

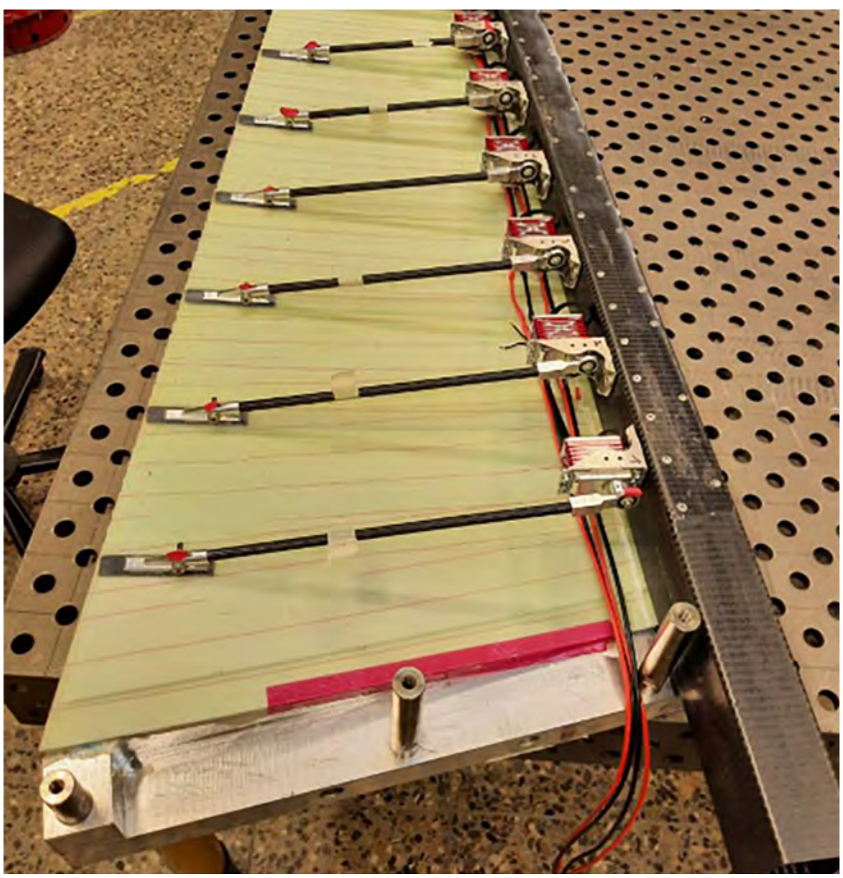
The surface is also corrugated, to allow it to stretch if a situation demands it — perhaps when an aileron section abuts a length used as a flap, for instance.

▲ The above schematic denotes other aircraft components the DLR team thinks could one day be replaced with morphing elements.

DLR

The Proteus drone reached top speeds of 300 kilometers per hour during initial trials of DLR's shape-shifting wing.

DLR



▲ To create their morphing wing, DLR researchers distributed 10 actuators (above) equally along the span of the wing to modify the shape of a composite trailing edge skin. DLR/Martin Radestock

The key here, says Radestock, is how the top and bottom corrugated skins are bonded: "Our inventive step is to join the glass fiber skin shells with a hyperelastic polyurethane adhesive," he says.

Altogether, the stretchier, corrugated material, held together by hyperelastic glue, allows the morphing surface its high degree of flexibility — rippling in a sine pattern almost like the pectoral fins of a swimming stingray.

AI for flight control

The wing design is just one piece of the equation. For the concept to work in flight, commands from the safety pilot's remote control station must produce the right motions from the 10 actuators inside each morphing wing. So DLR turned to AI in general, and reinforcement learning in particular, to train the drone's flight control system.

"What we are not doing is saying: 'OK, AI, here are all the actuators, learn to fly this.' That would be brutal," says Radestock. "What we are doing is getting the AI to tune the parameters controlling the actuators, to decide what are the best actuator deflections for a rolling motion, say."

The engineers are training the algorithm on a simulation model of the wing and actuators, but as more and more flight tests are completed, they plan to incorporate real-world data, Radestock adds.

The flight tests, limited to 20 minutes by Proteus' 12-liter fuel capacity, were all conducted in visual line of sight of the safety pilots, but DLR has a beyond visual line of sight station for more ambitious sorties later.

Safety pilots already report the morphing trailing edge is providing "quite interesting handling characteristics," says Radestock, with roll agility boosted by some 50%.

To Kota, the FlexSys CEO, the project amounts to an "an exciting research demonstrator."

"As with any technology at this stage, real challenges lie ahead," Kota told me by email, "including the material's long-term durability, system complexity from distributed actuation, sustaining greater wing loads, and the certification pathway for learning-based flight controls."

He added: "I'm looking forward to seeing how these challenges get addressed, especially as they move toward larger scales."

So is Radestock — not least because he wants to see shape-shifting technologies adopted more widely on planes of all sizes, but also on more parts of the airplanes than their wings and tail structures.

"My big hope is that morphing technologies get more and more integrated into aircraft, perhaps beyond the flight surfaces, as the fuselage itself could also benefit," he says. "Antennas cause turbulence, for instance, so perhaps a morphing surface could move them outside only when they're needed." ★

THE BIG QUESTION

Should the ISS be extended beyond 2030?

When assembly of the International Space Station began in 1998, NASA planned to operate the orbiting laboratory for 15 years. While the station has exceeded those targets — last year reaching 25 years of continuous human presence — its retirement is now looming. NASA has contracted SpaceX to build a deorbit vehicle to steer ISS into the atmosphere in early 2031, maneuvering so that any surviving parts fall into a remote part of the Pacific Ocean known as Point Nemo.

NASA's rationale is the increased cost and risk associated with operating a nearly 30-year-old platform, but not everyone agrees a controlled deorbit is the best course. And although the handful of companies developing commercial successors have expressed confidence their stations will be operating by 2030, NASA and U.S. lawmakers are also concerned about the possibility of a gap in U.S. presence in low-Earth orbit.

The House Science Committee in February passed a NASA reauthorization bill that directs the agency to submit a report on "potential options and associated costs" for preventing such a gap, including "Supporting the operation of the ISS beyond 2030." The Senate Commerce Committee's version that passed in March contains a provision extending ISS to 2032. The two bills were in conference as of press time in mid-June.

I asked lawmakers, researchers and a former astronaut whether ISS operations should be extended. NASA declined to provide a response, citing the pending legislation. — *Paul Brinkmann*

U.S. Rep. Brian Babin (R-Tex.)

Chairman of the House Committee on Science, Space, and Technology.

YES NO **MAYBE**

If extending the station becomes necessary to avoid a gap in low-Earth orbit, that's something we should be prepared to evaluate while ensuring continuity of U.S. leadership and fostering a competitive commercial sector.

We need to be realistic about the timeline for commercial replacements. Although the NASA Reauthorization Act includes a provision to study this issue, as Administrator [Jared] Isaacman has emphasized, this transition has to be managed carefully.

In the near term, the ISS can operate with or without Russia, but those are very different scenarios. With Russia, operations remain stable given its role in propulsion; while going it alone would require additional capabilities and introduce more risk. The real question is whether extending the ISS is the right move as we transition to a strong, U.S.-led commercial presence in low-Earth orbit.

Commercial space stations are making progress, but the timeline remains uncertain. While the ISS is showing signs of aging, engineering studies conducted by NASA and its contractors indicate it could be safely extended if necessary.

[A 2024 report from NASA's Office of Inspector General noted the agency is "is well-positioned to continue operations and maintenance of the ISS through 2030. However, as NASA pushes the retirement of the ISS farther into the future, a variety of long-standing challenges will continue to intensify. These challenges include maintaining and upgrading the Station; monitoring the structural integrity" and managing procurement contracts. — PB]

Any effort to extend the ISS must also take into consideration the private sector, which will invest in its replacement. We don't want to send the wrong signal that there is no near-term demand, because there is.

"Any effort to extend the ISS must also take into consideration the private sector, which will invest in its replacement."

An illustration of the U.S. Deorbit Vehicle docked to the ISS. NASA in 2024 awarded SpaceX an $843 million contract to develop this spacecraft to steer the station into the atmosphere.

SpaceX

"There's a lot of reasons we've had a continuous human presence in space for 26 years now. If the replacements aren't ready in time, you would lose that continuity and that access to space."

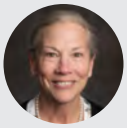
▶ For NASA's Twins Study, researchers tracked the various changes in astronaut Scott Kelly (right) over the course of his 340-day ISS mission that concluded in March 2016. His results were compared to those of his identical twin, astronaut Mark Kelly, who remained on Earth.

NASA

Susan Bailey

Professor and radiation cancer biologist at Colorado State University. Lead investigator of NASA's Twins Study, which determined that human telomeres lengthen over time spent in space, among other findings.

● YES ○ NO ○ MAYBE



I was so surprised that NASA would propose just letting the ISS deorbit into the ocean. I really don't think that's a good idea.

There's a lot of reasons we've had a continuous human presence in space for 26 years now. If the replacements aren't ready in time, you would lose that continuity and that access to space.

The fact that we are not going to build the lunar Gateway now might actually add to this argument that we still need the space station, whether we have people on it or not. It could be a supply place. It could be an emergency backup or stopover. I just think that, surely, there is something we can do with it, until we're really certain that we are established on the moon. Maybe then we don't need it anymore, but I think even then it could have value. We can't study the same kind of microgravity on the moon because it has its own gravity, of course.

It's going to be a long time until they're set up to do research on the moon. It will be a major thing just to get a structure or habitat, some kind of radiation protection. A lot has to happen before any kind of research can occur on the moon.

But the issue is a lot bigger than that. The approaching decommission date has already affected some of the studies. They've already cut short a study I'm currently involved in, CIPHER, because they have to finish these things up. There's this line in the sand now, and we have to start wrapping up research — prematurely in some cases.

[Short for Complimentary Integrated Program for Human Exploration Research, the CIPHER project since 2023 has tracked how the orbital environment affects astronauts' bodies over time. — PB]

The experiments involve this chronic exposure to the space environment, this unique combination of stressors, including microgravity and low-dose space radiation, which we cannot satisfactorily simulate on Earth — the chronic exposure especially. ISS is really our only option, the only place we can do that type of study. We were planning to study about 30 astronauts in space, but we will have to wrap up the work with seven instead.

In terms of planning for research in orbit, it's a very long, tedious process to get projects approved for ISS, especially with astronauts, and to go through all the process of getting them ready for flight. Then to actually do the experiment, get the data returned and do the post-flight evaluations — you can't just restart something like that overnight.

Tom Jones

Retired NASA astronaut who completed four space shuttle missions, including the 2001 one that installed the Destiny laboratory to the ISS.

YES ● **NO** ○ **MAYBE** ○

Having slept aboard the space station in 2001 as we installed the Destiny science module, I am familiar enough with it to say I'm comfortable with extending the ISS past 2030 from an engineering standpoint. Most of the structures up there get inspected regularly. And of course, the engineers on the ground are analyzing stresses on the vehicle, and they're looking for signs of degradation.

The only concern is in the Russian Zvezda module, where there are these cracks that have been causing a slow leak.

[The rate of the leak, first reported in 2019, increased in early June, and NASA directed five crewmembers to take shelter in the Dragon spacecraft docked to the station while cosmonauts attempted repairs. That work was paused shortly after, and NASA rescinded the safe haven order. — PB]

We can and do close the hatch between the U.S. and Russian segments to prevent catastrophic decompression should that occur. It's just a precaution, and the Russians don't think that's necessary, but we've agreed to disagree so that's a workaround.

If the Russians cannot support their segment of the station as it is today and they can't keep the risks controlled, that's when you say, "Let's decommission." Personally, I would like to see ISS preserved by moving it to a much higher orbit, where it could stay until we figure out how to recycle the aluminum alloys that make up most of the structure in space.

NASA needs to make a decision now on which partner to go with for a private station and stick with that, to ensure we get something up there before we have to decommission ISS — even if it's just a small one-room laboratory with sleeping space for extended missions.

I understand the desire to end ISS and eliminate any risk associated with it, but ultimately the optics of dumping the ISS into the ocean with more than $80 billion of taxpayer money going into the South Pacific really strikes me as a bad choice.

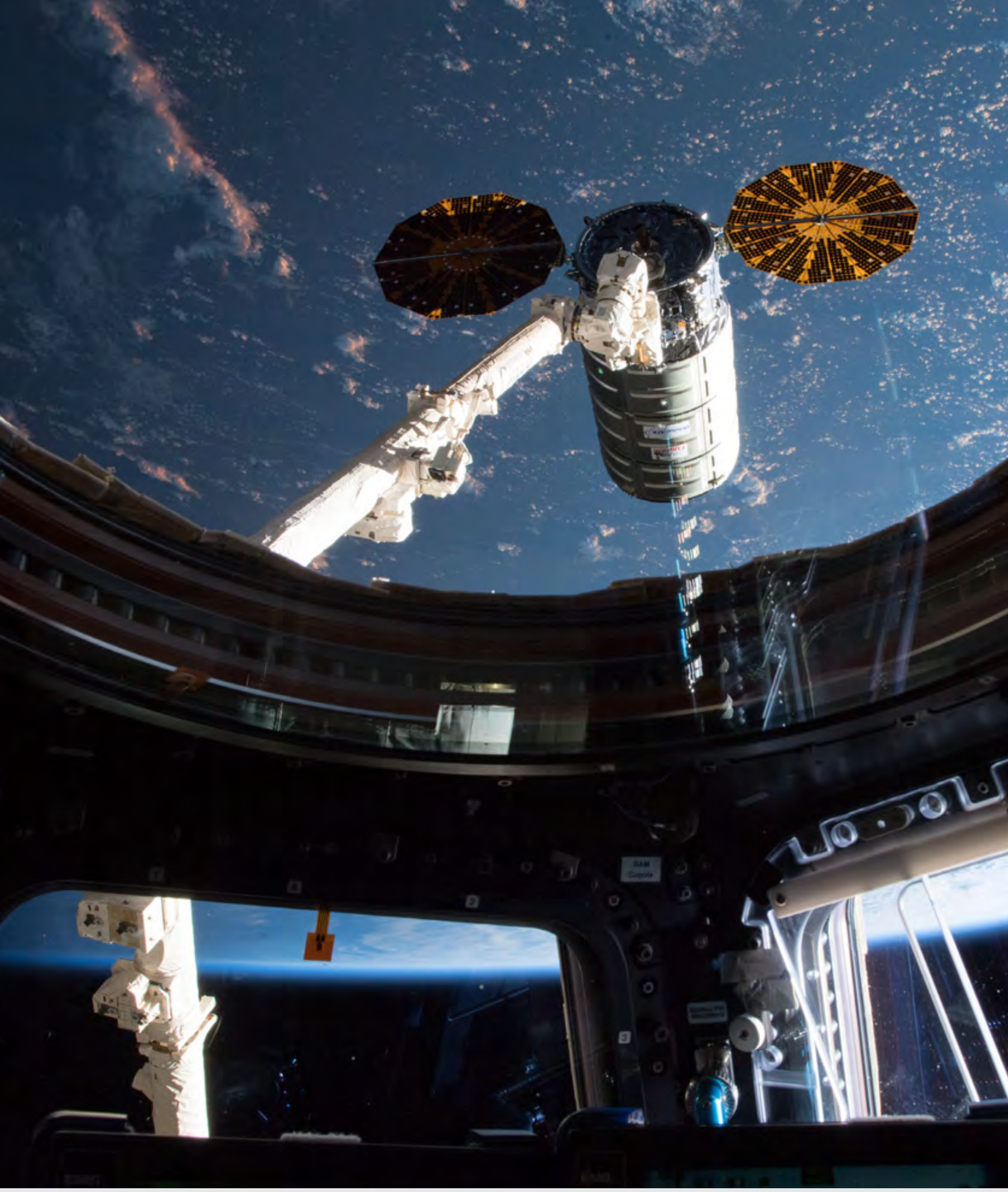
[NASA spends roughly $4 billion annually on ISS operations. Constructing the station cost $75 billion, according to a 2013 Office of Inspector General report, which translates to over $100 billion in today's dollars. — PB]

If they do crash it into the ocean, I want to be out on a cruise as close as possible to see it reentering the atmosphere, because I worked up there and it's very significant to me.

"Personally, I would like to see ISS preserved by moving it to a much higher orbit, where it could stay until we figure out how to recycle the aluminum alloys that make up most of the structure in space."

▶ Astronaut Tom Jones during one of several spacewalks conducted during the STS-98 mission in 2001, which delivered the Destiny laboratory module to the ISS.

NASA



"It's very important we avoid a gap in our presence there, to maintain our leadership with our international partners and to stay ahead of China."

◀ A Cygnus cargo freighter arrives at the ISS in 2018.
NASA

U.S. Rep. Zoe Lofgren (D-Calif.)

Ranking member of the House Committee on Science, Space, and Technology.

YES NO **MAYBE**

Whether our continuing presence in LEO is through an extension of ISS operations, a commercial space station, or another platform must be assessed.

U.S. presence in LEO needs to be maintained to continue our R&D activities in microgravity, as well as keep up other important functions, like human spaceflight capabilities. It's very important we avoid a gap in our presence there, to maintain our leadership with our international partners and to stay ahead of China.

Our committee has actively examined the future of the station and options in low-Earth orbit for many years. One particular question is whether there might be a way to store the ISS in a safe orbit for use by future generations.

Our recent authorization bill would direct NASA to revisit the question and conduct an engineering analysis of the technical, operational, and logistical viability of storing the ISS safely for future generations.

It's important that we have a robust U.S. strategy in place to guide our national vision for LEO and our next steps following the end of ISS operations. The ISS is one of the most complex engineering accomplishments the U.S. has undertaken and a shining example of U.S.-led international cooperation.

Our reauthorization bill directs such a strategy, and I look forward to working with the Senate to get this legislation enacted.

Clayton Swope

Deputy director of the Aerospace Security Project at the Center for Strategic and International Studies and a senior fellow in the think tank's Defense and Security Department.

● **YES** ○ **NO** ○ **MAYBE**

The question is, does anyone know how much it will cost to keep ISS up there, and how will that money be put on the table? At some point, we'd want to devote the ISS budget to developing a new alternative in low-Earth orbit, but if we want to have a continuous presence, there may be a period where we need to fund both ISS and a commercial replacement.

We need a schedule to identify when we think that transition is going to occur from a realistic standpoint, and that's kind of what we don't have right now. Certainly, if someone told me it's absolutely not safe to have the ISS operate past a certain date, my answer to your initial question would change to a negative.

Any extension of ISS really needs to be tied to a definite schedule for a replacement, so our whole presence in space doesn't drive off a cliff. It's like an old house: At some point, it's no longer worth spending money on. We have wanted for years to replace the ISS with a commercially owned and operated station, but we haven't historically put sufficient money forward to make that happen.

And this isn't necessarily completely separate from Artemis plans, because things like spacesuits for Artemis need to be tested adequately, which can happen on ISS. ★

"Any extension of ISS really needs to be tied to a definite schedule for a replacement, so our whole presence in space doesn't drive off a cliff."

A crew member aboard the space shuttle Endeavour took this photo as the orbiter approached the ISS in 2010.

NASA

Inside the space data race

SpaceX and others have proposed launching tens of thousands of massive satellites for AI processing and other functions in a bid to alleviate some of the woes of terrestrial data centers. But can the technical challenges be overcome? Jonathan O'Callaghan takes a look.

BY JONATHAN O'CALLAGHAN | jdaoca@gmail.com

What if the next time you sent a question to OpenAI's ChatGPT or Google's Gemini, the answer didn't come from microchips inside a massive building somewhere on Earth, but rather from ones housed within thousands of orbiting satellites? That's the pitch of orbital data centers, or ODCs.

To proponents, these spacecraft could solve the growing problem of needing to construct scores of massive facilities on Earth to run AI tools, among other computing tasks. These terrestrial centers are seeing considerable backlash as they soak up power and expel huge amounts of heat.

"People don't want to live next to an ugly data center," says Lori Gordon, a systems director at the Aerospace Corp. in Chantilly, Virginia, which is conducting a feasibility study on ODCs. A dozen U.S. states are now looking at ways to curb the growth of terrestrial facilities, such as freezing approvals.

Moving such computing to orbit could alleviate many of these concerns and ease data center operations, because solar power from the sun is free and abundant and the coldness of space provides a natural, if complicated, cooling remedy.

"We are almost hitting the energy limit on Earth to power data centers," says Yonggang Wen, a professor in the College of Computing & Data Science at Nanyang Technological University in Singapore. "We have to think creatively."

A handful of Chinese companies have announced plans to launch satellites for on-orbit AI processing, and multiple U.S. companies are seeking regulatory approval to launch thousands of ODCs of their own. Among the largest proposals are 1 million from SpaceX, 88,000 from Starcloud and 51,600 from Blue Origin. The market is predicted to grow to a value of $39 billion by 2035, according to market intelligence company BIS Research.

But many challenges remain, not least the size of the satellites — some of which could be nearly as big as the International Space Station — and their impact on the orbital environment. Also under discussion are the technical hurdles of building them and the sheer volume of satellites being proposed.

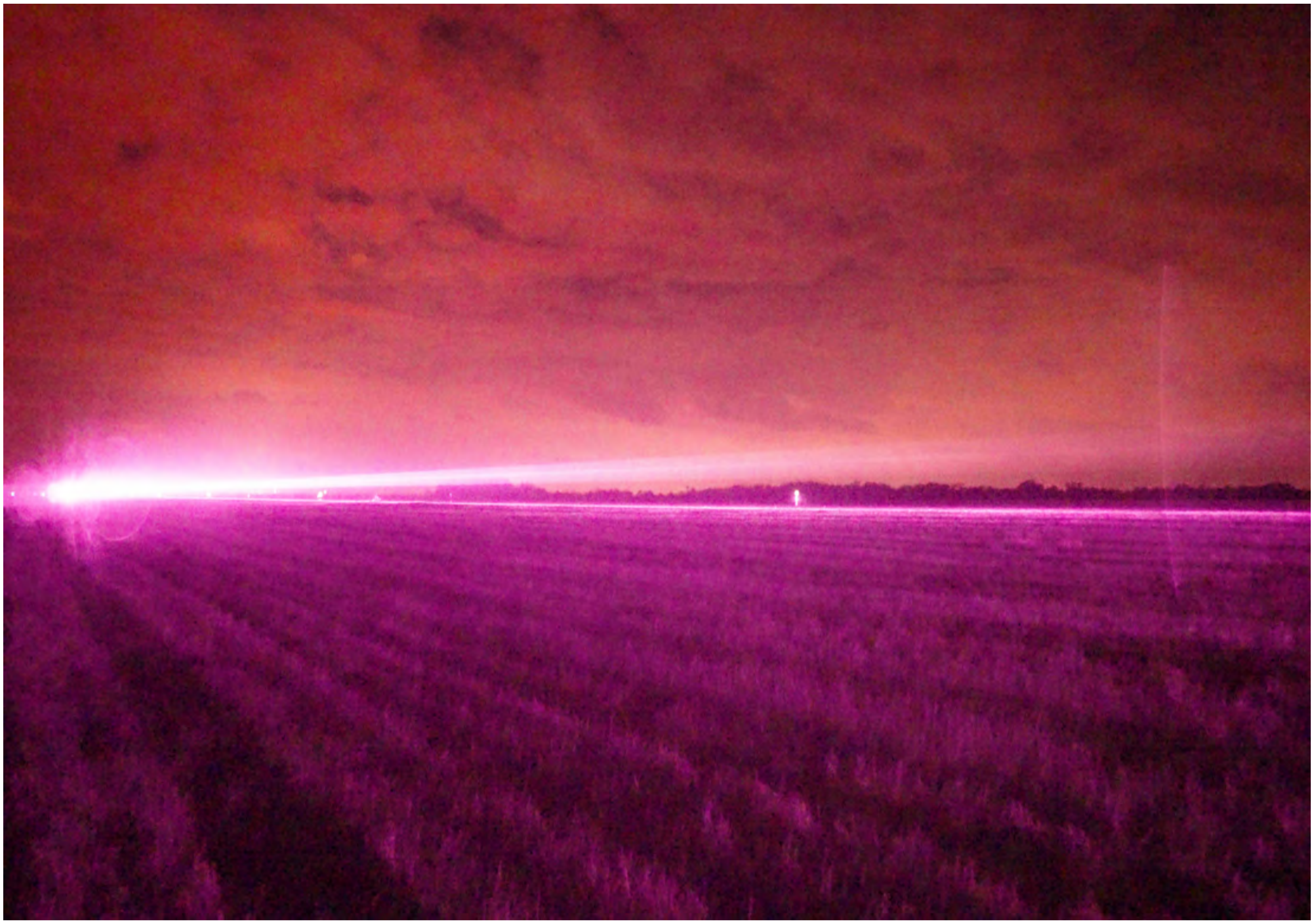
Space chips

ODCs are, at a very basic level, containers for high-performance chips operating in space. There are a small number of satellites currently demonstrating this technology, one of which is Starcloud-1. That spacecraft, launched in November, carries an NVIDIA H100 chip to train a Google AI model. And last May, the Chinese firm ADA Space launched its first 12 satellites of a planned 2,800-satellite constellation for on-orbit AI processing.

As news of these developments trickled out, interest in ODCs started to grow. It skyrocketed in January, when SpaceX founder Elon Musk tweeted the company will launch 1 million AI satellites. (The Federal Communications Commission filing specifies a constellation of "up to" 1 million, indicating that fewer could be launched.)

"The history about how space data centers accelerated in just the last six months is incredible," says Jaroslaw Jaworski, CEO of the Luxembourg-based space computing firm Edge Aerospace. "Elon tweeted, and here we go. We have a new reality."

Jonathan O'Callaghan is a space and science journalist from the U.K. A regular contributor to Scientific American and New Scientist, his work has also appeared in Forbes, the New York Times and Wired.



▲ An infrared image of Star Catcher's late 2025 ground demonstration, in which the company beamed 1.1 kilowatts of electricity to commercial off-the-shelf solar panels. Plans call for establishing a constellation of solar-power-collecting satellites to beam power to orbital data centers or terrestrial data centers.

Star Catcher

Moving these operations to orbit would relocate some of the compute power needed for AI. Instead of your query to an AI chatbot being handled inside a data center on the ground, it could be sent to a fleet of satellites, each running state-of-the-art chips.

From the user perspective, there won't be much difference, says Wen. "You give a command to your [AI] agent, it will run, and then come back to you."

"For low-Earth orbit, the round-trip time is around 800 milliseconds," he adds, a latency that is more than sufficient for most modern AI needs.

Satellites equipped with high-performance chips could also handle the growing problem of processing space data. Take Earth imaging satellites, for instance. Every day, they generate a huge amount of data that must be downlinked and then processed on the ground, which can be time-consuming. But what if the satellites themselves could process their own images, without ground involvement?

Jaworski gives an example of soldiers on a battlefield needing to know if enemy troops are nearby. "They're not looking to do map interpretation," he says. "This interpretation in real time could be done on the satellite, and you could pass the information directly to them."

ODCs could also allow countries to develop sovereign AI capabilities in space, which are harder to attack than on the ground, notes Wen.

"The potential attack to a data center in space is much more challenging than on Earth, both physically and in cyberspace."

It is energy, however, that is one of the biggest drivers. The International Energy Agency estimates that by 2030, terrestrial data centers could consume as much power as the entire country of Japan. Another study, by Arizona State University, found that the heat generated from running and cooling these facilities can increase the temperature of nearby neighborhoods by as much as 4 degrees Fahrenheit (2 degrees Celsius).

But for all their seeming potential, ODCs also raise governance questions.

"I would not allow one company, one country or one institution to decide alone whether orbital data centers are worth it," says Nimra Javed, a research officer at the Center for International Strategic Studies in Pakistan. "If we build them first and think about rules later, then we may simply transfer the problems of Earth into space."

Power hungry

For orbital data centers to make a meaningful dent in

Inside the plans

A handful of U.S. companies have proposed launching tens of thousands of satellites for AI computing. If plans hold, the five largest of these orbital data center constellations would amount to more than 1.2 million new objects on orbit.

		MAXIMUM NUMBER OF SPACECRAFT	TARGETED ALTITUDES (KM)	FIRST LAUNCH
	**Stampede** (Cowboy Space, formerly Aetherflux)	20,000	700–1,000 km	2028, with a LEO computing demo planned for 2027
	**Project Sunrise** (Blue Origin)	51,600	500–1,800 km	No target announced
	**Starcloud**	88,000	600–850 km	Starcloud-1 launched in late 2025 to demonstrate on-orbit training of an AI model
	**Orbital Compute**	100,000	Not disclosed	Pathfinder in 2027 and first operational satellite in 2028
	**Starmind** (SpaceX)	1 million	500–2,000 km	No target announced

terrestrial center usage, they would need access to gigawatts of power. Generating such amounts is no easy feat. The ISS today generates just 75-90 kilowatts of continuous power — one kilowatt being 0.000001 gigawatts — from its football-pitch-sized solar panels.

SpaceX and others have proposed ODCs with similarly huge solar panels. According to a June fireside chat with Musk, SpaceX's AI satellites will be 20 meters tall, more than double the size of the largest variant of the company's Starlink broadband satellites. Once unfurled on orbit, their solar panels would have a wingspan of 70 meters (230 feet) — roughly the height of a Falcon 9 .

Although necessary to generate the 120-150 kW of power Musk estimated, these solar arrays would also give each satellite a huge footprint. Coupled with the sheer size of the constellation SpaceX is proposing, that dramatically increases the chance of collisions, experts say. Starlink alone — which currently numbers a little over 10,000 satellites — performed 300,000 collision avoidance maneuvers in 2025, according to documents SpaceX filed with the FCC.

SpaceX did not respond to a request for comment.

"That's an awful lot of maneuvers to attempt to keep those [data center] systems safe," says Hugh Lewis, a professor of astronautics and an expert in space sustainability at the University of Birmingham in the U.K. "I don't think that's really reasonable."

Further complicating matters is that many ODCs would also need to be located in sun-synchronous orbits, which travel almost from pole to pole, to keep them in near-constant sunlight and provide power almost around the clock. This means they would continuously cross the paths of most other satellites, which orbit around the equator.

▲ Starcloud's 60-kilogram satellite is running a version of Google's Gemini AI chatbot on orbit. Launched in late 2025, Starcloud-1 (left) carries a NVIDIA H100 graphics processing unit and is a precursor to a planned data center constellation of 88,0000.

Screengrab of SpaceX livestream

Millions of maneuvers would be needed not every year, but every day, Lewis predicts.

"You're into territories of half a billion maneuvers a year."

One novel solution might be to erect separate satellites that would collect solar power and beam it to ODCs, or even directly to terrestrial data centers, avoiding the need for ODCs altogether. One company investigating the former is Florida-based Star Catcher, which last year completed a ground demo of its power-beaming technique. The company converted electricity generated from solar panels into a laser, focused with lenses, and beamed it across a football stadium and then an old space shuttle runway, both in Florida. The runway test reached 1.1 kW, a world record for optical power transmission.

The company's plan is to station thousands of satellites in relatively high orbits, about 1,500 kilometers (930 miles) above Earth, to transmit power to ODCs and other satellites.

"Our approach is a one-to-many architecture," says Andrew Rush, co-founder and CEO. "Each one of our power node satellites can provide energy to tens of client satellites simultaneously," with the beamed power also providing "five or 10 times the amount of energy density they would get from the sun."

Overview Energy of Virginia is taking a different approach, planning to operate thousands of satellites in geostationary orbit, roughly 35,000 kilometers (22,000 miles) above Earth. The satellites would beam the power they collect directly to terrestrial data centers, many of which are already equipped with vast solar panels.

In April, the company announced an agreement with tech giant Meta to provide up to one gigawatt of power from space. Overview hopes to start launching satellites in 2030, says founder and CEO Marc Berte, with each satellite capable of sending a megawatt of power back to Earth.

"We want to be deploying a gigawatt a year by 2035," he says.

Even if the power issues can be solved, there remains the challenge of how to expel the heat from ODCs that will be generated as the microchips use electricity. This heat does not convect in the vacuum of space, so large radiators will be needed — like those on board ISS — to get rid of it.

"On Earth, we reject heat from data centers using cooling towers," says Igor Bargatin, an associate professor of mechanical engineering and applied mechanics at the University of Pennsylvania. "In space, that doesn't work. You cannot use any water. The only thing we can do is use infrared radiation, and that just needs a lot of area."

Some companies, like Sophia Space of California, propose a different method: Make the satellites so thin that some heat radiates away directly, eliminating the need for elaborate radiators. Sophia's satellites, called TILEs, would be grids of flat platforms only a few centimeters thick with a solar panel on one side, a disassembled chip flattened into a middle layer and a thin aluminum radiator on the other side. Co-founder and CEO Rob DeMillo compares it to an Oreo cookie.

▲ The third generation of SpaceX's Starship-Super Heavy made its debut in late May. This version of the rocket is needed to deploy the up to 1 million orbital data centers for which SpaceX is seeking regulatory approval.

SpaceX

By connecting these into 50-meter-squared structures made of thousands of TILEs, the company believes it can offer megawatts of power. "Two thousand of our TILEs with the current CPU [central processing units] and GPU [graphics processing units] combination we're using will generate a megawatt of power," says DeMillo.

The hope is that as chip designs advance, smaller groups of TILEs in the hundreds or fewer can provide the same amount of power.

Launch costs

Another big factor working against orbital data centers at the moment is launch costs. To deploy enough satellites to make them competitive with terrestrial centers, prices must drop to a few hundred dollars per kilogram, Wen and others spoken to for this article estimate.

"We have to really wait until launch costs get to $200 or $300 per kilogram," says Wen. And to do that, "you will need Starship."

Today, it costs thousands of dollars per kilogram to send something to space, and it's unclear — even when SpaceX begins Starship operations — if costs will ever drop low enough for ODCs to be viable at a large scale.

"I do not think it is the most effective solution to the problem," says Kathleen Curlee, a research analyst at Georgetown University's Center for Security and Emerging Technology in Washington, D.C. "It would be cheaper, faster and much easier to just come up with more environmentally friendly solutions for [terrestrial] data centers, rather than trying to put them in space."

Chipmaker NVIDIA agrees orbital data centers "are more likely to complement terrestrial infrastructure than replace it," said Dion Harris, NVIDIA's senior director of HPC and AI hyperscale infrastructure solutions, in response to written questions.

Despite the uncertainty, there remains considerable interest in how these orbital platforms could develop. In May, the European Space Agency announced a contract with Edge Aerospace to study the future of ODCs. In the same month, Aetherflux (created by Baiju Bhatt, who co-founded the trading platform Robinhood) announced it is rebranding as Cowboy Space to focus on both space-based solar power and ODCs, having raised $275 million in backing.

The company has yet another concept of operations in mind: building rockets with detachable upper stages that also serve as the individual data centers.

"Our current roadmap is to have our first chips operating in a space environment in early 2027," Bhatt told me via email. "From there, we iterate toward our first proprietary rocket launch carrying a one-megawatt data center, which we are targeting by the end of 2028."

The company is planning a constellation of 20,000 satellites, he added.

Even if these constellations deploy on schedule, it will take some time to erect them. In the near-term, Jaworski and others think it's more likely AI processing will focus on space data as a particular niche.

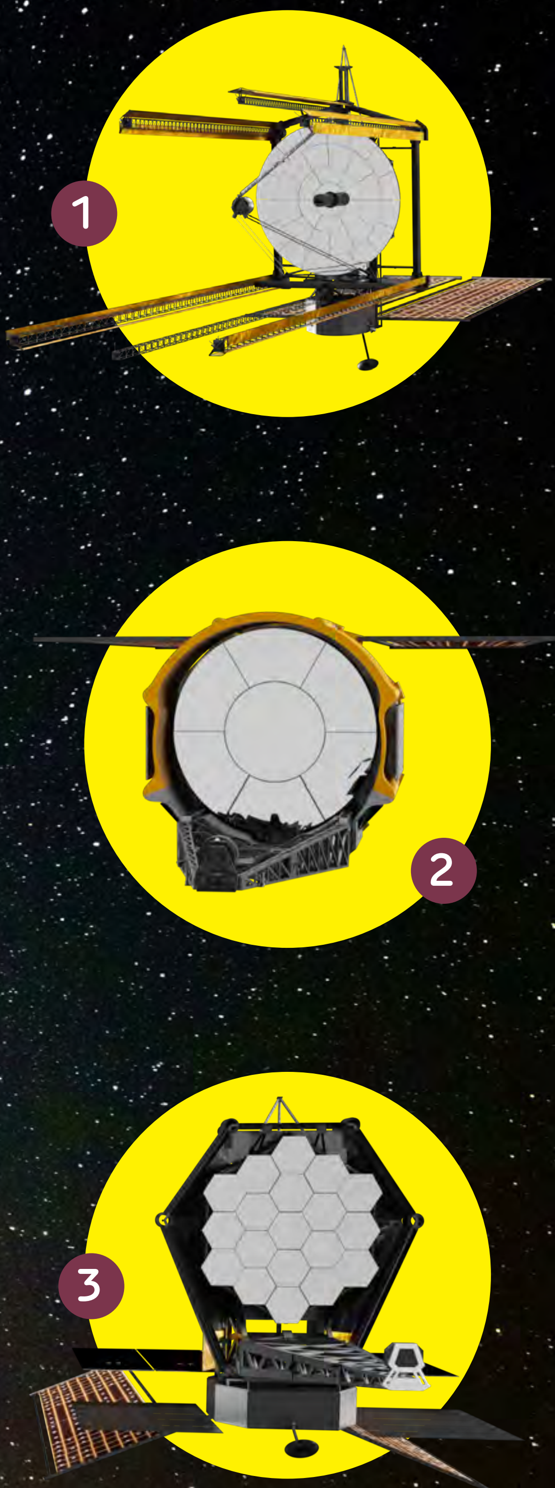
"We think the immediate step is to actually provide space data center services for space customers with problems processing or moving data," he says. ★

NASA's habitable planet seeker comes into view

Before locking in the design of its next flagship telescope, the Habitable Worlds Observatory, NASA plans to spend millions of dollars advancing the host of technologies required to seek out life on planets outside our solar system. Adam Hadhazy dives into the progress and impetus for this new strategy.

BY ADAM HADHAZY | adamhadhazy@gmail.com

Photo Illustration | Adobe Stock



▲ Engineering architecture concepts for the Habitable Worlds Observatory. Mission planners are using them in simulations to help determine which configuration is best suited to achieving HWO's science goals.

NASA Goddard/Conceptual Image Labs

Some two decades from now, if all goes as planned, NASA will have a new telescope stationed around Lagrange Point 2. From this gravitationally stable orbit some 1.5 million kilometers from Earth, the Habitable Worlds Observatory will hold watch for several hours at a time, collecting thousands of photons reflected by gases in the atmospheres of far-off exoplanets.

What is it seeking? An answer to one of the biggest questions about what's beyond our solar system.

"'Are we alone?' is the most ambitious question that has really ever been addressed by any mission, and an observatory capable of addressing this question must also be ambitious and powerful," says Breann Sitarski, deputy principal architect for HWO at NASA's Goddard Space Flight Center in Maryland.

HWO (pronounced "who" and called Hab Worlds for short) is NASA's first-ever mission dedicated to searching for signs of life on planets beyond the solar system. Slated for launch in the 2040s, the telescope represents an enormous technological leap forward in multiple ways — which has also prompted NASA to reimagine its approach for developing flagship missions.

Configuration-wise, HWO is to be the most stable spacecraft ever constructed — about 100 times stabler than the James Webb Space Telescope, with the instrumentation portion of the spacecraft wobbling no more than the width of a hydrogen atom during observations. To see Earth-like worlds against the glare of their host stars, HWO needs a coronagraph that suppresses starlight by a factor of 10 billion, another double-order-of-magnitude jump from the current state-of-the-art. Finally, mission planners also want to build in the capability for robotic craft to service the telescope all the way out at L2 — a far cry from the basic servicing possible today in the geostationary-geosynchronous realm 35,000 km above Earth.

To further develop and mature today's limited versions of these technologies to meet HWO's stringent requirements, NASA in January awarded three-year, fixed-price contracts to seven companies. The agency did not disclose individual contract amounts, but Congress approved $150 million for HWO development for fiscal year 2026.

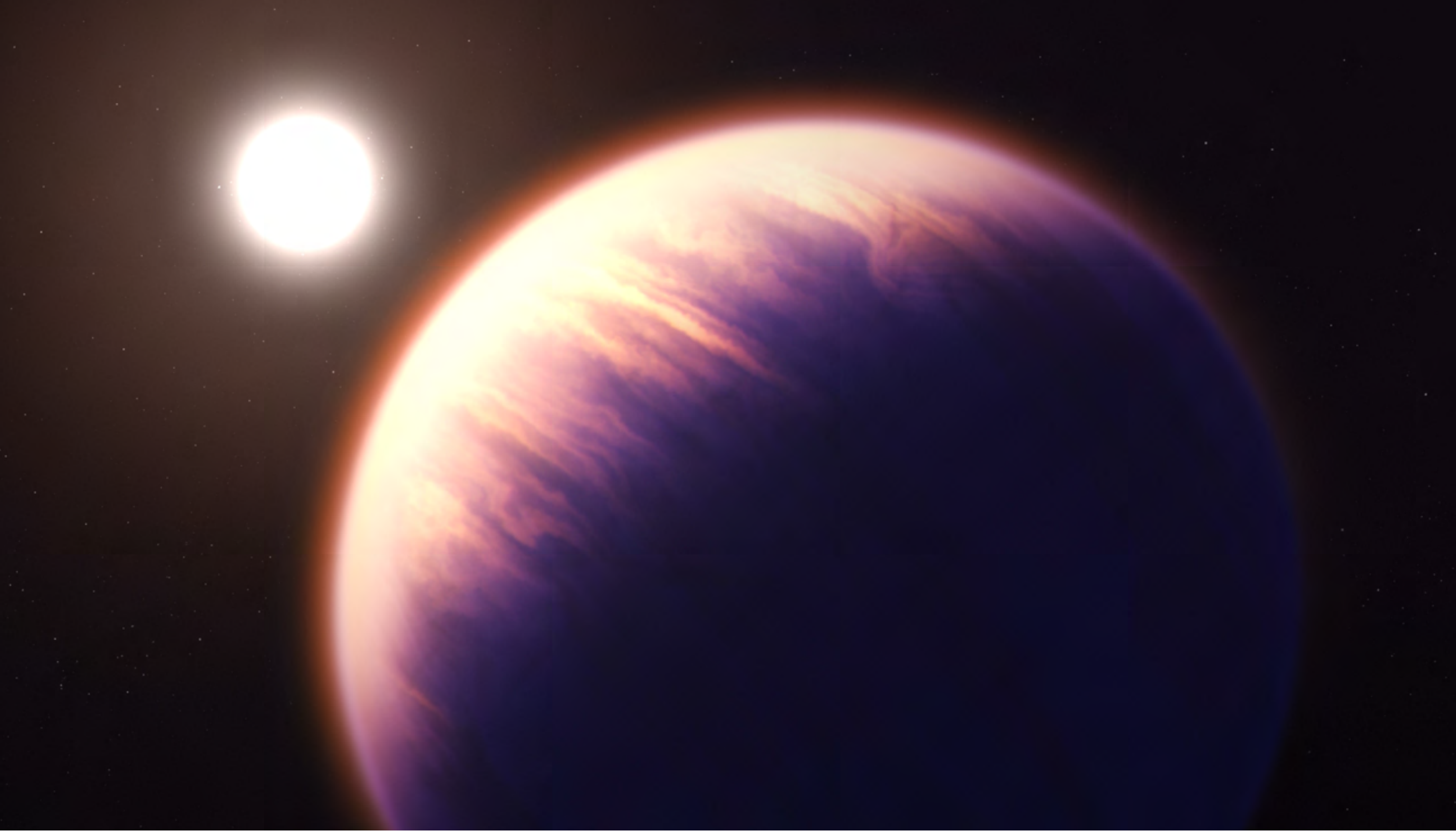
Although much work remains, those involved with HWO say they're optimistic about the mission's prospects.

"This is our first chance to directly search for life because we live in a time where technologically we think we know how," says Evgenya Shkolnik, a professor of astrophysics at Arizona State University and co-chair of the HWO Community Science and Instrument Team (CSIT) that is contributing scientific expertise to the fledgling mission. "It's an amazing opportunity that humanity has never had before."

Programmatically innovative

Astronomers identified HWO as their community's top-priority large mission in the 2020 Decadal Survey on Astronomy and Astrophysics, with a budget estimate of $11 billion. That report also called for a more cautious development trajectory compared to Webb, which ran roughly 10 times over its initial $1 billion cost estimate and was launched a decade behind schedule.

NASA is accordingly taking a more proactive programmatic approach with HWO, setting aside extra time and budget up front before locking in the design and proceeding to fabrication.



▲ The coronagraph on NASA's Nancy Grace Roman Space Telescope was designed to image Jupiter-sized exoplanets, like WASP 39-b (shown here in an illustration). HWO's coronagraph must be magnitudes more powerful and precise to image Earth-sized exoplanets.

NASA, ESA, CSA, Joseph Olmsted (STScI)

"A lot of it is making sure that the technology is ready to go, so before you actually start sprinting with a mission, you've actually assured that you can do the mission," Nicola Fox, head of NASA's Science Mission Directorate, told reporters at an April press event. "So with Habitable Worlds, we're putting a lot of focus right now on maturing the technology."

Sitarski says NASA is also relying on exploratory analytic cases during HWO's ongoing preformulation phase, mapping science goals to engineering parameters to better inform "virtual telescope" simulation, modeling and architecture assessment.

"This is a new paradigm that we haven't really looked at in previous flagship missions," she says.

The agency's contractors have noticed and embraced the shift.

"We're learning from Webb: Don't start a program and expect miracles to happen," says Alison Nordt, director for space science and instrumentation at Lockheed Martin, which received one of the development contracts.

Among the factors contributing to Webb's delays, says Nordt — who for 16 years served as the principal engineer for the telescope's near-infrared camera — was the longer-than-anticipated time required to develop the 10 critical technologies needed to fulfill its mission. These included a deployable, layered sunshield; lightweight beryllium mirrors; and cryogenic detectors. The project moved into design and manufacturing before these technologies had fully gestated, resulting in forced redesigns and workmanship issues along the way.

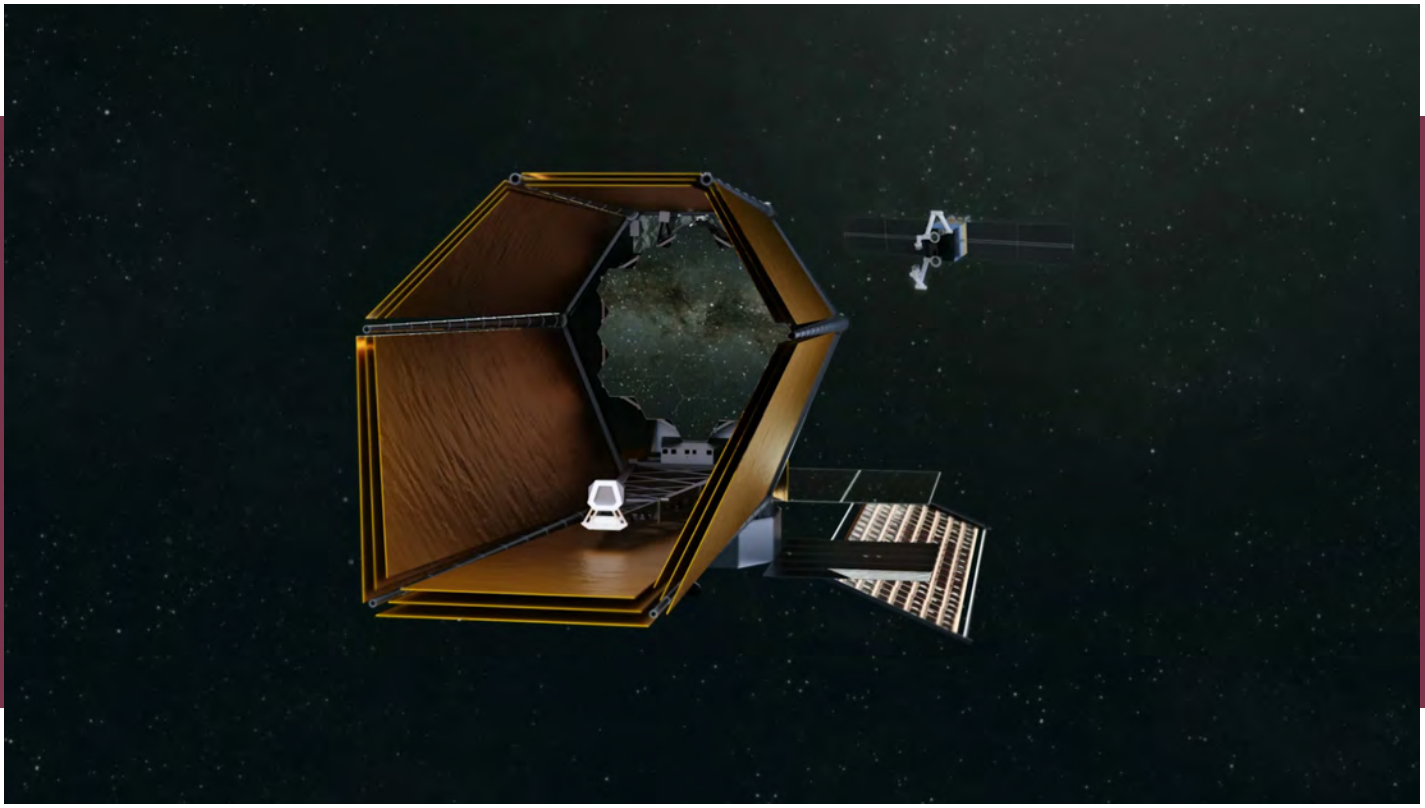
Instead, the strategy for HWO is "spend a decade developing technology first and fund it well before you have the marching army of developing a flight observatory," Nordt says.

The agency awarded the first study contracts in 2024, so the pivot to manufacturing is not likely to begin until the mid-2030s.

Another difference is fewer launch vehicle constraints. HWO is expected to be at least the size of Webb, with a folding primary mirror that will expand to at least 6 meters in diameter — perhaps up to 8 meters. Webb's design was constrained by the 5-m fairing of what were then the latest heavy-lift rockets. Since then, new designs have been introduced, including SpaceX's Starship and Blue Origin's New Glenn, that offer wider fairings and greater mass launch capabilities.

With Webb, "they had limited margins and limited capability to respond to challenges," says Matt Bolcar, HWO chief technologist at NASA Goddard. With HWO, "we can carve out more margin for mass and volume and make sure that we have more flexibility in the future."

Rather than appointing a single prime contractor, as has often been the case for Webb and other big missions, Nordt hopes NASA will pursue a more integrated, multi-contractor approach for HWO beyond the current development phase, fostering competition as well as teamwork. "It's a different paradigm than I think any observatory or NASA mission has ever been in, trying to make this kind of a collaboration together," she says.



▲ Astroscale U.S. received a HWO study contract early this year to look at possibilities for servicing the observatory. In this illustration, a robotic servicer approaches HWO.

NASA/Astroscale U.S.

New levels of stability

HWO's chief science goal is to find and observe up to 25 Earth-like planets orbiting sun-like stars located roughly 15–30 light-years from Earth. In addition, the telescope will also serve as a general-purpose observatory — continuing the legacy of the Hubble Space Telescope, Webb and the Nancy Grace Roman Space Telescope slated to launch later this year — deepening knowledge across astrophysics, cosmology and planetary sciences.

For its exoplanet-hunting mission, HWO must maintain precise optical alignment, focus and pointing while withstanding inevitable heat and mechanical perturbances from itself. The primary mirror — which, like Webb's, will be segmented — secondary mirror, support structures and coronagraph all require active control systems and sensors that must perform at a newfound level of picometer (trillionths of a meter) precision. That's 1,000 times greater than Webb's nanometer control.

As Nordt put it, "the No. 1 requirement for Hab Worlds is we've got to be stable, stable, stable."

Lockheed Martin is one of the contractors studying how to achieve this. For the mirror, Nordt says the company is leveraging its prior work on the Space Interferometry Mission, a NASA project that was canceled in 2010. For that spacecraft, Lockheed engineers developed laser-based metrology using photonic integrated circuits for measuring mirror segments, which still remain in the vanguard and they believe can now help HWO reach its requirements.

Partnering with Lockheed is L3Harris Technologies, who through its predecessors and subsidiaries has been a long-time NASA collaborator on mirrors and optics for Hubble, Webb and Roman.

"We build the eyes for these NASA systems," says Charles Clarkson, vice president and general manager of space superiority and imaging at L3Harris. The company plans to construct a testbed at NASA Goddard to analyze the thermal stability of potential HWO mirrors, experiment with gauge placement for precisely measuring where the mirrors are and configure actuators to move them as needed.

As for mirror coatings, NASA has contracted Illinois-based ZeCoat to develop durable, large-scale thin films that maximally reflect light with wavelengths from 100-2,500 nanometers, from near-ultraviolet wavelengths through visible into the near-infrared. (ZeCoat did not reply to multiple requests for comment.)

For extremely stable pointing, NASA is evaluating microthruster technology. The agency has contracted Busek, a Massachusetts-based spacecraft propulsion company that contributed microthrusters to the 2015 LISA Pathfinder mission and demonstrated technologies for future space-based detection of sublimely subtle gravitational waves. The colloid micronewton thrusters that flew for the first time on that spacecraft had a maximum thrust of 30 micronewtons, equivalent to the weight of a mosquito, necessary for counteracting forces such as the incessant pressure of sunlight.

The thrusters use an electrospray technique, in which electric charge is applied to droplets of an ionic liquid. The droplets are then accelerated by an electric field and expelled to produce precise, low-force thrust. That technique controls the position of the satellite to within "the width of a strand of DNA," which is "directly applicable to HWO," says Peter Hruby, vice president of business and strategy at Busek.

For its HWO contract, Busek is advancing its microthruster tech for longer lifetimes and greater redundancy and serviceability, Hruby says.

Regarding spacecraft architecture more broadly, the plan is to isolate the instrument payload side as much as possible from the rest of the observatory, where solar panels, communications, propulsion and other heat- and mechanical-disturbance-producing components reside.

To that end, Lockheed Martin has developed what it calls "disturbance-free payload." This noncontact method relies on components known as voice coil actuators — essentially a coil of wire that goes inside a high-strength magnet cylinder. The two elements do not actually touch and are mounted opposite each other. As a current goes through the coil of wire in the presence of a magnetic field, a force is created, allowing control of one degree of freedom. Placing six coils in a hexapod configuration enables full pitch, yaw and roll control, and thus active control, keeping the instrument side locked in during observing runs.

"The spacecraft could vibrate all at once, and the telescope's rock solid above it," says Nordt. "'You go ahead and dance away, spacecraft, but I'm going to do what I want to do and point directly at that star.'"

The only elements connecting the spacecraft and instruments would be cables across the interface, "but we'll make those as flexible and as compliant as possible so that they don't transmit a lot of the disturbances across," adds Nordt.

Meanwhile, BAE Systems' Space and Mission Systems division, based in Boulder, Colorado, is working on picometer-level control specifically for HWO's mirror segments. Ball Aerospace, which BAE acquired in 2024, made Webb's actuators and primary mirror segments.

In a statement, BAE described how Webb's nanometer-level stability only required occasional segment fine-positioning via those actuators, whereas HWO necessitates constant active control. The company says it has developed patented ultrafine actuators with picometer-level resolution that are "strong enough to hold the weight of the primary mirror through ground testing and survive the forces of launch."

BAE also has a patent-pending capacitive sensor in the works for measuring mirror motion across all six rigid body degrees of freedom. A control loop would connect the actuators to the sensors, enabling continuous correction of unwanted changes in mirror position.

Northrop Grumman, another HWO contractor, did not respond to requests for an interview about its technology. Conference proceedings and general summaries of HWO contractor focus areas supplied by Lockheed Martin, however, describe that Northrop Grumman is working on stiff, ultra-stable telescope structures. These include latches for deployment of elements — such as solar panels after launch — but with avoidance of structural micro-lurching, where unpredictable shifts in position occur when deployed structures "jerk" into lower-energy states.

The company is also leading development of a shield to protect HWO's mirrors from micrometeoroids, which came into play following a strike to one of Webb's mirror segments in May 2022. That impact left a dimple and required actuator adjustment of the segment to compensate. While mission engineers had planned for sand-grain-sized micrometeoroids at L2, the velocity of the offending grain exceeded expectations. HWO's team accordingly wants a barrel-like baffle, given the extreme sensitivity of the instrumentation.

Finally, at the heart of HWO will be its coronagraph. This instrument is entrusted with creating a 10-billion-to-1 contrast ratio, letting dim worlds emerge into view with their stellar host's light squashed.

Lockheed's Nordt offers an illustrative analogy: "It's like seeing a firefly next to stadium floodlights in San Francisco from Colorado Springs," about 1,500 km distant.

Much groundwork has already been done, courtesy of Roman's Coronagraph Instrument (CGI), set to launch with the telescope as soon as late August. Built at NASA's Jet Propulsion Laboratory as a technology demonstration, CGI is expected to see down to Jupiter-sized planets around sun-like stars. The instrument also doubles as a spectrograph for atmospheric characterization.

"We can take what was done on CGI and apply it directly to the coronagraph that we need for Hab Worlds, with a few additional advances," says NASA's Bolcar, who also is the optical systems lead for Roman.

Basically, all CGI's relevant components and technologies to actively suppress starlight — including masks, detectors and deformable mirrors — will have to be honed further for HWO, Bolcar says. "One of the main design principles is to evolve from what we know how to do versus trying to do something brand new," he adds.

Keeping Hab Worlds within reach

Where HWO will be breaking entirely new ground is its baked-in serviceability. The idea is to ensure the observatory can be repaired, should a malfunction occur, and upgraded as sharper instrumentation emerges. Robotic service missions could thus significantly extend HWO's useful scientific life beyond a baseline of five to 10 years, akin to the five astronaut-led missions to Hubble that have allowed that workhorse to deliver science 36 years and counting.

To study the feasibility of L2 servicing, NASA has contracted Astroscale U.S., a Denver-based on-orbit servicing company currently developing servicing vehicles for low-Earth and geostationary orbit. Although upfront costs and complexity increase with designing HWO to be serviceable, the gains can help ensure mission success and longevity.

"Serviceability offers a level of risk reduction for the net science program that you can't offer when you have just a singular monolithic telescope that can't be serviced," says Jeff Schloemer, the company's senior director of engineering.

Among the challenges Astroscale is examining is how to deal with the roughly 10-second communications latency between L2 and Earth. So far, the basic plan is for robotic servicers to semi-autonomously handle a task, then check with the human mission controllers before proceeding to the next step, Schloemer says.

Another issue is how to avoid potential contamination of mirror surfaces from the fuel used by the servicing craft for rendezvous maneuvers. Astroscale's proposed solution is for any residue-generating chemical burning — for instance, hydrazine — to be conducted at a determined safe distance, with substantially lower residue-generating cold gas (such as nitrogen) thrusters a good candidate for close-in maneuvering, says Schloemer.

It's also key to ensure servicing does not jeopardize HWO's exquisite stability. Any science observations would be paused during service, but part swap-outs and maintenance must be performed carefully to avoid introducing errors.

As far as potential upgrades, says NASA's Sitarski, a prime example is a next-next-generation ultraviolet coronagraph-spectrograph, sensitive down to about 200 nanometers. Such short wavelengths pose similar, though even more daunting, technical challenges than HWO's intended instrument, including unprecedented stability and mirror smoothness.

But developing such an instrument by, say, the 2050s could be worth the wait. "The key feature that we would get out of [such an instrument] is this very deep ozone feature in the near-ultraviolet," says Sitarski. In concert with other, easier, longer-wavelength gas detections, "that would be a very good indicator of potentially life on that planet."

Because ozone decays rapidly, it requires a replenishing source of highly reactive oxygen that, in Earth-like planetary regimes, would most reasonably come from biology. Should HWO indeed produce such a finding of probable life, the exo-world in question would likely become one of the most studied objects in science, prompting NASA and other organizations to devote considerable future resources to revealing a potential alien biosphere.

But before any of that comes years of grind to endow a host of technologies with never-before-obtained powers.

"It's an audaciously difficult observatory," says Lockheed's Nordt. "But I think if we put the best of everybody together, it can be accomplished." ★

Adam Hadhazy
is a New Jersey-based journalist who writes about astrophysics and technology. His work has appeared in Discover and New Scientist magazines.

NASA's Roman telescope could help solve this cosmic mystery

BY JON KELVEY | jonkelvey@gmail.com

An illustration of the Nancy Grace Roman Space Telescope. NASA

In the coming months, the Nancy Grace Roman Space Telescope will be launched 1.5 million kilometers from Earth to investigate dark energy and dark matter. But in building the observatory to tackle these cosmological enigmas, NASA is also poised to help solve another mystery that has emerged since Roman was first conceived more than a decade ago: conflicting calculations of how fast the universe is expanding.

"The discrepancy is not marginal," says Charles Bennett, an experimental cosmologist at Johns Hopkins University and its Applied Physics Laboratory.

Researchers using the standardized brightness of objects like supernovae to establish the current cosmic expansion rate, called the Hubble Constant, get a rate of about 73 kilometers per second per megaparsec, plus or minus one. But researchers extrapolating the Hubble Constant from measurements of the Cosmic Microwave Background, the faint radiation after-image of the universe shortly after the Big Bang, get a figure of around 68 kilometers per second per megaparsec, plus or minus one, Bennett says.

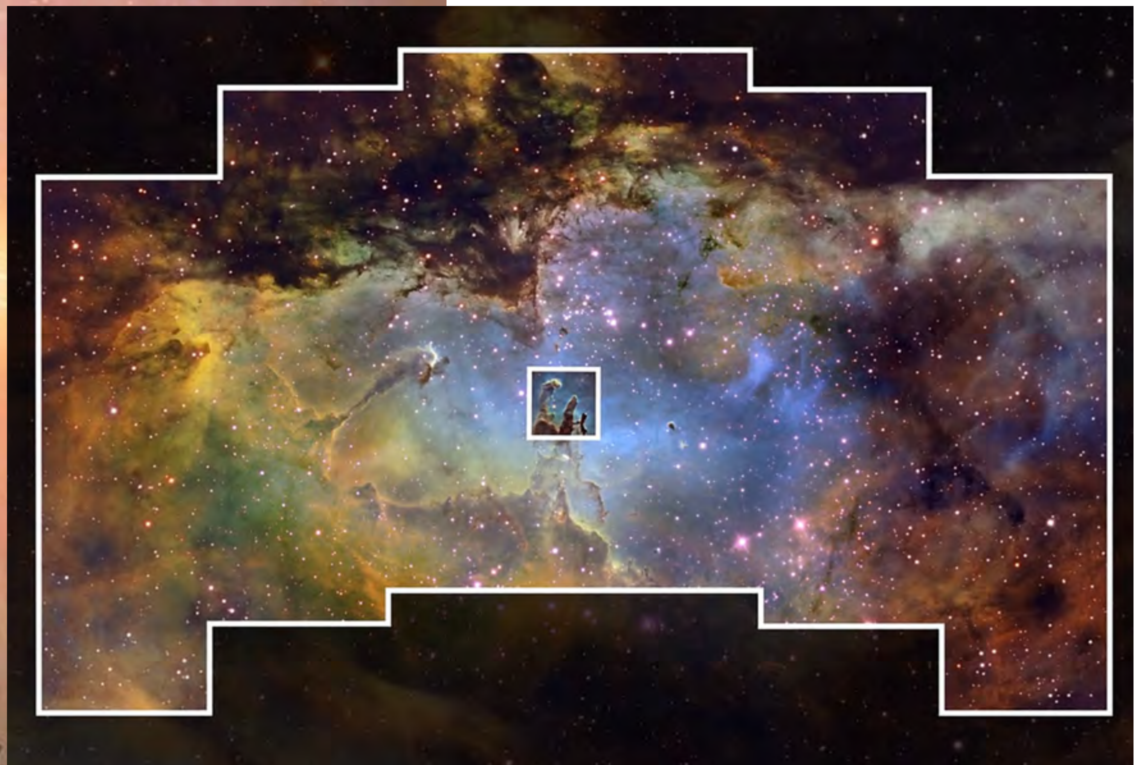
"It's been over 10 years now since we've known there was a conflict, and it gets more and more significant every year," he adds.

Cosmologists call this discrepancy the Hubble Tension, and the experts I spoke with described two possible solutions: Either there's some subtle, as-yet-undiscovered flaw in the different methods used to measure the expansion rate, or "our standard model of the universe is incorrect" and there's new physics to discover, says Julie McEnery, Roman's senior project scientist at NASA's Goddard Space Flight Center.

Solving this puzzle requires "a mission or an experiment that can probe the universe to about a factor of 10 better than we did before," she says, and Roman is slated to do just that.

Either solution to the Hubble Tension will move science forward, says Roman Program Scientist Dominic Benford, who oversees the science mission from NASA Headquarters. Discovering the measurement methodologies are subtly flawed would lead to more accurate astronomy, and "if it turns out that there is something fundamentally wrong in our understanding of the universe, we really ought to find out what that is," Benford says, "because its ramifications could be enormous" — and not just for astrophysicists.

Consider, for example, how astronomers once puzzled over small deviations in Mercury's orbit from what Newtonian physics predicted. Once Einstein published his Theory of General Relativity explaining how massive objects



▲ This image of the Eagle Nebula represents how much wider Roman's field of view will be compared to that of the Hubble Space Telescope. The square image at center is Hubble's view of the Pillars of Creation star formation.

T.A.Rector (NRAO/AUI/NSF and NOIRLab/NSF/AURA) and B.A.Wolpa (NOIRLab/NSF/AURA)) and an image by amateur astronomer Liam Murphy

warp both space and time around them, scientists were able to match their math with observations of Mercury. This in turn required engineers to apply the principle to Earth-orbiting satellites. Without those corrections, Benford says, GPS navigation would never work because coordinates for locations would drift out of alignment over time.

Dark energy explorer

Roman's mission stems from a recommendation in the 2010 Astronomy and Astrophysics Decadal Survey that NASA build a telescope to investigate dark energy, the mysterious, repulsive force believed to be driving the accelerating expansion of the universe. Also among this telescope's objectives would be to study the equally enigmatic phenomena of dark matter, which is observable only by its gravitational effects and may play a role in the structure of galaxies and galaxy clusters.

For these observations, Roman needs more precise optics and instruments than its predecessors. Like the James Webb Space Telescope, it must fly in deep space to avoid atmospheric perturbations and the glare of the sun. Roman will observe in the near infrared to capture the light of the most distant galaxies, which has been stretched into longer, redder wavelengths by the expansion of space over billions of years.

The telescope also requires a wide field of view to survey large sections of sky and measure subtle differences in the structure of galaxies and galaxy clusters. All of these attributes are equally important for the observations necessary to solve the Hubble Tension.

Though its 2.4-meter diameter primary mirror is the same size as Hubble's, Roman is also equipped with a Wide Field Instrument that can see at least 100 times as much sky at a glance and reorient on new target patches of sky 1,000 times faster than Hubble, McEnery says.

Plans call for completing a High-Latitude Time-Domain Survey, in which the telescope will hunt for supernovae by repeatedly observing 18 square degrees of the sky to discover an estimated 27,000 type 1a supernovae — about 10 times more than are currently known. Because astronomers already know the intrinsic brightness of type 1as, they can calculate their distance based on the supernovaes' relative faintness, Benford says.

And measuring their red shift — how much their light has been stretched by traversing expanding space over time — tells scientists how fast the supernovae are moving away from Earth, yielding the Hubble Constant out to that distance.

Roman will not measure the Cosmic Microwave Background directly, but it will use two primary methods

to map the expansion history of the universe from the time of the Cosmic Microwave Background to the present.

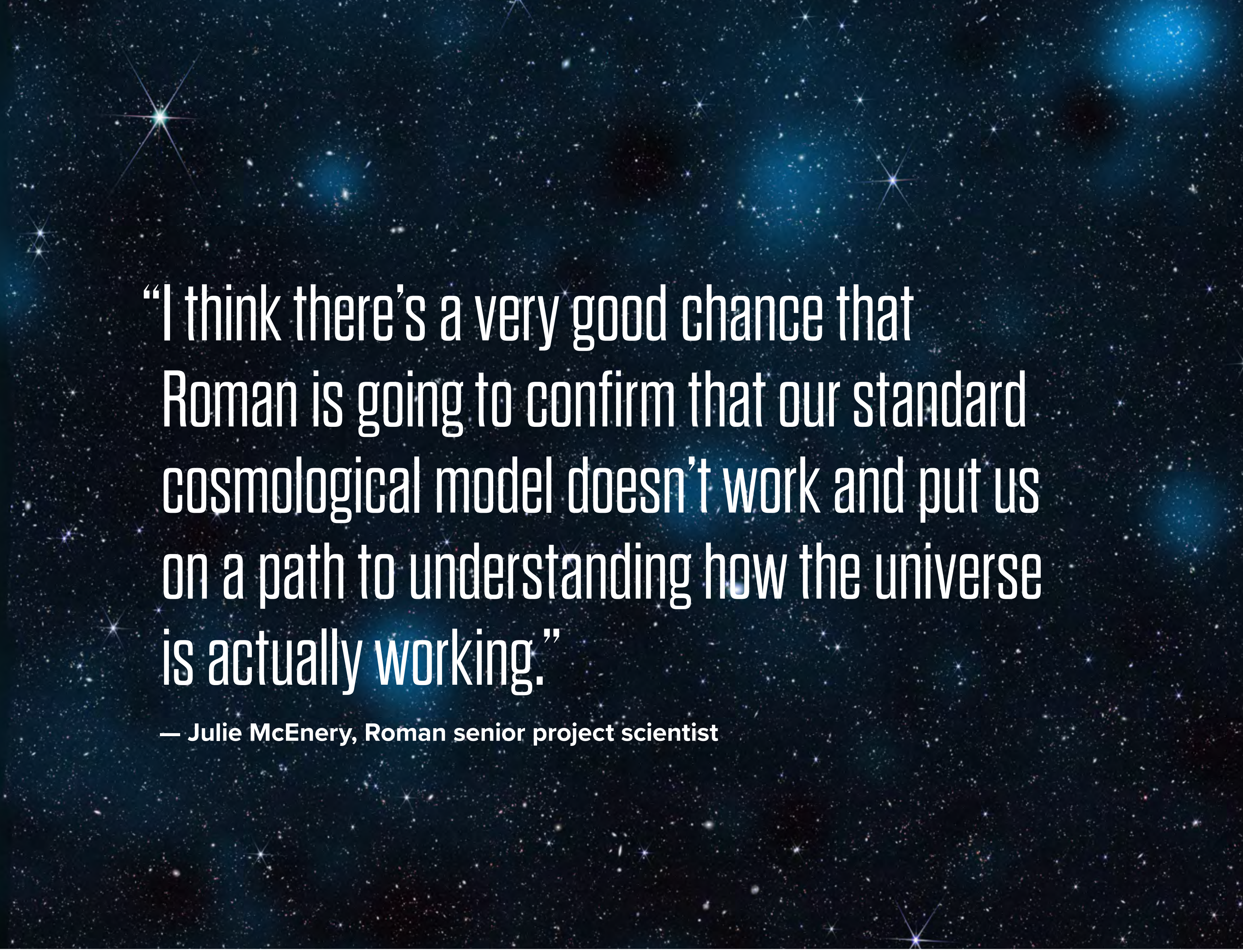
First, Roman will study Baryon Acoustic Oscillations (BAO), says Ami Choi, deputy scientist for the telescope's Wide Field Instrument. If the Cosmic Microwave Background is the afterglow of the Big Bang, BAO are the echoes: sound waves that reverberated through the infant universe, creating rings of slightly higher densities of early matter. Galaxies would later form along those rings, which have been stretched farther apart as space itself has expanded, providing a sort of cosmic ruler for the growth of the universe to be read in the large-scale pattern of galaxies.

With Roman's spectrographic instrument equipped with a "grism," a hybrid prism and diffraction grating, scientists can obtain the spectra of the light of the thousands of objects Roman views in one frame. Measuring the red shift of those spectra to obtain distances will allow them to construct a three-dimensional map of the distribution of galaxies and calculate the Hubble Constant.

Roman is also to conduct a weak gravitational lensing survey, studying the minute distortions in the observed shapes of background galaxies as the gravity of foreground

▲ Roman's primary mirror, surrounded by its visor-like sunshade.

NASA/Sydney Rohde



> "I think there's a very good chance that Roman is going to confirm that our standard cosmological model doesn't work and put us on a path to understanding how the universe is actually working."

— Julie McEnery, Roman senior project scientist

matter, including dark matter, warps the galaxies' light. By building a 3D mapping of the distribution of matter over time, scientists can arrive at another calculation of the Hubble Constant, according to McEnery.

Other ground- and space-based observatories have or will make similar measurements, but Roman will peer deeper into the cosmos, Choi says, and is unique in its ability to make so many of the measurements of the Hubble Constant from the same instrument. Earth's atmosphere limits the ability of ground-based telescopes like the Vera C. Rubin Observatory, for instance, to see the most distant supernovae with the same resolution as Roman. Rubin can discover type 1a supernovae up to about 5 billion years in the past, but Roman will capture supernovae 11 billion years in the past.

Most weak lensing surveys to date have also been conducted from the ground, and in optical wavelengths. The space-based and near-infrared-focused Roman will see more distant galaxies with greater clarity.

The European Space Agency's Euclid space telescope studies BAO, and with a wider field of view than even Roman, but will not see as deep into the sky as Roman. Its grism is also lower resolution than Roman's, says Choi, who is also a member of the Euclid science team.

"Roman is unique in this combination of being space-based, near infrared, with very well-controlled instrumental systematics and resolution," she says, and its results will be combined with other observations to provide the best measurements to date of how fast the universe is expanding and how that expansion has changed over cosmic time.

But it's not guaranteed Roman will solve the Hubble Tension. If its observations also generate the same conflicting measurements with greater precision, "the mystery could get deeper," Bennett notes.

Still, McEnery remains optimistic. "I think there's a very good chance that Roman is going to confirm that our standard cosmological model doesn't work," she says, "and put us on a path to understanding how the universe is actually working." ★

Jon Kelvey
previously covered space for The Independent in the U.K. His work has appeared in Air and Space Smithsonian, Slate and the Washington Post. He is based in Maryland.

ABOVE + BEYOND

AIAA'S PHOTO SECTION HIGHLIGHTING THE BEST IMAGES OF THE QUARTER

In April 2026, Joby Aviation's electric air taxi flew over New York City during a 10-day flight campaign celebrating the FAA's eVTOL Integration Pilot Program (eIPP), showcasing quiet, zero operating emissions air travel across the city, including flights to JFK.

Joby Aviation

The first crewed Artemis flight, 1–10 April, marked the first time humans traveled to the vicinity of the moon since 1972. This image shows the lunar surface in sharp detail during the lunar flyby, while a distant Earth sets in the background (6 April, three minutes before the Orion spacecraft went behind the moon).

NASA

The Artemis II crew – (from left) Mission Specialist Christina Koch, Mission Specialist Jeremy Hansen, Pilot Victor Glover, and Commander Reid Wiseman – pause for a group photo inside the Orion spacecraft on their way home.

From the Institute

JULY-SEPTEMBER | AIAA NEWS AND EVENTS

DATE	MEETING	LOCATION	ABSTRACT DEADLINE
2026			
7–10 Jul*	27th AIAA International Space Planes and Hypersonic Systems and Technologies Conference	Naples, Italy	
26–30 Jul*	2026 AAS/AIAA Astrodynamics Specialist Conference	Whistler, British Columbia, Canada (space-flight.org/docs/2026_summer/2026_summer.html)	
1–9 Aug*	46th Scientific Assembly of the Committee on Space Research (COSPAR 2026) & Associated Events	Florence, Italy (cospar2026.org)	
8 Sep–1 Oct	Guidance and Control of Next-Gen Missiles and Hypersonic Vehicles Course	ONLINE (learning.aiaa.org)	
13–17 Sep*	45th Digital Avionics Systems Conference	Orlando, FL (dasconline.org/2026)	
13–18 Sep*	35th Congress of the International Council of the Aeronautical Sciences	Sydney, Australia (icas2026.com)	
14 Sep–21 Oct	Turbomachinery for Emerging Space Applications Course	ONLINE (learning.aiaa.org)	
18 Sep–13 Nov	Global Space Leadership and Strategy Series – Executive Certificate in Global Space Leadership	ONLINE (learning.aiaa.org/diweb/catalog/item?id=18541734)	
18 Sep–2 Oct	Global and Agile Space Leadership Course	ONLINE (https://learning.aiaa.org/diweb/catalog)	
21 Sep–26 Oct	Machine Learning for Aircraft Applications Course	ONLINE (learning.aiaa.org)	
22 Sep–22 Oct	Advanced Sustainable Aviation Fuels and Aircraft Design Course	ONLINE (learning.aiaa.org)	
28 Sep–1 Oct	Space Systems Verification and Validation Course	ONLINE (learning.aiaa.org)	
29 Sep–13 Oct	Weapons Bay Cavity and Store Separation Course	ONLINE (learning.aiaa.org)	
5 Oct	2026 AIAA-NAE Yvonne C. Brill Lecture in Aerospace Engineering	Washington, D.C.	
5–9 Oct*	76th International Astronautical Congress	Antalya, Turkey (iac2026.org)	
6 Oct–5 Nov	Diagnostic Methods for Electric Propulsion Research and Development Course	ONLINE (learning.aiaa.org)	
6–15 Oct	Business Development for Aerospace Professionals Course	ONLINE (learning.aiaa.org)	
9–23 Oct	Global Space Business, Diplomacy, and Law Course	ONLINE (https://learning.aiaa.org/diweb/catalog)	
13 Oct–19 Nov	Airplane Performance and Flight Test Practices Course	ONLINE (learning.aiaa.org)	
20 Oct–12 Nov	Hypersonic Propulsion Concepts Course	ONLINE (learning.aiaa.org)	
26 Oct–4 Nov	Technical Writing Essentials for Engineers Course	ONLINE (learning.aiaa.org)	
26–29 Oct	Mission Design Workshop	ONLINE (learning.aiaa.org)	
27 Oct–3 Dec	Fundamentals of Python for Engineering Programming and Machine Learning Course	ONLINE (learning.aiaa.org)	
30 Oct–13 Nov	Transformative Space Technologies Course	ONLINE (https://learning.aiaa.org/diweb/catalog)	

DATE	MEETING	LOCATION	ABSTRACT DEADLINE
2026			
3–12 Nov	Project Execution for Aerospace Professionals Course	ONLINE (learning.aiaa.org)	
3–12 Nov	Aircraft Reliability & Reliability Centered Maintenance Course	ONLINE (learning.aiaa.org)	
7–8 Nov	SmallSat Education Conference	Kennedy Space Center, FL	
9–18 Nov	Generative AI for Code Generation and Evaluation Course	ONLINE (learning.aiaa.org)	
16–19 Nov	Practical Design Methods for Aircraft and Rotorcraft Flight Control Course	ONLINE (learning.aiaa.org)	
16–19 Nov	Applied Model-Based Systems Engineering Course	ONLINE (learning.aiaa.org)	
30 Nov–1 Dec	AIAA Region VII Student Conference	Adelaide, Australia & Online	
2027			
11–15 Jan	AIAA SciTech Forum	Orlando, FL	21 May26
13 Jan	2027 AIAA Associate Fellows Induction Ceremony and Dinner	Orlando, FL	
6–13 Mar*	2027 IEEE Aerospace Conference	Big Sky, MT (www.aeroconf.org)	
16–18 Mar	AIAA DEFENSE Forum	Laurel, MD	13 Aug 26
17 May	2027 AIAA Fellows and Honorary Fellows Induction Ceremony and Dinner	Washington, DC	
18–20 May	ASCEND 2027	Washington, DC	8 Oct 26
27–30 May*	ICNPAA 2027: Mathematical Problems in Engineering, Aerospace and Sciences	Sanlirufa, Turkey	
7–11 Jun	AIAA AVIATION Forum	San Diego, CA	12 Nov 26

**Meetings cosponsored by AIAA. Cosponsorship forms can be found at aiaa.org/events-learning/exhibit-sponsorship/co-sponsorship-opportunities.*

● AIAA Continuing Education offerings

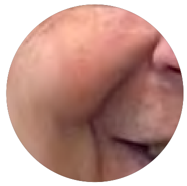
FOR MORE INFORMATION on meetings listed below, visit our website at aiaa.org/events or call 800.639.AIAA or 703.264.7500 (outside U.S.).

AIAA Special Service Citations Awarded

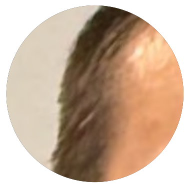
READ awarded 4 Special Service Citations last week at their spring business meeting

Ed Laverdure — For extraordinary planning, leadership, and organization to rebuild the AIAA Oklahoma Section and Arkansas Chapter.

Ramuhalli Krishna — In recognition of leadership and uncompromising excellence as Head Judge of the 2026 AIAA Region VI Student Conference in San Luis Obispo.



Linda Bangert — For sustained service to the Hampton Roads Section as Retiree Committee Chair, Honors and Awards Committee Member, and K-12 Education Outreach volunteer.



Christopher Ruscher — For outstanding service as the Chair for the Dayton-Cincinnati Aerospace Sciences Symposium (DCASS) event.

PREMIER:
- AIAA Goddard Astronautics Award
- AIAA Reed Aeronautics Award

TECHNICAL:
- AIAA Aeroacoustics Award
- AIAA Aerodynamics Award
- AIAA Aircraft Design Award
- AIAA Chanute Flight Test Award
- AIAA Fluid Dynamics Award
- AIAA Ground Testing Award
- AIAA Haley Space Flight Award
- AIAA Hap Arnold Award for Excellence in Aeronautical Program Management
- AIAA Losey Atmospheric Sciences Award
- AIAA Missile Systems Award
- AIAA Otto C. Winzen Lifetime Achievement Award
- AIAA Plasmadynamics and Lasers Award
- AIAA Space Systems Award
- AIAA Thermophysics Award
- AIAA von Braun Award for Excellence in Space Program Management

LECTURESHIP:
- AIAA David W. Thompson Lecture in Space Commerce
- AIAA Wright Brothers Lecture in Aeronautics

NOW ACCEPTING

Technical Awards and Lectureships Nominations

NOMINATION DEADLINE: 1 October 2026
REFERENCE FORMS DUE: 1 November 2026

Please submit the nomination form and endorsement letters on the online submission portal at **aiaa.org/OpenNominations.**

For additional questions, please contact **awards@aiaa.org.**

AIAA

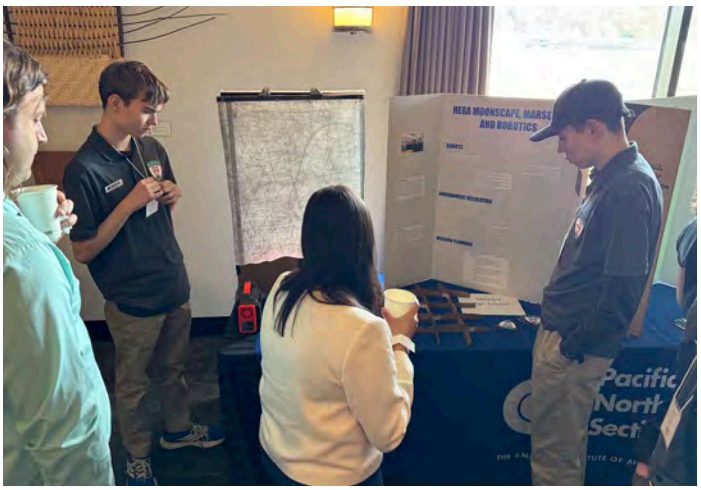
1 At ASCEND 2026, Dan Hastings, AIAA Immediate Past President, passed the gavel to new AIAA President Keoki Jackson. Jackson will serve a two-year term as president. Hastings will serve as chair of the AIAA Foundation Board of Trustees for a two-year term.

2 2026 AIAA Honorary Fellows (L to R): Daniel J. Scheeres, University of Colorado Boulder; Laura J. McGill, Sandia National Laboratories; and Steven H. Walker, Lockheed Corporation (retired).

3 During the annual 2026 Fellows Induction Ceremony on 18 May in Washington, DC, 3 Honorary Fellows and 28 Fellows were recognized for their extraordinary accomplishments.

AIAA Sections Bring Aerospace Communities Together

AIAA sections are where the action happens. Each section offers technical programs and activities tailored to local aerospace professionals, students and educators.



On 18 April the AIAA Pacific Northwest Section held its 18th Annual Technology Symposium, examining Resilience in Aerospace: Rethinking Innovation in Today's Changing World

The event at the Seattle Museum of Flight showcased the passion that continues to drive aerospace forward with speakers, technical presentations from regional experts, and networking opportunities. Georgia Tech's Dimitri Mavris gave a presentation on "The Value of Systems of Systems in Today's Engineering Environment," while Gaudy Bezos-O'Connor discussed aerospace electrification, and Will Francis from Agile Space Industries looked at the future of space commerce.

Additionally, the high school and college students who attended were especially impressive, asking many thoughtful questions.

On 25 April, the AIAA Orange County Section and the AIAA San Gabriel Valley Section held their 21st annual AIAA Southern California Aerospace Systems and Technology (SoCal ASAT) Conference at the University of California, Irvine. The event brought together seasoned and new engineers, researchers, leaders, managers, academia and students, and provided a forum to exchange new ideas, review achievements, and chart a new course for aerospace in the local area.

MAKING AN
IMPACT

AIAA Announces 2026 Regional Student Conference Winners

AIAA's annual U.S.-based 2026 Regional Student Conferences, held in the spring, attracted more than 1,100 students and professionals attended across all six of the recent conferences. There were a record-breaking 389 student papers presented, most of which will be published by AIAA and available on Aerospace Research Central (ARC) later this year. This is also the first year every region hosted a high school category.

The AIAA Foundation funds the regional student conferences, in addition to contributions from many other regional-level sponsors. The first-place winners in each of the high school, undergraduate, graduate, and undergraduate team categories (listed below) receive cash prizes.

Region I Winners

High School Category

First Place: "Real-Time Detection and Active Mitigation of Command-and-Control Link Exploits in Consumer UAVs," Joseph Park and Matthew Jablonski, Ardsley High School (Ardsley, NY)

Second Place: "AEROCOOL: Aerospike Engine Research On COOLing through Biomimicry," Devin Wanchoo, Mazen Ben Chouikha, and Michael Obeng, Osbourn Park High School/Governor's School at Innovation Park (Manassas, VA)

Third Place: "Feel the Beat: A Wearable Vibrotactile Device for the Deaf and Hard of Hearing," Tanmayi Mendu, Thomas Jefferson High School for Science and Technology (Alexandria, VA)

Undergraduate Category

First Place: "Free-Flight Aerodynamics of Ellipsoidal Clusters in Hypersonic Flow," Robert Chase Latyak and Stuart Laurence, University of Maryland College Park (College Park, MD)

Second Place: "A Computational Approach to Graduate Centrifuge Profiles for Patrial Gravity Planetary Environments," Cabell Jones, Old Dominion University (Norfolk, VA)

Third Place: "Design and Implementation of a Six-Element Autonomous Active Aerodynamics System for Formula SAE," Duncan Kuchar, Leonard Hamilton, and Huan Xu, University of Maryland College Park (College Park, MD)

Graduate Category

First Place: "Partial Optimization of Spacecraft Sandwich Shielding from Hypervelocity Impacts," Brandon Soto and Javid Bayandor, University at Buffalo (Buffalo, NY)

Second Place: "Overcoming the Parametric Modeler: A Native Python Approach to the Particular Risk Analysis," Joey Vézina, Luca Leccese, and Susan Liscouët-Hanke, Concordia University (Montreal, Quebec, Canada)

Third Place: "Inverse Kinematic Solutions for the BioBot Concept's Support Umbilical Tending Manipulator," Romeo Perlstein, Sai Srujana Theerthala, and David Akin, University of Maryland College Park (College Park, MD)

Team Category

First Place: "Comparison of High Energy Density Fuel Additives Hybrid Rocket," Cayden Smedley, Aidan Lennon, and Ian Keil, Virginia Polytechnic Institute and State University (Blacksburg, VA)

Second Place: "Development of a Low-Cost, High-Precision Two-Stage Airdrop Model," William Scheirey, Paige Rust, William Kiley, and Tanner Ferguson, Worcester Polytechnic Institute (Worcester, MA)

Third Place: "Design and Validation of a Gravity-Gradient Boom Arm for Hybrid Attitude Control of a PocketQube Satellite," Leopold Zitzmann,

Lucas Wing, Trout Marnell, Olivia DeMelo, Kyle Leger, Emily Hagen, Aiden Leduc, and Saurav Basnet, Wentworth Institute of Technology (Boston, MA)

Region II Winners

High School Category

First Place: "Integrated Aero-Structural Optimization of Bio-Inspired and Generative AI Airfoils with Internal Lattice Architectures," Saahil Doshi, Cashton Isaac, and Ramana Pidaparti, Oconee County High School (Watkinsville, GA)

Second Place: "Computational Analysis of Propeller-Wing Interaction: Quantifying Lift on a NACA 4412 Airfoil," Tejus Peri and Ansh Mishra, Alliance Academy for Innovation (Cumming, GA)

Third Place: "Real-Time Digital Twin Implementation for Predictive Maintenance of UAVs Using Embedded Sensor Fusion and Machine Learning," Naren Pai, William G. Enloe High School (Raleigh, NC)

Undergraduate Category

First Place: "Aero-Acoustic Optimization and Experimental Validation of a NACA 2415 Toroidal UAV Propeller," Abhinav Das, University of North Carolina at Charlotte (Charlotte, NC)

Second Place: "Design, Manufacturing, and Testing of a Data Acquisition System for Use in the Development of Control Systems for Fixed-Wing Unmanned Aerial Systems," Tucker Jaudon and Austin Hoff, Mississippi State University (Starkville, MS)

Third Place: "Modeling and Stability Analysis of Inertial Roll Coupling in Supersonic Sounding Rockets," Saptak Das, Georgia Institute of Technology (Atlanta, GA)

Graduate Category

First Place: "Exact Beltramian Solution of the Bidirectional Vortex Motion in a Capped Ellipsoidal Cyclonic Rocket Engine," Patrick Eid and Joseph Majdalani, Auburn University (Auburn, AL)

Second Place: "Novel Modification of Shock-Tube Facility for Strain-Testing of Carbon Fiber Airframes Under Impulsive Shock Loading," Jonathan Zak, Vanderbilt University (Nashville, TN)

Third Place: "An Image–Based Stochastic Model for Predicting Microstructure Effects on Shock-Induced Ignition and Burn in Pressed HMX," Philip Melton and Keith Gonthier, Louisiana State University (Baton Rouge, LA)

Team Category

First Place: "Reaction Wheel Roll Stabilization and Control for an L1 High-Power Rocket," Sebastien Martinez, Ethan Koh, Renato Dell'Osso, Rachit Gupta, Dahananjay Manikandan, Dante Midei, and Lucas Alonso-Munoyerro, Georgia Institute of Technology (Atlanta, GA)

Second Place: "Integrated Design and Analysis of a Low-Cost, Motor-Driven Airbrake System for a Sounding Rocket," Juan Alizo Ewald, Gavin Wilson, Nicholas Dagnino, Parsa Novin, Austin Applestone, Andrew Darby, and Brooklyn Schnupp, University of Georgia (Athens, GA)

Third Place: "Design of a 1000 N N2O/Paraffin-ABS Hybrid Rocket Engine for a Reusable VTVL Lander," Sukhmani Sethi, Matthew Xu, Veer Gudhka, Chengle Qian, Felix Gusic, Valeriy Donchev, Amaan Patel, Grace Dilgard, and Szu Heng Chen, Georgia Institute of Technology (Atlanta, GA)

Outstanding Student Branch Category

First Place: "How to Plan Your Conference: the University of South Carolina's Guide to Large Event Planning," University of South Carolina (Columbia, SC)

Second Place: "From Rocky Top to the Classroom: K-5 STEM Outreach by the Volunteers," University of Tennessee Knoxville (Knoxville, TN)

Third Place: "Florida Tech AIAA: Expanding Student Opportunity on the Space Coast and Beyond," Florida Institute of Technology (Melbourne, FL)

Open Topic Category

First Place: "Applications of Quantum Optimization Algorithms in Low-Thrust Spaceflight Navigation," Aneesh Sattiraju and Skyler Kim, Georgia Institute of Technology (Atlanta, GA)

Second Place: "Comparative Analysis of Energy Absorption in TPMS vs. Honeycomb Lattices for Lunar Lander Strut Attenuation," Gabriel Brazzeal and Kenza Rih, University of Florida (Gainesville, FL)

Third Place: "Exploring Space Medicine: Human Health Hazards in Space Exploration," Alyssa Bice, University of Tennessee, Knoxville (Knoxville, TN)

Region III Winners

High School Category

First Place: "A Probabilistic Framework for Terrain-Aware Emergency Site Selection Under Thrust Loss," Bhavna Jonnadula, Troy High School (Troy, MI)

Second Place: "Interaction-Induced Momentum Redistribution in Clustered Hall-Effect Thrusters Using a Reduced Prescribed-Field Model," Venkataashish Gogineni, Illinois Mathematics and Science Academy (Aurora, IL)

Third Place: "Optimization of Rocker-Bogie Suspension Systems for Improved Rover Traversal Speed on Extreme Extraterrestrial Terrain," Emilee Colton, Sumedh Pendyala, and Makayo Cheung, Oswego East High School (Oswego, IL)

Undergraduate Category

First Place: "Feasibility of Low-Cost Hypersonic Vehicles for Second-Mode Instability Data Collection," Aditya Singh and Brandon Chynoweth, Purdue University (West Lafayette, IN)

Second Place: "Development and Optimization of Inductively Coupled Plasma Neutralizer for Electric Propulsion Applications," David Rubin, Stephen Tushentsvo, and Alexey Shashurin, Purdue University (West Lafayette, IN)

Third Place: "Automated Processing and Classification of Lidar Point Clouds for Flight Path

Modeling Software," Kavanaugh Frank and Chad Mourning, Ohio University (Athens, OH)

Graduate Category

First Place: "Thermodynamic Cycle Analysis of Turbo-Compound Engine with High-Efficiency-Hybrid-Cycle Internal Combustion Rotary Configuration," Chloe Amoroso and Maryam Younessi-Sinaki, Cleveland State University (Cleveland, OH)

Second Place: "Hybrid Actuator Control Allocation: A Hardware Comparison of QP and PI Allocators on an Air Spindle Testbed," Jad Halabi, Ritwik Majumdar, and Oliver Jia-Richards, University of Michigan Ann Arbor (Ann Arbor, MI)

Third Place: "Pulse Detonation Driven Ignition of a Rotating Detonation Engine," Ryan Timmerman and Jason Payyappilly, Purdue University (West Lafayette, IN)

Team Category

First Place: "Examination of the Viability of Reclaimed Gas Electric Propulsion for Orbit Maintenance of Crewed Space Stations," Noah Negron, Sashvat Krishnan, Henry Poutasse, and Oliver Jia-Richards, University of Michigan Ann Arbor (Ann Arbor, MI)

Second Place: "Design, Testing, and Comparisons of a Carbon Dioxide Compressed Gas Propulsion Module for IU CubeSat Platforms," Varun Chitiveli, Brody Booker, Max Cirino, Antonio Accardo, and Nishanth Kunchala, Ohio State University (Columbus, OH)

Third Place: "Design and Analysis of a Hydrogen-Air RDC for Power Generation Research," Deepesh Balwani, Sumit Laha, Anjali Patel, Oluwaniademi Ogundana, and David Taranowski, Purdue University (West Lafayette, IN)

Region IV Winners

High School Category

First Place: "Feasibility of Oblique Wings in Aircraft Design and Efficiency," Maximus Pongkorung, Atascocita High School (Humble, TX)

Second Place: "Analyzing Lift Generation in a Modified Magnus Cylinder-Integrated Airfoil for Short Take-Off and Landing," Ajinkya Joshi, Marzia Cescon, Daniel Floryan, John Foster Dulles High School (Sugar Land, TX)

Third Place: "Velocity and Angle Compensated Turret Aiming for Simultaneous Shooting and Motion," Arka Rebbapragada, Arun Rebbapragada, Wanni Zhu, and Stuart Otten, Newman Smith High School (Carrollton, TX)

Undergraduate Category

First Place: "Characterization of Mack Mode Instabilities in Mach 7 Flow," Smruthi Shashidhar and Mackenzie Vargas-Lebron, University of Texas at San Antonio (San Antonio, TX)

Second Place: "Experimental Evaluation of Counter-Rotating Co-Axial Propellers with Variable Spacing and Dissimilar Shaft Speeds," Gage Nold and Nathan Revor, Oklahoma State University (Stillwater, OK)

Third Place: "Image Processing and Time of Flight Analysis of Propagating Shocks," Richard Otano, University of Texas – Arlington (Arlington, TX)

Graduate Category

First Place: "Configuration Aerodynamics Methodology for Conceptual Design of Hypersonic Vehicles," Stephen Atkins, University of Texas at Arlington (Arlington, TX)

Second Place: "Design and LPV Modeling of Deployable Integrated Tensegrity Torus–Cable Domes," Weizhi Cao, University of Houston (Houston, TX)

Third Place: "Markov Chain Monte Carlo Estimation of Satellite Ballistic Coefficients for Re-entry Prediction," Caden Matthews, University of Oklahoma (Norman, OK)

Team Category

First Place: "FSO Communications with Liquid Crystal Spatial Light Modulators for Hypersonic and Re-entry Vehicles," Ashlan Benson, Ruben Ooms, and Austin Eckert, Tarleton State University (Stephenville, TX)

Second Place: ""Jinx": High Thrust-to-Weight Ratio Design for Collegiate Bi-Propellant Liquid Rocket Development," Grace Zimmer, Haven Russell, and Emilio Mayorga, University of Texas at San Antonio (San Antonio, TX)

Third Place: "Concentration of Ozone and Cosmic Radiation in the Stratosphere," Evan Sie, Deborah Luo, Advaith Madala, Janani Arunpraksh, and Afreeda Hossain, University of Texas at Dallas (Richardson, TX)

Region V Winners

High School Category

First Place: "Physics-Informed Learning of Jet Stream Variability and Aircraft-Relevant Momentum Transport Using Reanalysis Data," Naga Sai and Dhiraj Kasam, Moline Sr High School (Moline, IL)

Second Place: "A Multi-Fidelity Framework for Trustworthy AI-Driven Transonic Airfoil Optimization with Automated Hallucination Detection," Krithik Senthilkumar, Illinois Mathematics and Science Academy (Aurora, IL)

Undergraduate Category

First Place: "Reducing Sputtering on Spacecraft to Mitigate Secondary Radiation Exposure," Anton Golovko, University of North Dakota (Grand Forks, ND)

Second Place: "Aerodynamic Shape Optimization for the DPW4 Transport Aircraft Using DAFoam," Nicholas Barber, Iowa State University (Ames, IA)

Third Place: "Multidisciplinary Design Optimization of Adaptive Cycle Engine Aircraft using Aviary," Marcos De Leon, Iowa State University (Ames, IA)

Graduate Category

First Place: "Online Inertia Tensor Identification for Non-Cooperative Spacecraft via Augmented UKF," Batu Candan, Iowa State University (Ames, IA)

Second Place: "A Data-Driven Assessment of Impact Erosion Resistance Using ML and Multi Criteria Decision Making," Debanan Bhadra, Iowa State University (Ames, IA)

Third Place: "Modeling Relativistic Effects on Clocks in Cislunar Space Along Reference Trajectories of Varying Dynamical Fidelity," Emily Matteson, University of Colorado Boulder (Boulder, CO)

Team Category

First Place: "Use of Formal Verification Techniques for the Dynamic Degradation of the GRIFEX CubeSat." Michael Jacks, Gustavo Abagge Luzzi, Isabella Brewer, and Erin Riley, Iowa State University (Ames, IA)

Second Place: "Multi-Rover GNC Architecture for Autonomous Searching Using Frontier Planning and Gain-Scheduled Control," Yu Kang Kong and Vishnu Duriseti, University of Colorado Boulder (Boulder, CO)

Third Place: "Evaluation of Subsurface Probe for Investigating Cryogenic Environments for the Enceladus Underwater Robotic Observation and Property Analysis Mission," Benjamin Forbes, Adrian Acevedo, Melanie Reym, Brandon Velarde, and Nathan Brubaker, Saint Louis University (St. Louis, MO)

Region VI Winners

High School Category

First Place: "A Heuristic Load-Balancing Algorithm for Multi-Mesh Simulations on GPUs," Leo Sitaraman, Homestead High School (Cupertino, CA)

Second Place: "Passive Flow Control with Turbulators on the ROAMX-0201 Airfoil at Low Reynolds Numbers," Daniel Guo, The Bishop's School (LA Jolla, CA)

Third Place: "A Novel Method for Reorienting CubeSats Using Non-Commutative Internal Movements," Gregory Shechter, Palos Verdes High School (Palos Verdes Estates, CA)

Undergraduate Category

First Place: "Residual Learning of Universal-Variable Corrections for Fast Lambert Transfers," Drew Stannard-Stockton, California Polytechnic State University San Luis Obispo (San Luis Obispo, CA)

Second Place: "GPU Acceleration of 2D Panel Methods for Rapid Aerodynamic Prediction," Gisselle Frisby, California State University, Long Beach (Long Beach, CA)

Third Place: "Two-Mode Adaptable Camber Wing Design for Subsonic Cruise Efficiency," Samuel Thomas Joseph, San José State University (San Jose, CA)

Graduate Category

First Place: "SpaceOTTER – Space Optically Tracked Testbed for Experiments and Research," Alexander DeBartolo, California Polytechnic State University San Luis Obispo (San Luis Obispo, CA)

Second Place: "Development of a 3 Degree of Freedom Manipulator for Use on a Planar Microgravity Testbed," Jackson Cordova, California Polytechnic State University San Luis Obispo (San Luis Obispo, CA)

Third Place: "Design and Optimization of Repeat Ground Track Constellation for Discontinuous Regional Coverage," Paige Jewell, California Polytechnic State University San Luis Obispo (San Luis Obispo, CA)

Team Category

First Place: "Development and Testing of an Autonomous Guided Parafoil for Small Suborbital Payload Recovery," Nicholas Lototsky and Andrew Lana, University of Southern California (Los Angeles, CA)

Second Place: "Particulate Contamination Detection and Targeted Removal for Telescope Optics," Jack Clark and Alisa Higuchi, University of Southern California (Los Angeles, CA)

Third Place: "Design and Construction of Water Electrolysis Propulsion System," Nathan Huynh and JC Garcia, University of Southern California (Los Angeles, CA)

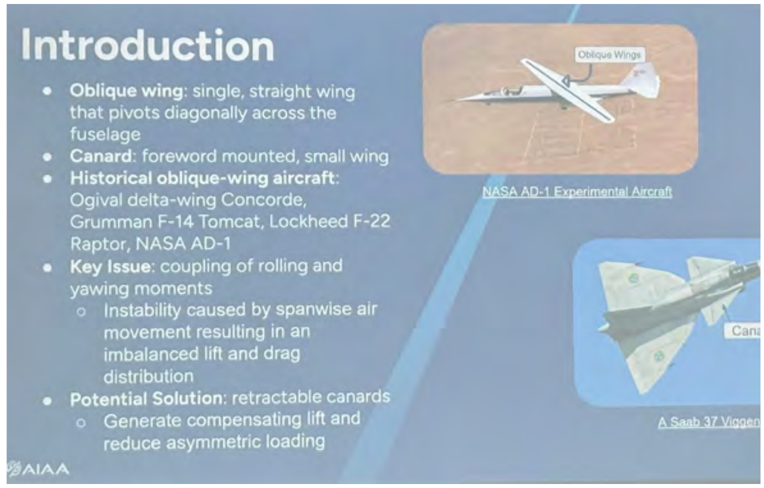
High School Students Dive into Aerospace Research at Regional Student Conferences

Jake Williams, Senior Manager of K-12 and Young Professional Programs, AIAA

At AIAA Regional Student Conferences students present their research in a formal technical meeting atmosphere, as well as exchanging ideas and discussing programs with students from other schools in the region. 2026 marks the first time that every student conference featured a dedicated track for high school students to present their work. Between the six 2026 Regional Student Conferences held in the United States, a total of 42 papers were presented by high school students.

Mudit Budhdev, a high school junior from California, presented work on behalf of his team at the Region VI Student Conference at Cal Poly – San Luis Obispo in March. Mudit's interest in aviation kicked off when he was in the 8th grade. "I used to be really into playing flight simulator games online. I think I logged about 2,000 hours in one of those games."

Interested in building his own video game, Mudit explored "learning how to do the 3D modeling and coding," and realized he "learned so much about aircraft from that." This research led him to his current passion for aircraft and aerodynamics, and he started reading everything he could about the subject.



One pivotal book for Mudit was *Skunk Works: A Personal Memoir of My Years of Lockheed* by Ben Rich. "It's a really good book. Exhilarating." Mudit recalled, "After that I read a lot of aerodynamics textbooks and then I self-taught myself a bunch of computational fluid dynamics (CFD) because I just find it super cool. And then, I heard about AIAA and joined as a high school member, and now here we are."

Mudit's research group is a mix of high school seniors, juniors, and some sophomores. They met through the AIAA High School Subcommittee (**www.aiaa.org/get-involved/committees-groups/high-school-subcommittee-interest-form**): the group of highly active High School Student Members who collaborate on a variety of hands-on activities and initiatives. At first, Mudit's group would meet every Sunday, connecting on the AIAA high school Discord server. As the conference got closer, they started meeting more frequently to reach their goals – a challenge as many of them live in different time zones across the globe.

Mudit described their topic, "A couple years ago, NASA wanted to see how to optimize aircraft for supersonic flight. They came up with the idea of, instead of making the wing perpendicular to the fuselage, instead they angled it. That's known as an oblique wing aircraft." This design was made a reality with the creation of the NASA AD-1.

Mudit read all the papers about the aircraft he could find. This research led him to the understanding that the design had an inherent instability; the aircraft consistently wants to roll.

The high school team's paper, "Optimization and Practicality of Canards on Oblique-Winged Aircraft at Transonic Speeds," describes a possible solution, a forward-mounted small wing that generates additional lift, called a canard. "What we were looking at," said Mudit, "Was the impact of placing a canard at the deflection angle, and we measured the oblique wing angle and then measured how, hypothetically, a canard could fix the inherent aerodynamic instability within the oblique wing aircraft. What's great about the oblique wing is they actually get rid of the sonic boom that you hear in supersonic fight. And it's much more fuel efficient. Because these oblique wing designs are so fuel efficient, it could hypothetically help solve many challenges we now face with supersonic flight."

Presenting at the AIAA Region VI Student Conference was a new experience for Mudit. "It was very fun. It was cool to see other people who are also so interested in planes and aircraft and aerospace in general. I don't think I've ever been in a place before that had so many people who are so knowledgeable and excited about aerospace all in one place." He appreciated the opportunity to talk in depth with students

and professionals of all ages about planes, aircraft, and CFD. "I enjoyed speaking about the research our team did. It was fun having people ask me thoughtful questions about it. And it was great to get feedback from the judges so I can improve next time."

Finding this network of people energized and interested in the same fields has been transformative. Beyond the people he met in person at the conference, Mudit is appreciative of the high school subcommittee group. "They're a community of young people that I can work with and I can talk to about planes."

His experience with both the research team and conference presentation have strengthened Mudit's commitment to the field. When he goes to college in a few years, he plans to major in aerospace engineering or aeronautical engineering. "I want to do more research in aerodynamics. The regional student conference was a very fun experience. So, I'm excited to continue doing this."

Abstract submissions for the 2027 Region I–VI Student Conferences will open in September. Learn more at www.aiaa.org/get-involved/university-students/regional-student-conferences/

AIAA Strengthens Connections with Student Branches

AIAA has more than 270 student branches, including over 60 international student branches, and a total active membership of over 9,000 students worldwide. These branches connect students who share a passion for aerospace while fostering collaboration, professional growth and education development.

AIAA University Relations Manager Carla Soto recently visited several student branches across the Mid-Atlantic region to connect with students, learn more about their activities, and support student engagement in aerospace.

At Virginia Tech, the student branch hosted its final meeting of the academic year, sharing tips and lessons learned from summer internship experiences. The meeting also celebrated graduating seniors while welcoming a new group of freshmen joining AIAA and becoming involved in aerospace opportunities on campus.

At Virginia Commonwealth University, students shared the inspiring story of reactivating their AIAA Student Branch from just a small group of interested students into a growing aerospace community on campus. Their branch has created a collaborative space for students interested in aerospace and engineering and participated in the 2026 AIAA Region Student Conference.

At the University of Maryland, College Park, Soto attended the student branch's spring banquet, where students recognized faculty advisors, celebrated student achievements, and introduced the newly elected executive board for the upcoming academic year. Students also reflected on their experience hosting the AIAA Region I Student Conference and shared many of the accomplishments, planning efforts, and collaboration that went into organizing the event.

These visits reflect AIAA's continued commitment to supporting student branches and fostering the next generation of aerospace professionals.

New Student Branches Approved

At the spring business meetings, nine new student branches have been granted three-year provisional charters to ensure they are sustainable before being officially chartered as a student branch.

The universities include:

- Aviation & Aerospace University, Bangladesh
- College of New Jersey
- Florida Polytechnic University
- Midland Community College
- McMaster University
- Temple University
- University of Hong Kong
- University of Tulsa
- Westmont College

Student branches allow university members to build valuable networks, develop leadership skills, and engage in activities that support their academic and career aspirations. To find out how your institution can establish a student branch, visit **aiaa.org/get-involved/university-students/student-branches**.

AIAA Fellow Vinson Died in October 2025

Pioneering UD mechanical engineer remembered for shaping the field of composite materials

Jack R. Vinson, H. Fletcher Brown Professor Emeritus of Mechanical Engineering and co-founder of the Center for Composite Materials (CCM) at the University of Delaware, died on 8 October 2025. He was 95.

Vinson earned his bachelor's degree in mechanical engineering from Cornell University in 1952. He later studied theory of structures and advanced strength of materials at Cambridge University in England as a Rotary International Fellow.

In the mid-1950s, he served as an officer at the Aeronautical Research Laboratory at Wright-Patterson Air Force Base before joining General Electric's Missile and Space Division, where he contributed to early intercontinental ballistic missile and satellite systems.

After earning his doctorate in engineering mechanics at the University of Pennsylvania in 1961, Vinson became vice president and senior scientist at Dyna/Structures, Inc., where he consulted on major aerospace projects such as the Minuteman intercontinental ballistic missile.

In 1964, he joined the University of Delaware as an associate professor, later becoming the H. Fletcher Brown Professor of Mechanical and Aerospace Engineering and serving as chair of the Mechanical and Aerospace Engineering Department from 1965 to 1979. In the late 1960s, he taught one of the first composite materials courses in the United States.

Vinson made seminal contributions to the understanding of composite structures, particularly curved shapes known as shells and "sandwich" structures. He also studied how these materials respond under extreme forces, such as impacts and explosions. Along with co-founders Tsu-Wei Chou, Roy McCullough, and R. Byron Pipes, Vinson established a center of excellence for composite materials research and education, serving as the first director from 1974 to 1978.

Throughout his career, Vinson authored eight textbooks and more than 400 papers. He founded the *Journal of Sandwich Structures and Materials* and served as its editor-in-chief for more than two decades, helping establish it as a cornerstone of the composites community.

After retiring from full-time academia in 2005, Vinson taught four graduate courses through distance learning and mentored students around the globe as a professor emeritus. He also advised industry and served as an expert witness in legal cases through his consulting practice, Structural Mechanics Associates.

His many honors included the AIAA Award in Structural Mechanics, the ASME Centennial Medal, the ASC Technomic Award, the ASC National Distinguished Research Award, the Medal of Excellence in Composite Materials and the Office of Naval Research–AIAA Research Award. He was a Life Fellow of ASME, and a Fellow of AIAA and ASC.

Photos courtesy of the University of Delaware Archives and Records Management

AIAA Associate Fellow Cash-Berry Died in May 2026

Carol Cash-Berry, an AIAA Associate Fellow and a long-time member of the AIAA Northern Ohio Section, passed away on 2 May.

Cash-Berry received her BA in Business/Marketing from Baldwin Wallace University in 1994. She then worked for GE Aircraft Engines for 37 years as a Field Representative and a Marketing Manager. After retiring from GE in 2007, she had a career as a consultant to the aerospace industry, establishing Carol Cash & Associates, and working with the Ohio Aerospace Institute where she was a long-term consultant and project manager for the Propulsion Instrumentation Working Group (PIWG).

Active in AIAA for more than 30 years, Cash-Berry was a leader across the Institute in the area of public policy. She served in leadership roles at the section, regional, and national levels, and for many years she helped shape AIAA's public policy initiatives. She served on the AIAA Board of Directors from 2010 to 2013 as the Vice President for Public Policy. She also led the Northern Ohio Section's Public Policy efforts for many years, and she was the original founder of the highly impactful "Team Ohio" Public Policy group, which she started back in 1998.

Cash-Berry was also instrumental in the planning and execution of many important AIAA conferences, including the 34th and 50th Joint Propulsion Conferences (JPC), which were held in Cleveland in 1998 and 2014, respectively.

She was recognized as a tireless AIAA advocate with 2000 and 2001 Special Service Citations and a 2005 Sustained Service Award for extended service to AIAA at the section, regional, and national levels including ongoing visionary leadership of AIAA aeronautics policy activities.

AIAA Fellow Williams Died in June 2026

David R. Williams, Professor Emeritus, Research Professor, Professor of Mechanical and Aerospace Engineering, Illinois Institute of Technology, died on 2 June. He was 71 years old.

Williams had an early interest in aerospace and fluid dynamics, building his first sailboat and a soap box derby car in his teen years. He received his Bachelor of Engineering in Mechanical Engineering from Stevens Institute of Technology (1976) and went on to receive his M.S. and Ph.D. in Fluid Dynamics at Princeton University in 1979 and 1982, respectively.

In 1982 Williams was an Alexander von Humboldt Fellow in Germany, before joining the Illinois Institute of Technology in 1984, where he taught for 42 years. His research was in the area of unsteady aerodynamics and active flow control for flight vehicle control. Williams retired in December 2025 as Professor Emeritus.

Williams was a member of ASME and an AIAA and American Physical Society Fellow. He was a long-time member of the AIAA Fluid Dynamics Technical Committee.

Examining the 'unknown knowns'

BY AMANDA SIMPSON | simpson.amanda.r@gmail.com

Even if you're not familiar with former U.S. Defense Secretary Donald Rumsfeld, you've likely heard the three categories he laid out in a 2002 press conference: "known knowns," "known unknowns" and "unknown unknowns." While much attention has been paid to the last category — the risks we cannot foresee — an equally intriguing and often overlooked concept is a fourth category that might be called the "unknown knowns."

These are truths, assumptions or pieces of knowledge that exist within a system or organization, but are not consciously recognized, articulated or fully understood. In aerospace, these "unknown knowns" can play a decisive role in both innovation and failure.

In aerospace, we develop and operate the most intricate machines humans have ever created. Our work transports people and cargo around the globe, to the moon and to the farthest corners of the solar system. Modern aircraft and spacecraft integrate aerodynamics, propulsion, material science, control systems, software and much more into highly coupled architectures.

We rely upon models and simulations to manage these systems. Yet, within these processes lie embedded assumptions included in the design or practices and rarely questioned or even noticed. These are the "unknown knowns."

While Rumsfeld did not include this fourth term in his original address (now often referred to as the Rumsfeld Matrix), some have suggested this might be the most significant category of all. Social scientist Steve Rayner argued these are "the things we don't admit that we know"— a form of what he called uncomfortable knowledge.

Philosopher and psychologist William James observed people cannot easily absorb every complex idea, which leads to overlooking their basis and influence in our decisions. "By far the most usual way of handling phenomena so novel that they would make for a serious rearrangement of our preconceptions is to ignore them altogether," he wrote in his 1904 lecture series, "What Pragmatism Means."

One way unknown knowns manifest is through legacy knowledge. Aerospace builds upon decades of prior work, so design standards, empirical formulas and safety margins are often inherited from earlier generations of best practices. Engineers working on one part of a system may not fully understand how their changes interact with other parts, and often no single engineering team has a complete mental model of the system's behavior due to the complexity. This is particularly common in today's systems, which are dependent upon millions of lines of computer code. This creates a gap between what is technically known and what is cognitively understood.

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.

Historical aerospace incidents illustrate the dangers of unknown knowns. Failures are rarely traced to a single cause; more often, they result from misinterpreted or overlooked information that was available but not properly understood. Data may have indicated a potential problem, but its significance was not appreciated due to assumptions, normalization of deviance or fragmented communication. In hindsight, these failures often appear preventable, precisely because the necessary knowledge was present.

Take the 1986 space shuttle Challenger disaster. There were concerns about launching given that morning's low temperature, but information about the problem was discarded. Thirteen years later, the Mars Climate Orbiter failed to reach Martian orbit because of an overlooked conversion error as it was assumed all teams were using the same units.

At the same time, unknown knowns are not purely negative. They can also be a source of innovation. Engineers often rely on intuition — patterns recognized through experience, but not fully articulated. This inferred knowledge can guide design decisions in ways that formal analysis cannot.

For instance, an experienced technologist might sense that a particular configuration "feels wrong" based on subtle cues, even before simulations confirm it. This intuition represents a form of unknown knowing: knowledge that is real and valuable, but not fully explicit.

> "These are truths, assumptions or pieces of knowledge that exist within a system or organization, but are not consciously recognized, articulated or fully understood. In aerospace, these 'unknown knowns' can play a decisive role in both innovation and failure."

The challenge is how to manage unknown knowns. One approach is to emphasize reflective practice. Engineers, designers and managers should be encouraged not only to apply established methods but also to question their origins and assumptions. Documentation can play a role by capturing not just what decisions were made, but why they were made. This helps transform unknown knowns into known knowns.

Another strategy is to foster interdisciplinary communication. Bringing together experts from different domains or organizations can surface hidden assumptions and reveal gaps in understanding. For example, a materials scientist and a software engineer might interpret the same data differently, and their dialogue can uncover insights neither would reach alone.

Similarly, robust peer review and independent verification processes can help identify knowledge that is present but unrecognized. Again, documentation and broad communication could assist others seeing similar assumptions in their work.

The use of artificial intelligence could offer new tools for addressing unknown knowns. Machine learning can detect patterns and anomalies in large data sets that elude human attention. However, these tools introduce their own challenges as they create a new layer of opacity. Engineers and designers must be careful that they are not shifting unknown knowns into a different domain by relying on automated systems. This care must be particularly employed as we incorporate new technologies, materials and processes that may invalidate some of our unknown knowns.

Ultimately, the concept of unknown knowns highlights a fundamental tension in aerospace: the gap between what a system actually is and what we humans understand about it. As the industry continues to evolve toward more autonomous, adaptive and interconnected systems, this gap is likely to widen. Managing it will require not only technical expertise but also epistemological awareness: an understanding of how we know what we know — and what we might be failing to recognize.

The Rumsfeld Matrix was originally framed in the context of national security, but its relevance extends far beyond. In aerospace, the unknown knowns remind us that knowledge is not simply a matter of possession, but of awareness.

The most dangerous risks may not be those that are hidden, but those that are hiding in plain sight, embedded in our systems, practices and assumptions. By striving to uncover and understand these hidden layers of knowledge, aerospace professionals can build not only more advanced systems, but also more resilient and self-aware ones. ★

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.

LOOKING BACK

100, 75, 50, 25 YEARS AGO IN JULY–SEPTEMBER

COMPILED BY FRANK H. WINTER AND ROBERT VAN DER LINDEN

1926

July 2 Following the passage of the Air Corps Act of 1926, the U.S. Army Air Service becomes the Army Air Corps. The corps gains more independent decision-making, a step toward the creation of a separate military branch. **Aircraft Yearbook, 1927**, pp. 70-72.

Aug. 11 William MacCracken, the driving force behind the Air Commerce Act of 1926, becomes the first assistant secretary of commerce for aeronautics, overseeing the new Aeronautics Branch tasked with regulating U.S. aviation. The organization is a precursor to the Federal Aviation Administration. **Aircraft Yearbook, 1927,** pp. 6-7.

1 **Sept. 21** The Sikorsky S-35 biplane crashes during takeoff from Roosevelt Field in New York. Fire demolishes the aircraft, killing radio operator Charles Clavier and mechanic Jacob Islamoff. Pilot René Fonck and copilot Lawrence Curtin escape with minor injuries. Witnesses report a crosswind that increased drag, although weight records indicate the plane was overloaded. Fonck was competing for the $25,000 Orteig Prize for completing the first nonstop flight between New York and Paris. **Aircraft Yearbook, 1927**, p. 177.

1951

July 6 A handful of Lockheed RF-80A reconnaissance fighters collect fuel from a tanker aircraft over Korea, the first instance of combat aerial refueling. Eugene M. Emme, **Aeronautics and Astronautics 1915-1960**, p. 67. Air Mobility Command, **Air Refueling: Without Tankers, We Cannot**, 2009, p. 14.

2 **July 27** A Bell X-5 research aircraft transitions its unique variable-geometry wings for the first time. This was the fifth of 133 flights by the X-5, during which the U.S. Air Force and the National Advisory Committee for Aeronautics gather substantial data for future variable-geometry aircraft designs. A.J. Pelletier, **Bell Aircraft Since 1935**, pp. 94-96.

Aug. 15 Douglas test pilot William Bridgeman reaches an altitude of 79,494 feet in the rocket-powered Douglas D-558-2 Skyrocket, an unofficial world record. After being released from a P2B-1S carrier aircraft, the Skyrocket ignites its Reaction Motors Inc. XLR-8 engine and climbs at a speed of Mach 1.35. Richard P. Hallion, **Supersonic Flight**, pp. 158-159.

Sept. 7 A RIM-2 Terrier surface-to-air missile completes its first shipboard launch from the USS Norton Sound, simulating the interception of a Grumman F6F-5K Hellcat target drone. **U.S. Naval Aviation 1910-1970**, p. 187.

1976

July 1 The Smithsonian Institution's updated National Air and Space Museum opens as part of the U.S. Bicentennial celebrations. For the ceremony, a signal relayed from NASA's Viking 1 spacecraft orbiting Mars activates a metal arm to cut a red, white and blue ribbon. The $41 million facility replaces the former National Air and Space Museum that had been housed for years in the Smithsonian's adjacent Arts and Industries Building. **New York Times**, July 2, 1976, p. B12.

3 **July 20** NASA's Viking 1 lander becomes the first spacecraft to land successfully on Mars. Touching down at the western edge of the Chryse region, its primary goals include collecting samples of Martian soil and attempting to detect evidence of life. Viking 1 also marks the first transmission from the surface of another planet. NASA, **Astronautics and Aeronautics, 1976**, pp. 148, 153-157.

Aug. 18 The Soviet Union's Luna 24 probe lands on the moon for the country's final lunar sample return mission. The spacecraft drills 2 meters into the Mare Crisium plain, collecting 170 grams of regolith. **Aviation Week**, Oct. 11, 1976, p. 53.

Aug. 24 Soyuz 21 cosmonauts Boris Volyonov and Vitaly Zholobov return to Earth after a 48-day mission to the Salyut 5 space station. The first of three flights to the station, the objectives include assessing the station's military surveillance capabilities. NASA, **Astronautics and Aeronautics, 1976**, pp. 193, 220-221, 250-251, 341.

4 **Sept. 3** NASA's Viking 2 lander reaches Mars, touching down on the Utopia Plains. Both landers detect organic chemicals in the Martian soil, but NASA ultimately concludes there is no definitive evidence of microbial life at either site. However, thousands of photographs taken by both spacecraft reveal water once flowed on Mars, with huge river valleys indicating floods that carved deep grooves into the bedrock. **New York Times**, Sept. 4, 1976, p. 1; Edward C. and Linda N. Ezell, **On Mars: Exploration of the Red Planet 1958-1978**, pp. 364-365, 398.

Sept. 17 NASA's first space shuttle orbiter, Enterprise, makes its public debut at Rockwell's facility in Palmdale, California. NASA had planned to name the orbiter "Constitution," but the agency and the White House receive thousands of letters from Star Trek fans urging the vehicle be named after the series' famous ship. President Gerald Ford concurs during a Sept. 8 meeting at the White House, telling NASA Administrator James Fletcher, "To explore the frontiers of space, there is no better ship than the space shuttle, and no better name for that ship than the Enterprise." **Aviation Week**, Sept. 13, 1976 p. 26 and other issues; **Washington Star**, Sept. 19, 1976, p. E-1.

2001

5 **July 20** The Lockheed Martin X-35B demonstrator completes "Mission X," becoming the first aircraft to complete a short takeoff, level supersonic flight and vertical landing all in a single flight. Smithsonian Air & Space Museum, **Lockheed Martin X-35B STOVL**.

6 **Aug. 13** NASA's solar-powered Helios Prototype reaches 96,864 feet, a world altitude record for winged aircraft. The remotely operated craft also demonstrates sustained flight at this altitude, spending 40 minutes above 96,000 feet. NASA Facts, **"Helios Prototype,"** FS-2002-08-068 DFRC.

Aug. 29 Japan's H-IIA launch vehicle makes its inaugural flight. Among other upgrades, the H-IIA has strap-on solid fuel boosters and is far more reliable than its predecessor, the H-II. **Flight International**, July 17-23, 2001, p. 30.

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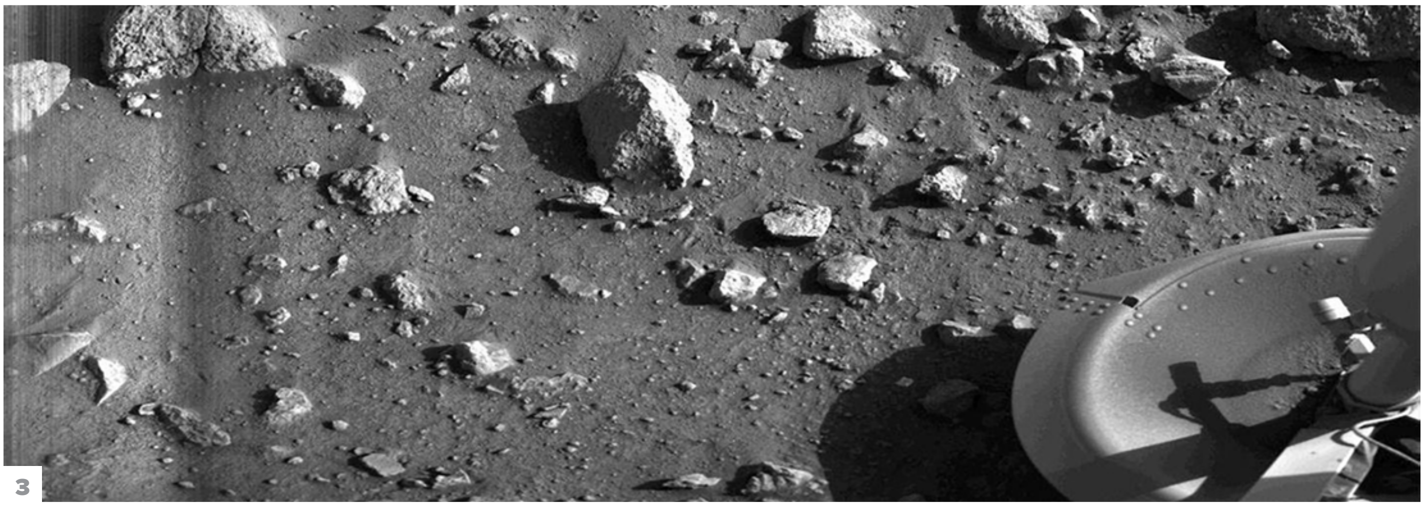

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Farah Diya Yasmine, 27

Secretariat General for the House of Representatives for the Republic of Indonesia

Law and space are Farah's top two passions, and she's found a way to combine them. In addition to her full-time job as a legislative drafter for the Secretariat General for the House of Representatives for the Republic of Indonesia, she's founder and president of Farah Law School, her educational outreach platform, and an independent legal researcher focused on space law. — *Aspen Pflughoeft*

What's your aerospace origin story? ▶ I grew up with dyslexia, which influenced my abilities in reading and writing. I avoided studying a lot back then, but fortunately I have a caring big brother. He realized my struggle with literacy, and he introduced me to a bunch of illustration books. Most of them were about animals, but I looked at one book by Steve McClure called "Alam Semesta dan Bumi," which means "The Universe and Earth Science." One of the pages depicted a beautiful and colorful nebula, which was unusual for me to see as a kid.

I reconnected again with my passion for space while studying law in university. There, I received my specialization in international law because it had space law as a subject. It was the university's first such cohort and had only three of us students. My thesis focused on the moon's natural resources for countries, and the concepts I explored there supported my journey in space law research through today.

Favorite thing about your job? ▶ In my work as an independent researcher in the space sector, I have learned a lot of new things, which I love, and it gives me a multidisciplinary perspective. In my educational work, I enjoy sharing with the indigenous people of Madura Island — my community — about my favorite subject and supporting their learning and opportunities in the space sector. I love seeing people's expressions when I tell them how space is a vital infrastructure for us.

What motivates you? ▶ I want to introduce space access to a wider audience, especially underrepresented groups, so they can be aware of how space utilization affects our welfare. I hope to generate like-minded space actors who have a mutual understanding of long-term peaceful, sustainable and cooperative use of space. I also hope that all countries in this world, especially emerging countries, could collaboratively experience space missions.

What tech outside your field that fascinates you? ▶ Biotechnology, as it could support us and other living creatures to adapt in microgravity or excel in research that could not be conducted on Earth due to distinct environments. It feels like taking a science fiction movie closer to reality.

What will the world look like in 2050? ▶ I think automation practices will be more advanced and controlled. Space would be far more accessible as a new area for research and capitalization. I also think space education and missions would follow standards with morals and multicultural skills with the expectation of forming generations with peaceful, sustainable and cooperative visions. ★

PHOTO BY DAVID BECKER

MORE ABOUT FARAH

AIAA CONNECTION Member of the 2025 AIAA Ascendants cohort. Her presentation at the July 2025 event in Las Vegas, "Environmental Interpretation from an Indigenous Madurese: A Proposal to Implement Long-Term Sustainability as a Legal Principle in Responsible Space Activities," described how her background shapes her approach to space law.

"From that opportunity, I envision that AIAA offers a life-changing experience as its value, and AIAA also embraces our diversity and authenticity because I could bring my values as a Madurese there. It was one of my milestones to introduce my work to [a] greater audience worldwide."

EDUCATION Bachelor of legal studies from Universitas Trunojoyo Madura in Jawa Timur, Indonesia, 2021.

BUILDING COMMUNITY In 2023, founded her namesake law school focused on teaching her community on Madura Island about space law, cyber law and constitutional law through classes, workshops and seminars. Serves on a pair of non-governmental organizations linked to the United Nations Committee on the Peaceful Uses of Outer Space: the Space Generation Advisory Council and the International Institute of Space Law. Also serves as working group co-chair for the Global Expert Group on Sustainable Lunar Activities.

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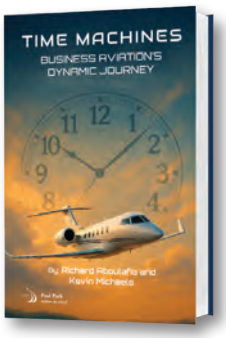

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