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Suiting up for the frontier

Expanding from a few dozen government astronauts to hundreds or more private sector ones will require spacesuits that are more user-friendly. PAGE 30

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AIAA
SHAPING THE FUTURE OF AEROSPACE

SpaceX has $4 billion in NASA contracts to develop a version of its Starship spacecraft for moon landings and to carry astronauts to the surface and back in them in 2026 and 2028. Starship Human Landing Systems are shown in this illustration. SpaceX

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SHAPING THE FUTURE OF AEROSPACE

IN THIS ISSUE

Keith Button
Keith 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. PAGE 16

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DEPARTMENTS

Putting Artemis spending in perspective

▲ The Artemis II crew descends the ramp of a U.S. Navy ship in February after exiting a mockup of their Orion capsule in the Pacific Ocean and being flown by helicopter to the ship.

NASA/Isaac Watson

A sizable chunk of this issue, 31%, is devoted to telling you about work funded under NASA's Artemis moon program. If that sounds like a lot, it happens to be the same percentage of the NASA budget that will be spent on Artemis this fiscal year.

Does NASA have its priorities right? Often, I have to put my personal opinion on a shelf in my role as editor-in-chief. On this one, that's not necessary, because at this writing I have questions but no opinion yet. I'm conflicted — and perhaps I'm not alone.

The Artemis work is no doubt technically bold.

Read, for example, our story on the upcoming VIPER rover (page 16) that's due to be landed at the lunar south pole in November. Artificial intelligence will be put to work in a new way.

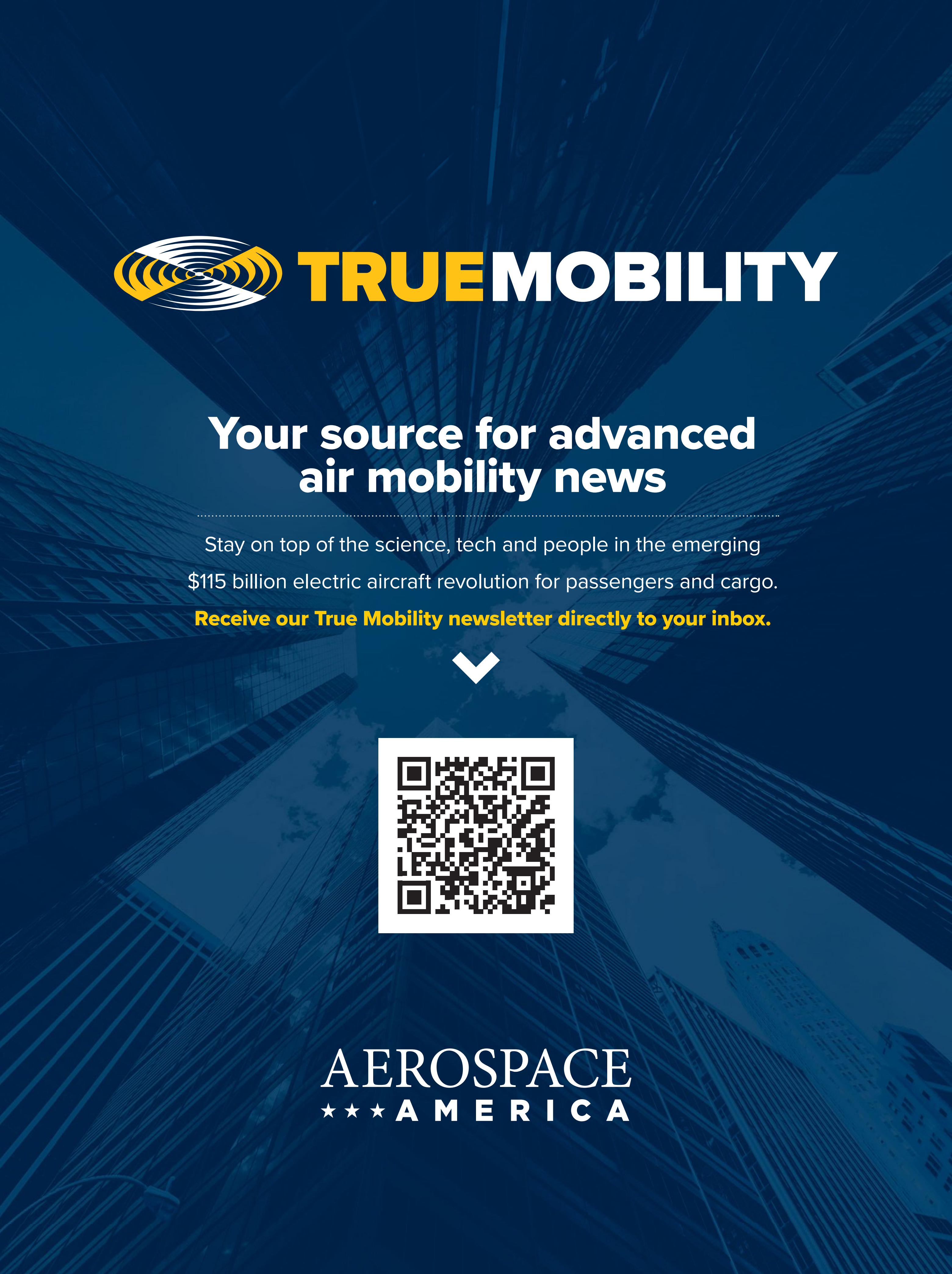
Or consider the cover story about next-generation spacesuits (page 30). You'll learn how NASA, Axiom Space, Collins Aerospace and SpaceX are doing more than creating new hardware. They are providing tools that could help democratize living, working and playing in space. Right now, NASA has 48 astronauts who are eligible for flight assignments. Are we about to see an explosion in the number of spacefarers through commercial exploitation of low-Earth orbit, cislunar space and the surface of the moon? If so, the suits will be ready for them.

There is more work to do, however, to prove that vast economic potential truly exists away from the planet. The value of the potential goods and services in space has to be balanced against the investments required to make them economic reality. Research in LEO could be the best gauge, but despite decades of intriguing medical and materials experiments there, a consensus has yet to emerge about the economic potential even farther into space. "For ISS, I think the thing that's still missing is some kind of fundamental scientific breakthrough," says Dave W. Thompson, one of the founders of Orbital Sciences Corp., in this month's Q&A (page 10). "I just don't know that they've ever gotten it. This goes all the way back to when we were trying to cook up some argument for nonspace companies to fly some kind of materials processing experiment on the shuttle," he adds.

Of course, reading the Thompson interview made me think of the catalyzing effect that Artemis is probably having at this very moment. The company that Thompson founded with two business school friends, Bruce Ferguson and Scott L. Webster, got its start with a NASA contract related to the space shuttle program. The next Orbital Sciences Corp. is probably being born right now because of Artemis.

At the same time, Artemis is playing out with opportunity costs that aren't always visible. Some spacecraft won't be built and some research won't be conducted because of it, or they will be deferred for years. It's how budgeting works. We at Aerospace America have it easier. If we overdid it on Artemis this next month, we can rebalance next month. ★

Ben Iannotta, editor-in-chief, beni@aiaa.org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FLIGHT PATH

Inspired by the Next Generation

In today's world, there is much to concern us about the future. Nonetheless, AIAA sees great promise in the future based on the young people we meet. Over the last several weeks, we have met many remarkable students (and educators) at AIAA events. Their common qualities are curiosity, a strong sense of purpose, imagination, innovation, and a willingness to tackle hard things – which are exactly what the aerospace community needs to solve the generational-scale challenges ahead.

While preparing to go on stage at the 2024 AIAA Awards Gala, members of the United States Space Force Honor Guard Colors Team were introduced to the Class of 2024 AIAA Fellows. The young Guardians were impressive, exemplifying teamwork, professionalism, and excellence – qualities honor guard members are known for. And they surprised us with their intense curiosity. New AIAA Fellows J.D. McFarlan and Rick Mange shared their F-35 experiences with them, further inspiring them in their career pursuits. The quality of curiosity in the next generation of aerospace professionals will make the most difference in advancing aeronautics and astronautics, and ultimately improving life on Earth for everyone.

During the Gala, we celebrated four graduating high school seniors who will embark on their university education supported by the AIAA Roger W. Kahn Scholarship. This fall, they will attend Georgia Institute of Technology (two winners), Stanford University, and Massachusetts Institute of Technology. We also celebrated three Trailblazing STEM Educators who are inspiring and teaching students at the K-12 levels. Each of these honorees shared a few thoughts with the audience. One student committed to using their aerospace education to transform the world for good. An educator said that receiving the honor was motivating them to do even more to advance STEM programs to the underserved youth in their community because they believe what aerospace contributes to the world is far more important than the hype of top sports competitions. With that type of passion, students will see great opportunity! It was clear by the standing ovation that the audience agreed – our future is bright because of a profound sense of purpose.

We recently hosted the 28th AIAA Design/Build/Fly Competition in Wichita, Kansas. Nearly 1,100 university students on 88 teams competed, including teams from 12 countries outside the United States, collaborating and cheering for each other on a long, windy weekend. We even welcomed a high school team with a plane they built that met all the requirements. Time constraints kept them from flying, yet they had a great experience and they will return as university students. The technical challenge this year was to design, build, and test a remotely operated radio control airplane for one of the newest modes of flight – urban air mobility. The teams demonstrated a delivery flight, a medical transport flight, and an urban taxi flight. Their DBF experience also included developing essential skills for their future: teamwork, camaraderie, perseverance, adapting to the unexpected, coping with defeat, and celebrating success. These qualities are vital in aerospace. We should all be encouraged that these students represent the next generation. They will be leading our community. They will help us experience flight in ways we are only beginning to imagine. Our community's future is bright because of their imagination and innovation.

This semester, the AIAA Regional Student Conferences showcased the research of our university members. The 268 papers presented across six student conferences were top quality, reflecting the high caliber of the students and their academic programs. You can read them on Aerospace Research Central (ARC) when they are published this summer. More than 90 universities were represented. We are fortunate that accomplished professors are preparing the next generation. Conducting challenging research and vigorous technical exchanges are helping make our future bright.

Most importantly, AIAA is reaching into communities not typically associated with or exposed to aerospace and STEM topics. The AIAA Foundation makes it possible for us to continue these programs and others in economically disadvantaged, underserved, and underrepresented communities. It's one powerful way we will increase and enhance the much-needed STEM-literate talent pool for our future globally competitive workforce. In addition, AIAA is helping lead the Space4All national space STEM awareness campaign aiming to inspire, prepare, and employ a diverse space workforce. We will be sharing much more about this exciting new effort soon and you can learn more now at **www.space4all.us.**

We often talk about the role of experienced professionals to inspire the next generation. Lately, it seems the next generation is inspiring everyone else, myself included. They remind us of what is possible. They embody what it means to be shaping the future of aerospace. ★

Dan Dumbacher
Chief Executive Officer, AIAA

Enjoy the photos of these events throughout this issue and on the event's AIAA Flickr pages. Read more about these events on ***aiaa.org****.*

Email us at aeropuzzler@aerospaceamerica.org

This mosaic of the Belva Crater was created from 152 photographs taken last year by NASA's Perseverance rover. NASA/JPL-Caltech/MSSS

Signs of life

Q: Would ancient features on a lifeless planet like Mars (if indeed it lacks life) become covered with meters of material, as we know happens on Earth with ancient cities and even natural features? Or is a carbon cycle required for the scale of the process we see on Earth?

SEND A RESPONSE OF UP TO 250 WORDS to aeropuzzler@aerospaceamerica.org. By responding, you are committing that the thoughts and words are your own and were not created with the aid of artificial intelligence. DEADLINE: noon Eastern June 18

Scan to get a head start on the July/August AeroPuzzler

FROM THE MAY ISSUE

LIFT FOR KIDS:

We asked you to complete a children's cartoon script about why the air molecule Bob would travel faster over an aircraft wing than the molecule Flo traveling under it. Your responses were reviewed by Haithem Taha of the University of California, Berkeley.

WINNER Flo: "I heard it was because of a law from Dr. Bernoulli."

Bob: "But Flo, why would I fly faster just because I have to go farther? That would be like saying when we'll ride our bikes to school, you take the shortcut and I'll take the long way, and we'll get there at the same time because I will pedal faster. But there's no reason why I should pedal faster other than to force the result to get to school when you do. My uncle, Klaus Weltner, told me that it is pressure difference that causes us air molecules to move. You will be compressed against our other friends on the lower side of the wing, which creates a force that helps lift the airplane. It's like when we put our hands out the window of a moving car. When we tilt them at a little angle, they are lifted up. But behind me, on my side of the wing, there is going to be less pressure on the shielded upper side of the tilted surface. So I will actually be forced to move faster because I will be subject to a greater pressure difference along the wing than you. I'm afraid I may not meet you again at the end of the wing, Flo. That's not a requirement that Uncle Klaus said can be guaranteed. But I will look for you with our other air molecule friends in the calming of our motions caused by this passing wing."

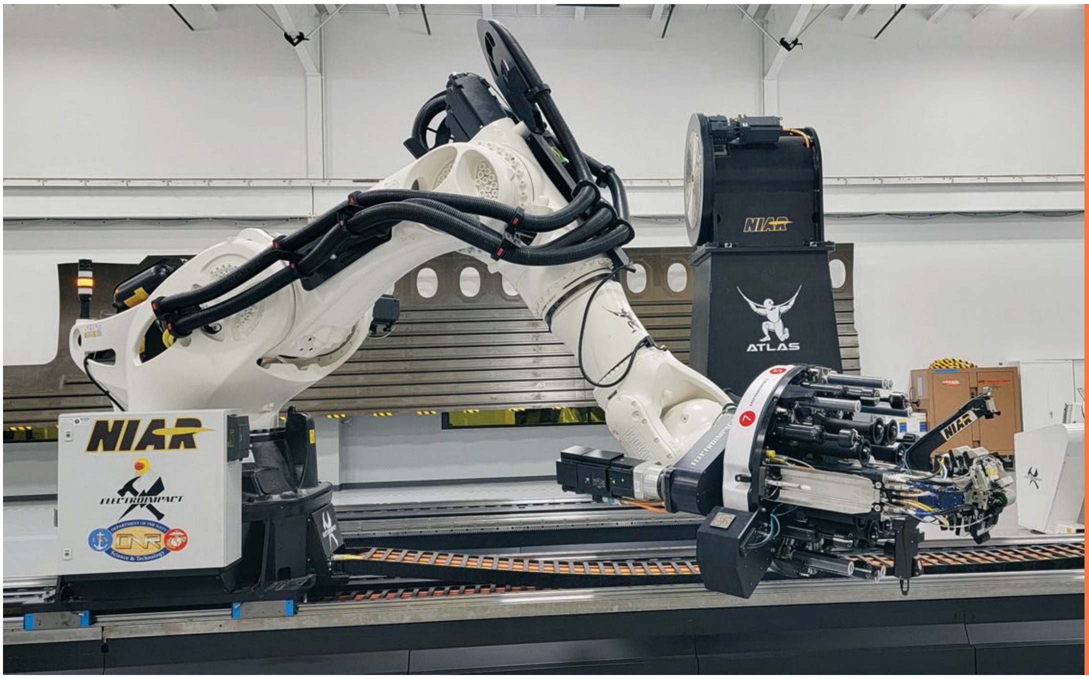
Jeffrey Cerro, AIAA Associate Fellow
Poquoson, Virginia
casincat_eng@aol.com

Jeffrey retired last year from NASA's Langley Research Center in Virginia, where he worked in the Vehicle Analysis Branch as a structures and mass properties engineer.

Haitham Taha would add this response from Flo: "As you know, Bob, we air molecules don't like to curve much. It's called the principle of minimum curvature due to Hertz. But the wing is curved, so we will have to figure out a way to flow around it without curving more than necessary. We'll create a circulation around the wing that makes you go faster. Otherwise, I and our friends traveling below the wing will have to rotate around the sharp trailing edge; I'm not sure we'll be able to sustain this much curvature, Bob."

The air taxi developer's 'Disneyland'

BY PAUL BRINKMANN | paulb@aiaa.org



This robotic arm wove carbon fibers into the shape of a wing section for eAviation's air taxi prototype in March. The arm is among the equipment in the Sector A lab of Wichita State University's National Center for Aviation Research, and part of the center's push into advanced air mobility

NIAR/Ethan McDaniel

A white robotic arm towers in a cavernous building at the Advanced Technologies Lab for Aerospace Systems at Wichita State University in Kansas, hoses along the arm leading to nozzles at the end of a large, cylindrical head. The arm was idle when I visited ATLAS in late April, but if I had been there in March, I would've seen it rotating and moving back and forth on plastic treads on a track as it laid down carbon fibers.

Staff from Textron's eAviation were at the facility that month, building an 11-meter-long carbon fiber section of the wing for the first prototype of the proposed Nexus air taxi. With the ATLAS equipment, the wing section was made "in a few days," whereas "it would have taken a few weeks for them to do it manually," ATLAS Director Waruna Seneviratne told me earlier that day in his office on Wichita State's main campus.

ATLAS is part of the National Institute for Aviation Research, or NIAR. The Wichita State lab's main goal is to help electric aviation companies build things quickly.

"A few years ago, you didn't hear the term 'advanced air mobility,' and now when you go to an aviation convention, that's all you hear about," Seneviratne says, using the umbrella term for the electric air taxi industry.

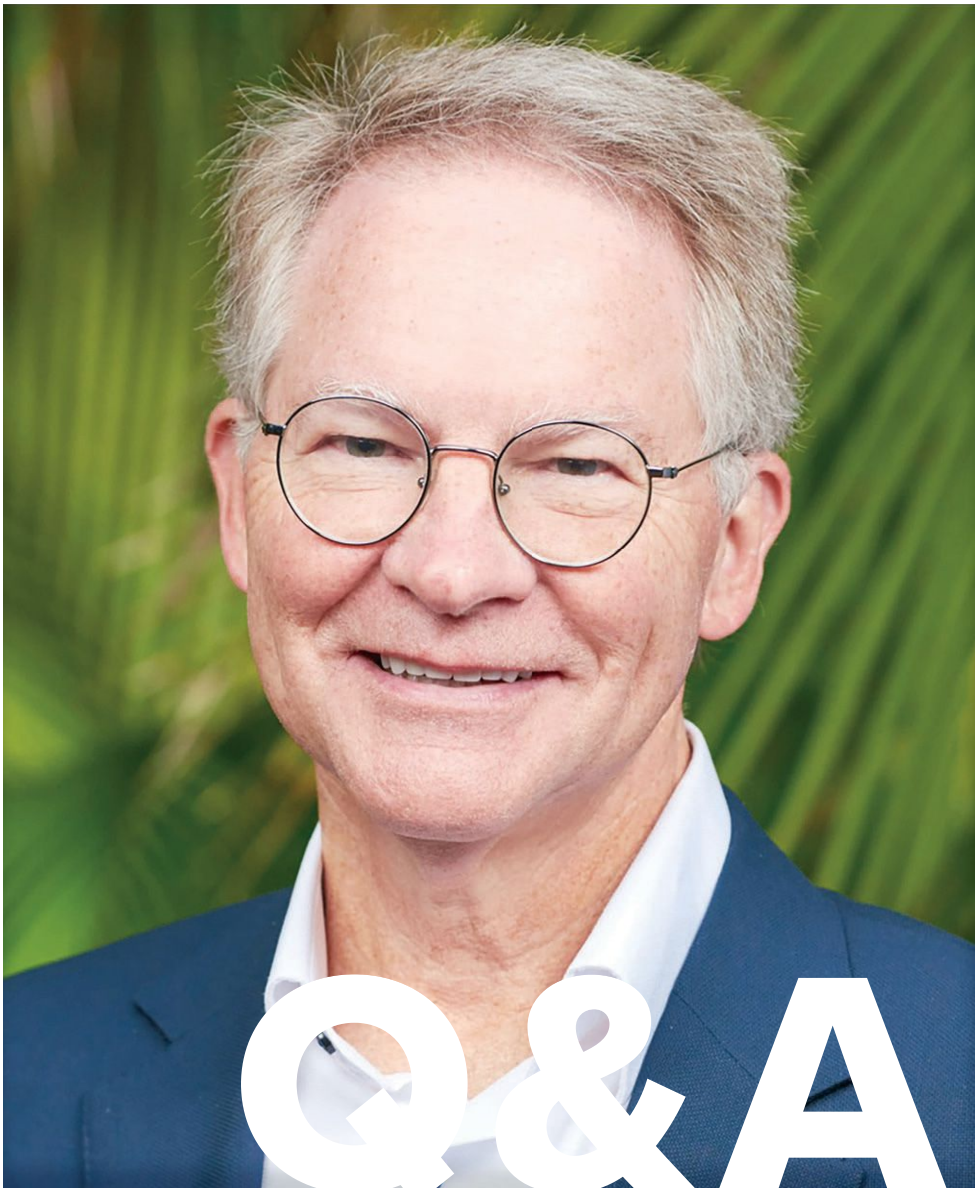
ATLAS "is like a Disneyland for these companies to come here and do all this prototyping," he adds. "These are small companies, and only a few of them have automated fiber placement machines. But here, they have access to whatever they need."

ATLAS is also researching high-rate manufacturing techniques that can be deployed once air taxi companies are ready to offer commercial products. Right now, the companies "are so focused on certification" that they can't yet devote many resources to figuring out exactly how their aircraft will be mass produced, Seneviratne explains.

The funding and staffing can work a variety of ways. When companies pay to use the equipment, the thinking is that they come out ahead by not having to purchase those machines. When the work is proprietary, sections of the ATLAS lab can be curtained off to restrict access.

Companies that have had work performed at ATLAS or sent people there to do work include Archer Aviation in Silicon Valley, BETA Technologies from Burlington, Vermont, and Joby Aviation in Santa Cruz, California. NIAR completed an aviation drop test with one of BETA's batteries in December 2022. For Joby, it installed a parts inspection laser scanner and software at the company's manufacturing plant in Marina, California.

As for the workforce, ATLAS aims to "create a pipeline" of future engineers who are trained in advanced manufacturing processes, Seneviratne says. ATLAS alone employs 130 people, many of whom are graduates or graduate students. NIAR overall has about 1,200 employees. "We're actually building the future workforce because these companies come here and work on this with our students," he says. ★



Caltech

Commercial space trailblazer

Texas oil is rarely associated with space — yet without the early and persistent financial support of Texas oilmen, Dave Thompson might never have achieved his dream of establishing a space business. Likewise, without the persistence and willingness of Thompson and his co-founders to adapt in response to shifting market and customer demand, Orbital Sciences Corp. (later Orbital ATK) might never have been sold to Northrop Grumman for $9.2 billion in 2018. “I always start with revenue because if you’re running a business and you don’t have revenue, you really don’t have anything but an idea,” Thompson says. Indeed, before its acquisition, Orbital reinvented itself multiple times in 36 years, becoming a spacecraft builder, constellation operator and launch vehicle provider, among other roles. Yet Thompson says there were plenty of “crises,” especially during the early years that could have prompted the company to fold. I visited Thompson at his Virginia home to discuss those crises, his assessment of today’s commercial space market and more. — *Jonathan Coopersmith*

DAVE THOMPSON

POSITIONS: Board member for the Aerospace Corp., Caltech, Carnegie Institution for Science and the Hertz Foundation. 2014-2018, president and CEO of Orbital ATK, the company created from the merger of Orbital Sciences Corp. with the aerospace and defense groups of Alliant Techsystems. 2009-2010, president of AIAA; honorary fellow since 1992. 1982-2014, president, chairman and CEO of Orbital Sciences Corp. 1981-1982, special assistant to the president of Hughes Aircraft Co.’s Missile Systems Group, assessing and planning discretionary research investments for tactical missile development. 1978-1979, engineer at NASA’s Marshall Space Flight Center in Alabama, overseeing industrial studies and limited prototyping of liquid fuel engines to replace the space shuttle main engines.

NOTABLE: Hired engineer Antonio Elias, who convinced him that satellites could be launched from a rocket released from an aircraft, which became the company’s Pegasus fleet; other products and services created under his leadership include the OrbComm communication satellites and Cygnus cargo spacecraft. Led the $9.2 billion sale of Orbital ATK to Northrop Grumman. In 2018, chaired the first independent review of NASA’s Mars Sample Return mission.

RESIDES: Great Falls, Virginia

AGE: 70

Education: Bachelor of Science in aeronautics and astronautics, MIT, 1976; Master of Science in aeronautics, California Institute of Technology, 1978; Master of Business Administration, Harvard Business School, 1981.

Q: Describe your early years in the industry and how you found your focus.

A: While an undergraduate at MIT, I interned for three summers at NASA's Langley Research Center in Hampton, Virginia. After my senior year, I had my most enjoyable summer working at NASA's Jet Propulsion Lab in California in the summer of 1976 when the two Vikings were landing on Mars. JPL really balanced my, until then, nearly complete focus on human space. It brought in the robotic side of the equation, which I actually ended up spending probably more time on than on the human side. The mid- to late '70s was a slow time for human spaceflight. Apollo had done its thing, the space shuttle was in development. Meanwhile, there was some exciting stuff on the robotic side, like the Voyager probes were launched. I was looking for something that was moving a little faster. In the tech world, Apple had been founded and Microsoft had gotten started. The pace was really fast and exciting, and I thought, "Why can't we do that in a space business?" So I went to business school with the idea of eventually starting a space company. I didn't know what sort, but I did meet two other students who thought that would be a really fun thing to do.

He's referring to Bruce Ferguson and Scott Webster, with whom he later founded Orbital Sciences. — JC

In 1980-81, we got a little grant from NASA to do a study. The space shuttle was almost ready to go, and our charge was to help them better understand the business opportunities for materials processing in space. We knocked on a bunch of doors, and it was a lukewarm response. We reported to NASA, "Don't count on this happening in a big way in the near term." Here we are, what, 45 years later? It's still not much.

> "From the perspective of customers, most employees and shareholders . . . [the sale of Orbital] has been a great success."

Q: When did the idea for Orbital come?

A: The second half of our second year of our MBA program, while I was waiting for a delayed flight out of Boston's Logan Airport on a snowy day. There were two transfer vehicles or upper stages either available or in development for the space shuttle: the McDonnell Douglas payload assist module and a mostly Defense Department-funded vehicle called the [Inertial] Upper Stage.

He's referring to rockets that would be released from the payload bay of a shuttle orbiter to carry a satellite or other payload to a higher orbit. — JC

NASA planned for a third, high-end vehicle: an Atlas Centaur upper stage modified to fly in the shuttle for big satellites and high-energy missions. My idea was we'll do it commercially, quicker and cheaper than the big guys. All NASA had to do was help us a little bit and, if we met certain milestones, agree to buy our product. Bruce Ferguson wanted us to start the company right away to implement this idea, but I didn't think we were ready for that. So we took respectable jobs, stayed in touch and hammered out the very rough outlines of what our business might look like. We reconnected in October 1981 when our NASA report on materials processing won an award from the Space Foundation in Houston. We were taken to this very nice dinner at the River Oaks Country Club, and sitting next to me, by happenstance, was an oil man named Fred Alcorn. I was telling him about our business plan, and at the end of the dinner, he said, "If you ever get serious about doing this company, come on down and let's talk. I might be able to provide you guys with some walking-around money," which was seed capital. We incorporated the company a year later on April 2, 1982. Fred and one of his colleagues provided the first external financing, and in summer 1983, three venture capital firms together put in a first round of more serious money. However, it became

▲ Northrop Grumman last launched a Pegasus rocket in 2021. One of them is shown here under the Stargazer carrier aircraft, a converted Lockeed L-1011. Each Pegasus is released at an altitude of about 40,000 feet. After a five-second free fall, the rocket's first-stage engine ignites to carry its satellite payload toward orbit.

NASA/Lori Losey

clear somewhere between the Alcorn walking-around money and the first venture capital that our plan wasn't going to happen. NASA was not at all keen — for understandable reasons — on having these three kids do this important element of the whole shuttle infrastructure. Instead, they wanted us to focus on this gap: The IUS does two maneuvers to get from low-Earth orbit to geosynchronous orbit. Most commercial satellites don't want the second maneuver, so this IUS provides functionality they don't need. So a transfer orbit stage would be our first product. Instead of a $500 million development program with a $50 or $75 million recurring cost price tag, this was going to be a $50 million development program with a $10 million or so recurring price tag. It was now up to us to raise the funds to actually carry out the development program.

Q: Let's go over the five crises that you've said Orbital faced early on.

A: NASA was still planning to do the transfer orbit stage as a traditional government-funded R&D program. They said, "We'll hold up that for a couple months because we've heard your story, but you have to convince us." So the first crisis was how do we in six weeks go up in terms of financial resources by a factor of 10 and line up one or more respectable aerospace integrators to commit to what they had to do? The second crisis was a year later. We had a $50 million financing problem, because you can't get there from where we were with traditional venture capital. Bruce Ferguson through his legal work learned about how early biotech companies like Amgen were structuring their R&D investments as limited partnerships. Nobody had ever done this for the space industry. We traveled the whole country for months and months, selling units for $50,000 increments apiece to high-net-worth investors from a whole variety of backgrounds: doctors, dentists, professional baseball players. It was structured so that limited partners — all these investors — would be able to deduct R&D expenses from their income taxes as we incurred the R&D cost. But it had to be funded in the particular tax year, which was 1983. It was pretty clear around the first of December that we were going to be short $20 million, which meant starting all over next year. So we had to convince the investment bank running this to potentially put as much as $20 million of its capital on the line if we couldn't finish the fundraising in the early part of the new year — which we finally did. With that money, our subcontractors lined up and a little bigger staff, come early 1984, we were pretty much off to the races developing the transfer stage. By early 1986, we had the prototype designed and were about ready to go into full testing. Ford Aerospace had signed up for three launches. NASA hadn't quite signed on the dotted line, but it was pretty clear they were going to buy a few.

Q: The third crisis was the January 1986 Challenger tragedy?

A: It was clear from that point forward that shuttles weren't going to be launched once a month or even going to be as routine. They weren't going to be as inexpensive because NASA was beginning to phase out the subsidy in a pretty big way. And they generally weren't going to be available for nongovernment customers, because the national policy became to rejuvenate the expendable vehicle business so the U.S. wouldn't be dependent on European vehicles if the shuttle wasn't available. It was terrible for the country and life-threatening for our little venture, but the silver lining was that it prompted us to rethink the whole strategy. Instead of plugging holes in the shuttle infrastructure, we're going to backward integrate ourselves from the very beginning; we're going to expand and develop a really great engineering team; we're going to acquire facilities and build our own products. The question was: what products? A couple months after Challenger, I called one of our board members, MIT professor Jack L. Kerrebrock, and asked his recommendation for the brightest systems engineer he'd seen. He told me Antonio Elias, who is the best person I ever hired. After about six months, he came up with the idea for the Pegasus. My first reaction was, "No, that's no good," but we did some internal work that convinced me otherwise. We know who the customers would likely be, who the competition would be, a pretty good idea of what it would take in time and money. As for the anchor customer, DARPA said, "If you guys can actually develop this thing, we'll buy the first six launches." All those pieces kind of miraculously fell in place. From the day he thought of it to the first flight was about a week less than three years.

Q: What were your initial concerns?

A: Since the 1970s, there have always been multiple small launch vehicle programs; they kind of come with the blooming of flowers in the spring. But Antonio convinced me that we had some advantages. In retrospect, one was that we were more knowledgeable about what could be done and what the options for doing it would be in terms of raising private capital, because we had done it already for our transfer vehicle.

Q: The fourth crisis was financial too?

A: We're now in the spring of 1988. The missing link is how we are going to come up with, coincidentally, another $50 million development program. We tried, again, the industrial partner route. It worked this time: Hercules Aerospace became our propulsion supplier. We needed Hercules to cover all their development costs on the rocket motors and to accept a joint venture arrangement on the Pegasus rocket. We could partly develop our own engineering and manufacturing and assembly capability. But we found this small private company in the Phoenix area that we really wanted to acquire.

He's referring to Space Data Corp., an Arizona firm that produced suborbital sounding rockets. Its acquisition allowed Orbital to enter the sounding rocket market. — JC

We needed them to agree to be acquired, and we needed some investor to put in $20 million for our part of the development program. It all came together.

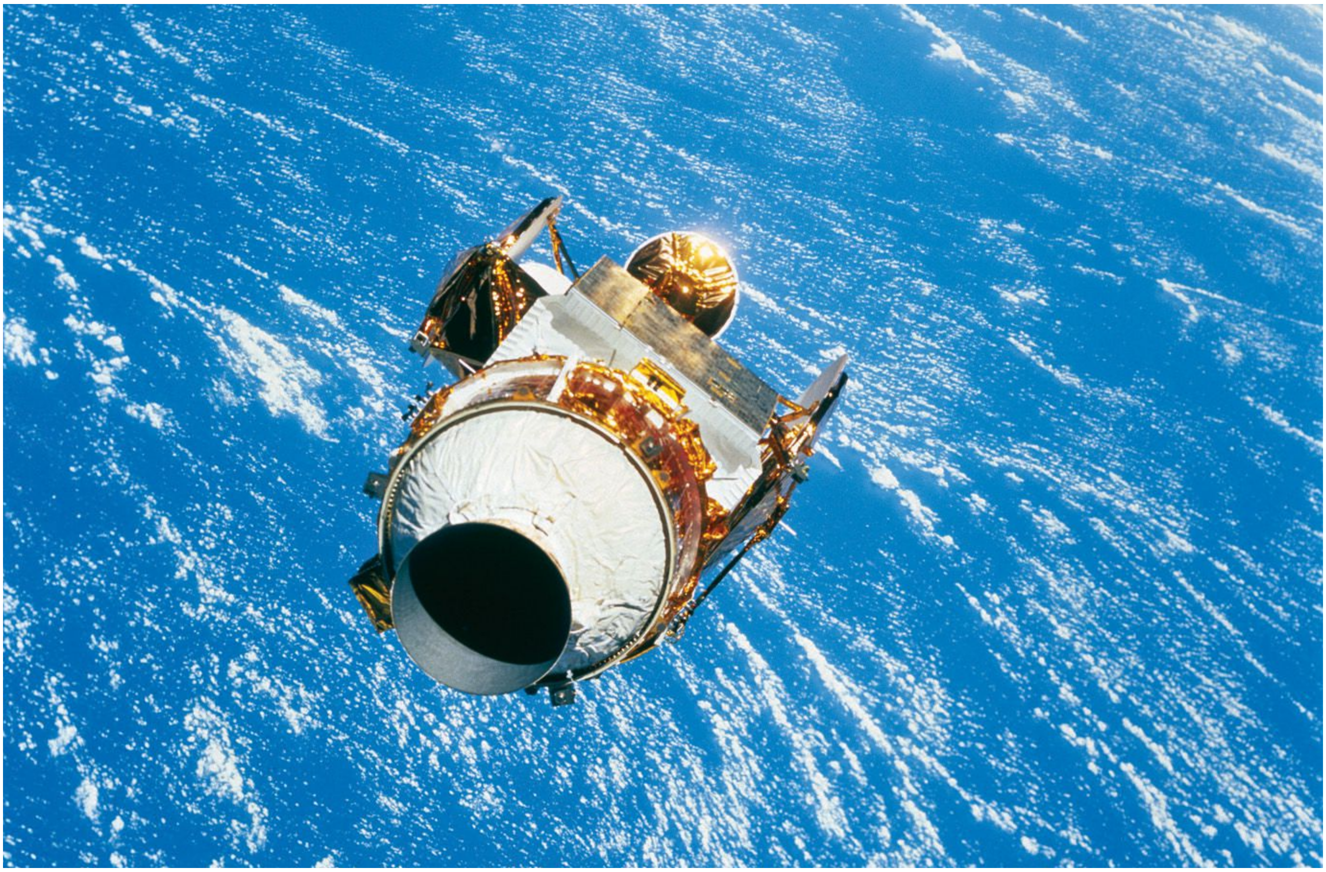
Q: Tell me about the fifth crisis, around Orbital going public.

A: In the run-up to the first Pegasus launch, I'd gotten a call from a reporter of a well-respected national newspaper.

He's referring to Bob Davis of the Wall Street Journal. — JC

He said, "You're doing some really cool stuff, and I would like the inside scoop." I foolishly agreed to let him come spend some time with us. By early 1990, we were really, really short on money. We weren't quite through the Pegasus development program, plus we were now building these transfer orbit stages. We thought it might be the time to go public, but the underwriters wanted to wait until after the first Pegasus launch. We convinced them to go ahead anyway. The January launch date became February, March and finally slipped into early April. But we were ready in late March to do the initial public offering and feeling pretty good about it. What happened was a little different: The day the stock is to start trading on the NASDAQ exchange, we are the front-page article, which is basically saying "Rockets don't always work. And these guys, they haven't been doing this for 30 years."

The article was "Start-Up Firm Faces Big Risks in Launching Rocket From a Plane: Orbital Sciences Might Offer Cheap Way for Companies To Put Satellites in Orbit" — JC



▲ Orbital's first contract, awarded in 1985, was to provide up to four transfer orbital stages to NASA for deploying satellites and other payloads out of space shuttle orbiters. Built by Martin Marietta, the second TOS is pictured here in 1993 shortly after its release from the payload bay of the Discovery orbiter.

NASA

The underwriter calls and says, "We think we ought to postpone. Go launch the first Pegasus, then come back." That's what we did. We were on fumes by the time that was over, but it worked.

Q: How did Orbital branch out after the success of Pegasus?

A: We completed the initial public offering at a little higher price than previously priced, so we now had a little more financial flexibility. It was time to start thinking about what to do with another idea that Antonio had come up with earlier: A network of 40-kilogram small satellites in LEO, forming what today would be described as a machine-to-machine data communication system. Not voice, not high bandwidth — all you really wanted to do was let something like a trucking company receive signals to track where the trucks were. We put together a little team, and it became Orbcomm — Orbital Communications. We launched the very first satellite, which was really just a spectrum test, in 1991. We launched the two more serious prototypes in 1992, then the first operational satellites in 1995. Over the following four years, we launched three dozen of these satellites all on Pegasus, in most cases stacked up inside the payload fairing like Oreo cookies. When they reached orbit, they would deploy and arrays would come out, big antennas would unfold. But by the end of the decade, we had to decide what business were we really going to be in: a hardware developer and builder or a space system operator? We concluded, like everybody else, that you could be one or the other, but you couldn't be both. The exception was Hughes Aircraft Co. and what became DirecTV. That was and — I think for some time to come — will be the one of two outstanding successes in commercial space. The other is SpaceX. It kind of pains me to say this, but I'm very impressed with what they've done. Their technical work is really impressive.

Q: On paper, air launch seems to make a lot of sense for reusability, but if SpaceX is any indication, chemical rockets are the wave of the future.

A: It certainly will depend on long-term sustainable levels of demand. You can say, "Well, it takes high flight rates to achieve and sustain cost at this level," but you need both the supply and the demand to be in sync. Right now, on the SpaceX side, it seems like anecdotally maybe two-thirds of the launches are essentially for their own account: Starlink.

SpaceX conducted 98 Falcon launches in 2023, 64 of which were for Starlink. — JC

At some point, they're going to not want to be continually launching Starlinks if they want to flip around from being a consumer of cash to being a producer of cash. And eventually, when they're in some stable situation, you want those satellites to last a long time so you don't have to launch constantly, even though it's pretty cheap to build them and pretty cheap to launch them. It'll be interesting to see how that all plays out.

Q: What would you tell students or young professionals who want to be space entrepreneurs today?

A: In 2019, a year after we sold Orbital, I was a visiting professor at MIT and taught a course on business principles in aerospace industry. There was a subset of students that came in thinking, "Come next spring, we're going to graduate and two or three weeks after that, we're going to be running our own mega company." I always start with revenue because if you're running a business and you don't have revenue, you really don't have anything but an idea. Toward the end of the course, we talked about new ventures. By that time, I've hopefully given the students most of the fundamentals they need to do a little bit more of a clear-eyed assessment of things like new business formation.

Q: What prompted the decision to sell Orbital?

A: It was a tough one. From the perspective of customers, most employees and shareholders — the three constituencies that I was responsible for — it's been a great success. The combination of our space business and Northrop space business has continued now five, almost six years later to grow like crazy. In 2018, the combined space businesses were about $7-ish billion dollars. Last year, they were $14 billion. So customers must be saying, "There's something good about this we like," because there has been general market growth, but overall space business of rockets and satellites hasn't doubled in the last five years. Some of that's been rising demand — some from NASA, a lot from the military.

Q: What are the big lessons you see from the International Space Station?

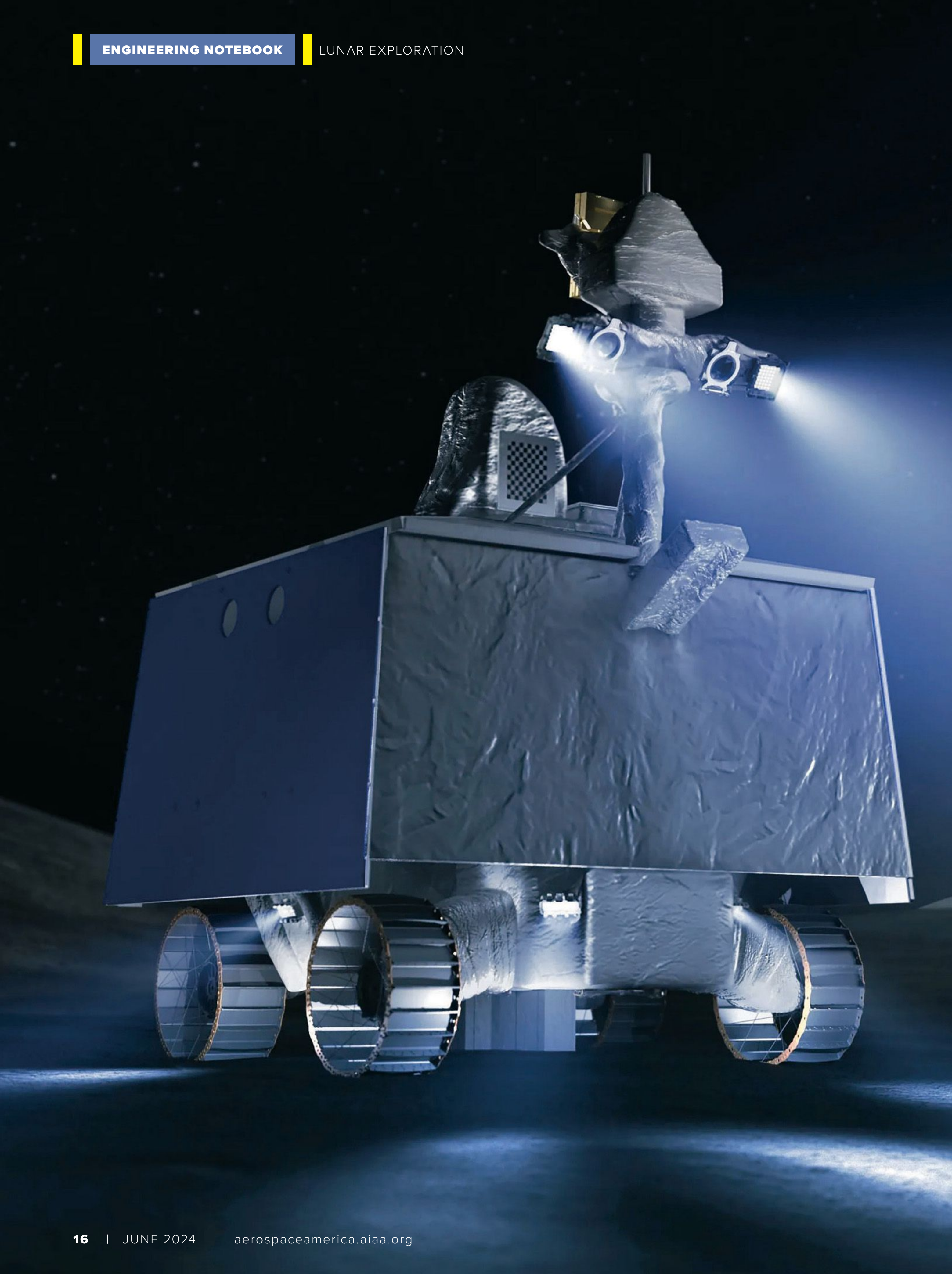
A: One of the really positive things that's come out in the last decade or so has been those Commercial Cargo and Commercial Crew initiatives. It's demonstrated to NASA and to Congress and the executive branch that if you pick the right problem and you maintain a reasonable degree of competition — not too little, not too much — and you try to get both NASA and the private company they're working with more or less on the same wavelength, you can do some pretty good stuff. Now, will they push it too hard in the lunar or cislunar era? I don't know. For ISS, I think the thing that's still missing is some kind of fundamental scientific breakthrough on the station. I just don't know that they've ever gotten it. This goes all the way back to when we were trying to cook up some argument for nonspace companies to fly materials processing experiments on the shuttle.

Q: When you chaired the first independent review of Mars Sample Return, the projected cost was $4.5 billion. The latest estimate is $11 billion. What are your thoughts on the program now?

A: I thought we did a pretty good job, but it was real early in the program — in terms of time or money, at the 5% complete point. The second Independent Review Board last fall had the benefit of three and a half years of actual experience. I'm quite worried about [the mission]. The cost increase has now forced particularly JPL, the overall mission architect, to think creatively about how the mission approach might be changed to keep the cost under control, at a level where it's not doing major damage to the other science programs that are competing for the same money. One option is to do what the James Webb Space Telescope did, which is to say, "The program may take a couple of years longer, but we're going to finish it at a flat annual cost." That lets NASA plan for the next five years or seven years because the budget line won't go up. I'd make the argument that Mars Sample Return is far and away the most likely space mission over the next 20 years or so that will either answer or leave us in suspense as to whether life might have emerged on another planet in the solar system. I think that's worth 3% per year of NASA's budget.

Q: Was space sustainability a concern for Orbital when it began launching satellites, as it is for today's operators?

A: That's much more recent. When we were almost 30 years ago conceiving, designing and beginning to deploy the Orbcomm network, we were building into the design the ability to satisfy the unwritten but informal understanding that any satellite being launched into LEO would have the means of deorbiting itself within 25 years. Today, the numbers [of satellites being launched] are so much bigger. The three constellations deployed in the late 1990s — Orbcomm, Iridium, Globalstar — collectively numbered 150 satellites. These days, two launches can deploy that many, and you got launches every other week. The concern is that you get one of these unintended collisions of some kind and it just propagates. I'm just not knowledgeable enough to independently tell you that it is getting enough attention, but it's certainly a changed environment. On top of that, of course, you've got military action. Hopefully we won't end up with Earth looking like a baby version of Saturn with a ring of debris. ★



VIPER'S AI ASSISTANT

If NASA's VIPER rover safely arrives at the lunar south pole later this year as planned, the race will be on to find water and hydrogen ice before the moon's winter stops the rover in its tracks. Pausing to debate each leg of its journey would be a terrible waste of time, so operators have turned to artificial intelligence. Keith Button has the story.

BY KEITH BUTTON | buttonkeith@gmail.com

NASA's Volatiles Investigating Polar Exploration Rover, or VIPER, is due to land in November at the lunar south pole to begin a 100-day mission of scouting for water ice, among other resources.

NASA

NASA engineers earlier this year installed the camera mast to the body of VIPER. The dark holes that resemble eyes are the navigation cameras that will take panoramic photographs of the rover's surroundings. The squares on either side of the cameras are the rover's headlights.

NASA/Josh Valcarcel

The artificial intelligence software that will help NASA decide how to direct its ice-hunting VIPER rover over the lunar surface later this year has roots in a doodle drawn on a cafeteria napkin a decade ago.

Doodling wasn't unusual for Edward Balaban, a research scientist at NASA's Ames Research Center in Silicon Valley. "It focuses my thinking," he says.

Balaban now leads strategic planning for the Volatiles Investigating Polar Exploration Rover mission. The golf-cart-sized VIPER is scheduled to land at the moon's south pole in November to look for water and hydrogen ice as its chief goal.

Back in 2014, when he was sitting alone at lunch in the Mega Bites cafeteria at NASA Ames, Balaban pondered the decisions that operators would need to make to steer a rover across the moon in a manner that would wring the most science from its time on the surface. An initial plan would be needed, and then once operators got a better look at the terrain from the rover's camera or cameras, the route would need to be adjusted as the rover roved.

Balaban drew a decision tree with each branch

> "We can have a system that reasons through all of these possibilities and can take more into account than a human can possibly do in a reasonable amount of time."
>
> **— Edward Balaban**

representing a potential path, with smaller branches extending from the main branches to represent decision points. One of the smaller branches might represent the choice to head along a rocky, steep route toward an especially promising site but whose transit time was hard to predict. The choice to go to that site might unexpectedly compress the time available to reach other attractive sites represented by smaller branches ahead along a main branch, posing still more choices.

Soon, the napkin looked like a poorly pruned tree. "All these permutations that I was thinking about for a mission that's supposed to be fast-paced and very productive — it was hard to think through it just with a pen and paper," Balaban says. "It just blows up exponentially."

AI hadn't yet exploded into the public's consciousness, but it was on Balaban's mind at that moment because of work he'd done earlier on AI for spotting performance trouble in space hardware. He thought: What if AI could be programmed to weigh not only all the factors for deciding the best current route to take but the best route when considering all those future decisions? "We can have a system that reasons through all of these possibilities and can take more into account than a human can possibly do in a reasonable amount of time," Balaban says.

He scribbled a name on the napkin: SHERPA, for System Health Enabled Real-time Planning Advisor. This envisioned AI software would be based on AI he and others had already written to quickly diagnose the causes of performance issues in space hardware during operations. Computer scientists led by Balaban set about writing SHERPA and testing it in a development project that required its own set of hard choices.

FACT

WHY NASA IS SEARCHING FOR ICE:
Locating water ice and hydrogen ice could help predict where else on the surface those resources are likely to be found. That's why VIPER is funded under NASA's Artemis human exploration program. Astronauts in a succession of Artemis missions could learn to exploit the ice to sustain themselves. In addition to supplying drinking water, the ice could be separated into oxygen and hydrogen to create breathable air and the oxidizer for a rocket engine that would burn hydrogen. This way, astronauts would not need to pre-position propellant from Earth or bring all the propellant they would need to return to Earth or for longer journeys, such as to Mars. — *KB*

The software, which now resides on computers at NASA Ames, saw its first action when Balaban and planetary scientists used it to plan a set of initial potential routes for VIPER.

"We're positioning SHERPA to be not as a robotic overlord but as a decision support and analysis tool for human operators," Balaban says. "We recognize as humans that, in real time, it's hard for us to process all of this information and make an informed decision."

Once the rover hits the ground, SHERPA will help managers make real-time adjustments to the navigation plan based on factors including whether the rover's actual pace over and around unmapped rocks is quick enough to reach all of the desired drill sites in the time available.

"We don't know yet what our effective speed of operations is going to be," Balaban says. "We're practicing, we're modeling, we're simulating. But until our wheels literally hit lunar dirt, we don't know."

What's certain is that time won't be on VIPER's side. The rover will have a 100-day lunar summer to operate in before the shadows grow too long in the south pole region for the sun to recharge its batteries via its solar panels. Plus, VIPER will have to hibernate for half that time. That's because the shifting angles of Earth relative to the orbiting moon makes Earth dip below the lunar horizon every two weeks. That makes radio contact with VIPER impossible until Earth rises again two weeks later. Operators will ideally park the rover atop the closest hill, with the least obstructed sunlight possible to recharge its batteries as it awaits the Earthrise.

The best candidate sites for water and hydrogen ice are "permanently shadowed" regions, typically the floors of deep craters that sunlight hasn't reached in a billion or so years, says Jasper Wolfe, head of the VIPER mission operations team.

Plans call for the rover to traverse a few kilometers, stopping at about a dozen sites in shadowed regions, being careful not to lose line of sight to Earth. It will be commanded to pause to drill as deeply as a meter below the surface to look for ice, measure the contents and temperature of the soil, and then drive back into the sunlight again so its batteries can recharge. These prime sites are dangerous though. If the rover gets stuck in one of the shadows, it won't be able to recharge, and the mission will be over. Likewise, the mission will be over if VIPER loses communications by driving behind the rim of a crater that blocks the rover's line of sight to Earth.

"That's what makes it exciting," Wolfe says.

With SHERPA as a guide, and with the rover rolling, operators will command it with a few seconds' lag time for the radio signal to travel to the moon from the NASA Ames mission operations center. Operators at keyboards will establish waypoints every few meters of the route as they view screens showing stereoscopic images from the rover's cameras looking 10 meters ahead of the vehicle.

SHERPA's AI is more model-based than data-based, which distinguishes it from the AI apps that have exploded in popularity among consumers in the last 18 months. Large-language AI, such as those apps, is programmed to accurately predict word sequences in the sentences they produce based on their training on massively large datasets, such as the entire contents

FACT

THE SHERPA, OR SYSTEM HEALTH ENABLED REAL-TIME PLANNING ADVISOR, SOFTWARE WAS BRIEFLY ORPHANED, SO TO SPEAK, ABOUT FIVE YEARS AGO. Computer scientists at NASA's Ames Research Center in California developed it with the proposed Resource Prospector mission in mind, but that lunar mining proposal was abandoned in 2018. The Volatiles Investigating Polar Exploration Rover was born out of the Prospector proposal a year later, and SHERPA was incorporated into the plan. It grew from research scientist Edward Balaban's earlier development of artificial intelligence for a health management system for space hardware. The idea was to identify a problem and how to solve it even when sensor readings pointed to several potential issues or the readings conflicted with one another, as sometimes happens with stuck engine valves in or pressure readings in a propellant tank. This early AI was incorporated into the X-34 reusable spaceplane, a planned uncrewed hypersonic test bed whose development was canceled in 2001, and three years later into a proposed automated drill for a Mars lander. — *KB* of the internet. SHERPA, on the other hand, has been adapted to the fundamental difficulty of planning for an unknown environment without much data to go on. For VIPER, the lunar terrain has been mapped by lunar orbiters but only at about a 1-meter resolution, leaving room for plenty of rocks and craters that could hamper the rover's travels, Wolfe says. In the permanently shadowed regions, the mapping is even more fuzzy, relying only on laser altimeter measurements taken by orbiting spacecraft.

SHERPA will define each state of the rover with 12 to 15 variables, including the time, its location, battery charge, how much time before it loses sunlight at the current location, the quality of terrain and the predicted depth of ice at the current location.

Balaban and his team needed a starting point for the VIPER version of SHERPA, so they built it from an AI model intended for Resource Prospector, a proposed lunar mining mission canceled in 2018, one year before VIPER began.

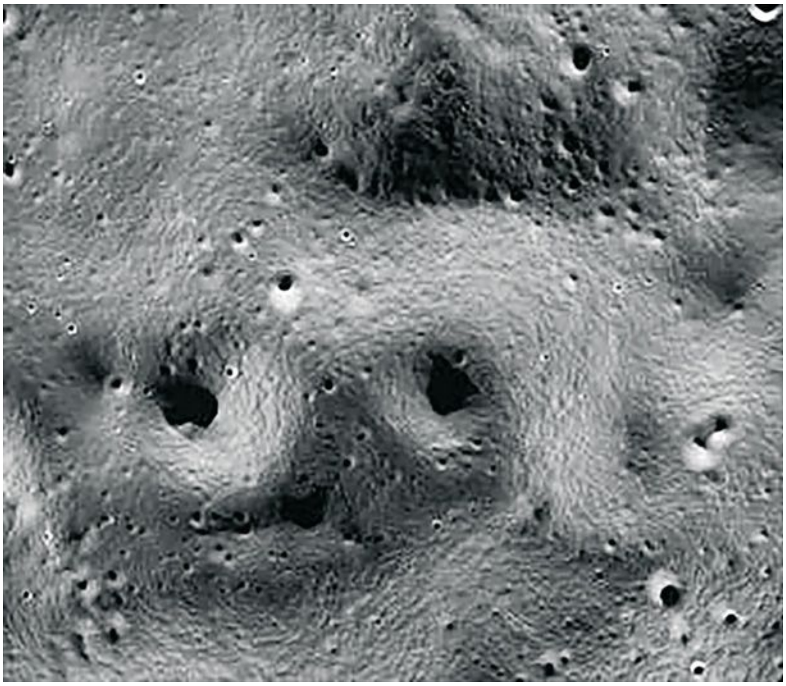
For Resource Prospector, they had initially tried to develop a look-up table model, in which each decision branch and its outcome would be predetermined. They built large decision trees, with predictions of what could happen at each branch based on probability distributions for many of the unknown factors, learning the best decisions to make based on the best results on average. But that fine-grained approach to building the AI model proved too difficult: The computations required were too great for a computer to manage for Resource Prospector's proposed two-week mission.

For VIPER's 100-day mission, that computation problem was compounded. As they continued to develop SHERPA for VIPER, they decided to break the AI model's planning into smaller pieces. Instead of calculating every possible decision branch ahead of time, they tried having SHERPA calculate only the future branches that would extend from VIPER's current state.

That was also too complex for a computer to calculate, so they tried breaking up SHERPA's planning into individual lunar days, generating mission plans for the two-week periods when VIPER would be active between hibernations, rather than for the entire 100 days all at once.

But even focusing on just the two-week periods was too large of a computational problem — it took hours to run through just one proposed route tree. So they tried a different track. "My team is probably sick of me saying this by now," Balaban says, "but I always tell them that when we are faced with a difficulty, let's try to think of how a smart human would" solve it.

Instead of planning out precisely how much science VIPER would accomplish during a two-week period, they tried to capture how much potential there was to do good science: to reach the best drilling locations, and the most locations, during the 100-day mission without putting the rover at risk of missing a safe haven for hibernation if something goes wrong.



▲ This composite of a plateau above the Nobile Crater, VIPER's planned landing site, was assembled from 147 images taken by NASA's Lunar Reconnaissance Orbiter.

NASA

To capture the idea of science potential, they came up with a model based on approximations with "just enough" information on the risks and benefits of possible routes for the rover. This avoided the complex computations required of their previous approaches. Then they tested the outline with simulations of random problems that could occur on the lunar surface and filled in the plan with more details.

Breaking down the problem this way also allowed the scientists to weigh in with their preferences, as potential routes with the biggest science potential were identified first, without an exact route and timetable established at first, Balaban says.

"When a planetary scientist looks at a map and he or she sees a little crater here and from their experience, they can tell, 'Well, by the shape of this crater, I can tell it's a relatively fresh crater and since we're nearby, it would be kind of nice to drive by it and look at the ejecta of that crater.'"

Once the humans are happy with the template of the basic route and science targets, SHERPA will calculate — before VIPER's journey to the moon — the precise route and how long to pause at each science station.

There's also the issue of unforeseen circumstances. Once VIPER is on the lunar surface, conditions could be different than what was expected. Operators expect the rover will drive within a range of speeds, but the motor on one of VIPER's wheels could malfunction, for instance, slowing its pace below expectations. Or initial drilling could reveal that the best

places for finding ice are different than what the scientists predicted.

"We may need to replan quickly, based on both good events and bad events," Balaban says.

Before VIPER hits the lunar ground, the plan will be constructed based on probability distributions for unknown quantities, such as how long the science activities will take, the speed of the rover and its power consumption inside the permanently shadowed regions. As the mission unfolds, the model will be updated.

With this outline-first, details-later construction of the route planning, SHERPA can compute the best plans much more quickly and react to unplanned circumstances, with some contingency branches planned ahead of time. For instance, if time is running out to reach a preplanned safe haven before one of the two-week communications blackouts, contingency plans could have an alternative safe haven site lined up, along with the subsequent plans for starting a new route from that point after the

> "All these permutations that I was thinking about for a mission that's supposed to be fast-paced and very productive — it was hard to think through it just with a pen and paper. It just blows up exponentially."
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> **— Edward Balaban**

◀ To practice maneuvering VIPER, test versions of the rover were driven around a soil bin at NASA's Glenn Research Center in Ohio, representing lunar terrain. Here, an engineer wearing a suit for protection from dust places rocks in the soil to simulate the consistency that VIPER could encounter as it traverses near the lunar south pole. NASA

blackout concludes. SHERPA will also identify weak spots and bottlenecks in the original plan and automatically construct contingency branches that could be chosen to avoid those issues, if needed. The route plan models will be updated during the two-week hibernations, based on new information gathered during the actual operations on the moon.

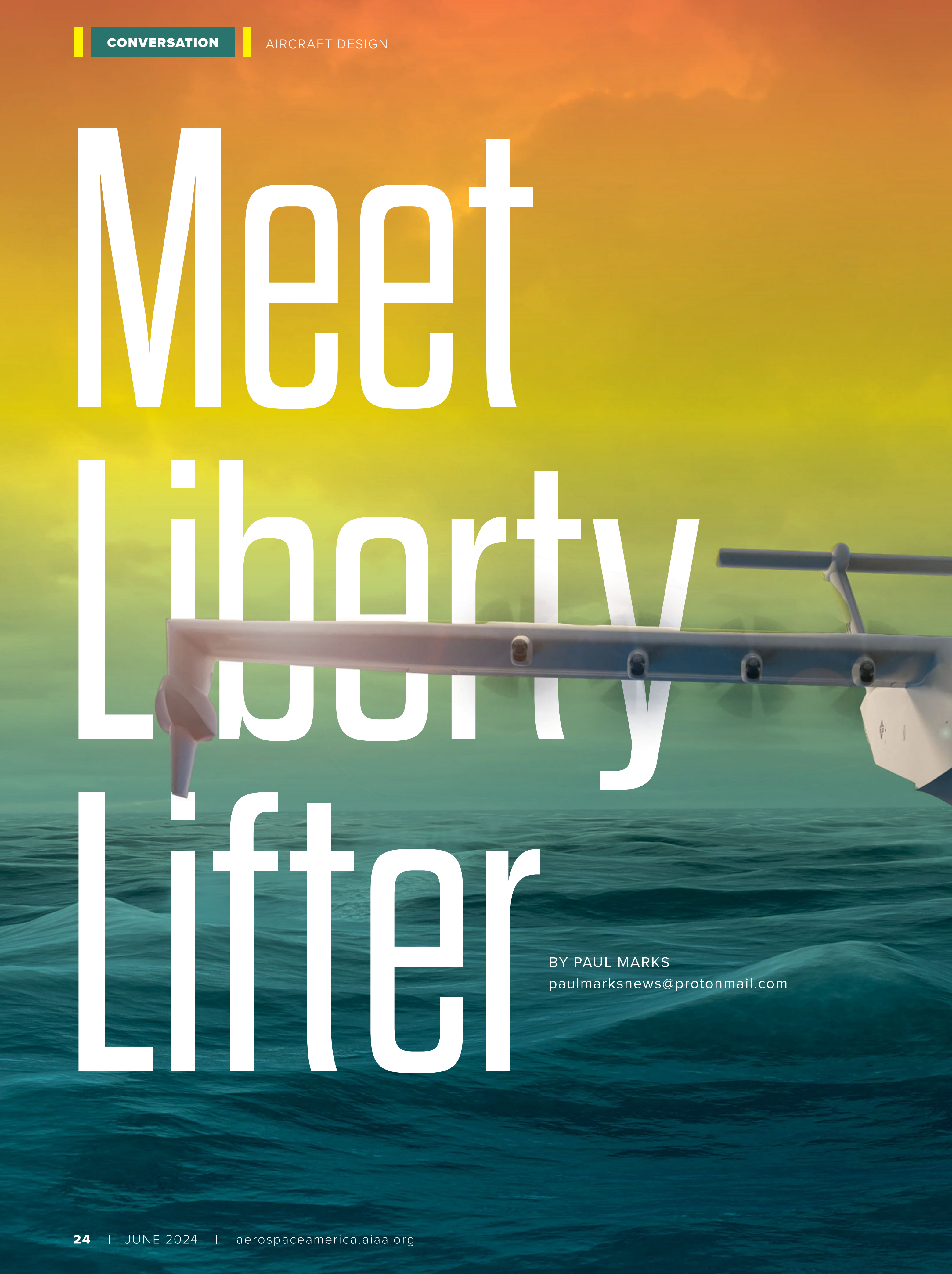
After VIPER, Balaban sees potential applications for SHERPA with a variety of other NASA missions. Because SHERPA was designed to be modular and reusable, "we think of it as a Lego set for mission planning and execution," he says.

One possibility is applying SHERPA to unusually complex missions. For example, SHERPA could plan routes and tasks for multiple rovers or human-robotic teams as they work in coordination at multiple sites, perhaps for an astrobiology mission or the construction of a lunar base.

SHERPA could also generate an offline AI for a future mission like Europa Lander, a proposed spacecraft that would look for signs of life on the icy moon of Jupiter, where extreme radiation would be expected to fry even a heavily shielded onboard computer within 20 days.

They're also developing SHERPA for future missions to become more conversational and interactive, Balaban says, so it's easier for humans to offer their input and for the AI to automatically explain its decisions and the pros and cons of alternative decisions.

"If SHERPA can help us sort through some of these options and make it easier for human operators to see what are some of the better or worse options, then humans still have the final say," he says, "but they are hopefully operating from a much more informed position." ★



Meet Liberty Lifter

BY PAUL MARKS
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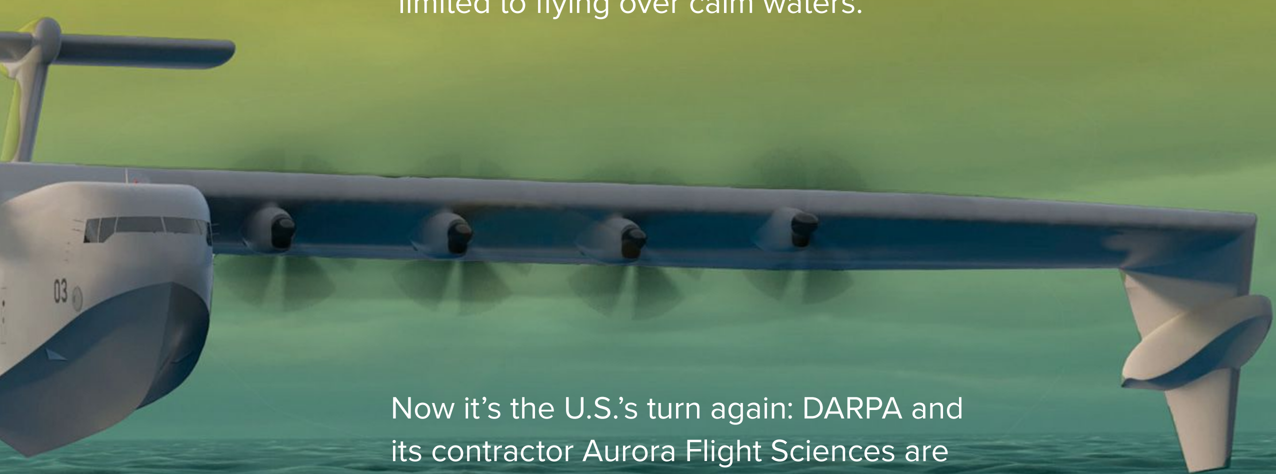
The U-boat sinkings of Liberty Ships, the vessels rushed into service during World War II, so disgusted American shipbuilder and industrialist Henry J. Kaiser that he got together with Howard Hughes to design the H-4 Hercules, better known as the Spruce Goose. The idea was to make a massive seaplane that would fly low to utilize the ground effect, a cushion of air between the surface and its wings. The Spruce Goose was flown just once, long after the war was over, and the concept was abandoned. Between 1966 and 1980, the Soviet Union flew research versions of a ground effect troop carrier, but only one operational aircraft, the Ekranoplan or Caspian Sea Monster, was flown, and it was limited to flying over calm waters.



Now it's the U.S.'s turn again: DARPA and its contractor Aurora Flight Sciences are drawing up the preliminary design for the demonstrator, while in parallel preparing to make structural test articles of components. Managing the program is not a plane designer but a maritime expert, Christopher Kent, who holds a Ph.D. in naval architecture and marine engineering.

We spoke by phone between London and Arlington, Virginia. — *Paul Marks*

Paul Marks: What does DARPA want to accomplish with Liberty Lifter?

Christopher Kent: We're trying to support maritime logistics at a fundamental level, but there is a need for a layer of flexibility and speed and agility on top of that. I call the concept "maritime airlift." Today, if you need to move a million pounds of stuff, ships are hard to beat for efficiency. If you need it to be there tomorrow, airplanes are hard to beat, but they cost a lot more per pound. Transport efficiencies are way worse. With Liberty Lifter, the aim is to occupy the space between conventional airlift and conventional maritime transport — there's quite a large gap in there. The idea is to transport troops and materiel at helicopter speeds but with efficiencies that are much closer to that of a ship. On top of that, we're trying to do it at a lower cost. The other thing Liberty Lifter can support is moving unmanned systems, placing them over a much larger region much more quickly: The Defense Department has unmanned air vehicles, unmanned surface vessels and unmanned underwater vessels. Liberty Lifter will provide an opportunity to transport groups of those over hundreds of miles instead of tens of miles, which is what you'd be able to do with a ship at 14 to 18 knots. We're looking at speeds of around 180 knots, similar to a helicopter. We're building a demonstrator at a smaller scale of about a C-130 size, with numbers very similar to a C-130's performance capabilities. When we originally visualized the program, we were building a larger demonstrator, but we've learned some hard lessons about the availability of the props and gearboxes that can support the kind of thrust we need for takeoff. Those are not available, so we've sized down. But the aim for the future production vehicle is capacity closer to that of a C-17: a 90-ton cargo capacity, so that's 180,000 pounds of men and materiel, not including a Liberty Lifter's crew or its fuel. It wouldn't be quite a C-17 size because it doesn't have the requirement to carry tanks, so the cargo bay is narrower.

Kent clarified this point in a follow-up email. *"We've optimized Liberty Lifter down from approximately the size of a C-17 to a C-130 — we didn't need to build the bigger plane to test our problem set. The Liberty Lifter is expected to have a wingspan of ~200 feet [60 meters], which is wider than either the C-17 (~170 feet) or the C-130 (~132 feet). So when we say 'C-130-sized' that refers to payload, not physical dimensions."*

DARPA's description of the program mentions transforming "fast logistics missions for the DOD and commerce." What's the commerce angle?

I grew up on a small island, so I see an opportunity here for providing fast inter-island transport for cargo. Because our transport efficiency will be better than a regular aircraft, it'll become a tool for UPS-type businesses, giving them an opportunity to get cargo delivered in a day, whereas at ship speed it'd take weeks. The other thing that it can do is Coast Guard rescue for large ship casualties. We have the opportunity to extract people at helicopter-type speeds at ship scale: rescuing hundreds of people from a disabled cruise ship, for instance, versus six, seven or eight, which is what you can take out right now. We also see a very critical need for humanitarian relief: Getting food into places would be very easy because Liberty Lifter is designed to go into an austere port. You'd just need a beach or landing area.

As a naval architect by training, are you approaching Liberty Lifter as a boat that can fly or a plane that can float?

In this case, we're technically a flying boat, as seaplanes are sometimes amphibious and we are not planning to do that.

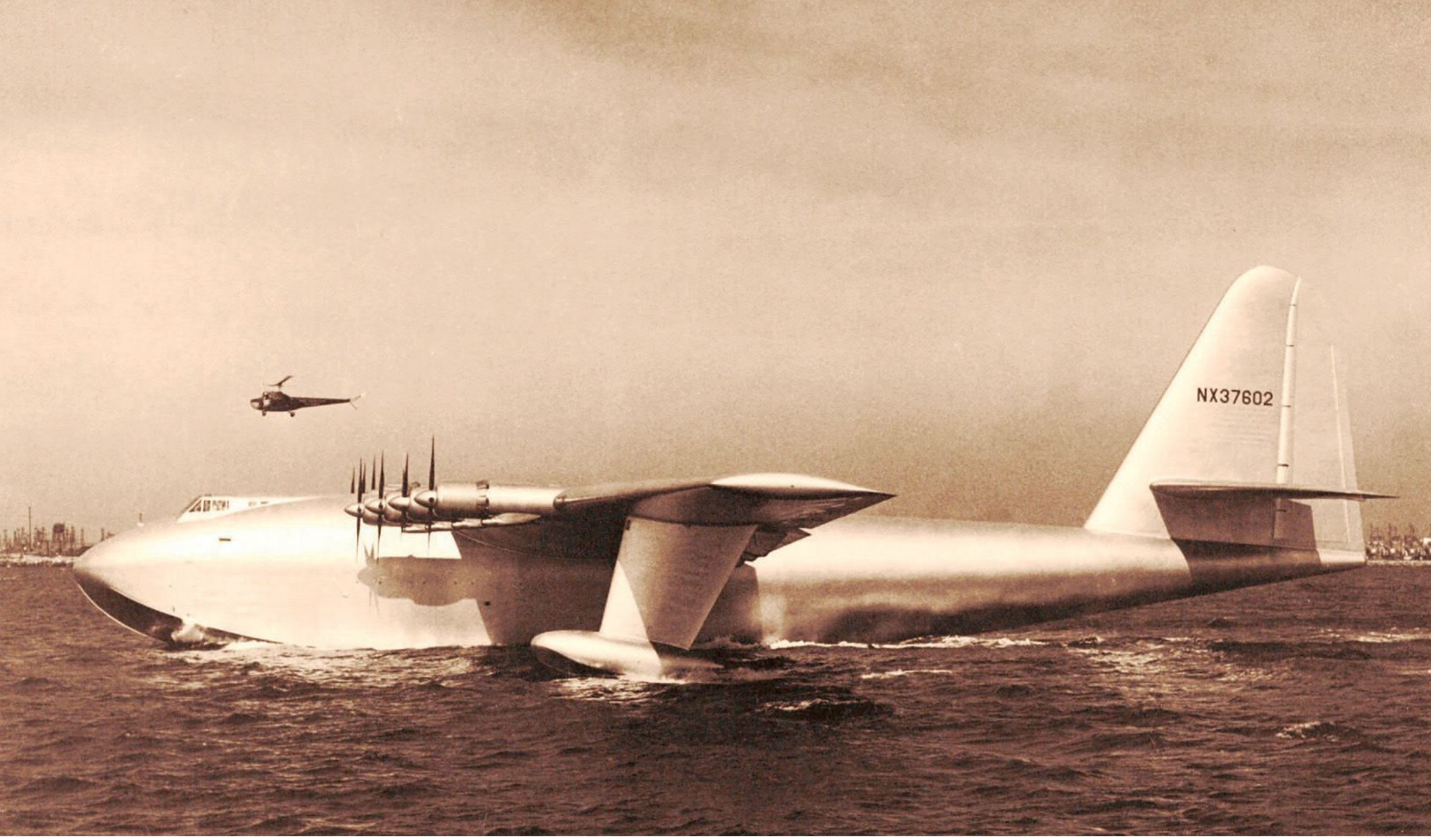
A Cessna Caravan Amphibian, for example, can take off from a runway and land in the water or vice versa. Liberty Lifter will only take off from the water and will need water to land. — PM

Fundamentally, we're still an aircraft, and we still have aircraft requirements and aircraft safety standards to meet. The reason they hired me to run this program was because I had a good understanding and brought a viewpoint and a healthy skepticism to the takeoff and landing problems. We want to be able to operate in high sea states, up to Sea State 4 for takeoff and landing, and Sea State 5 for flight in ground effect. My background in hydrodynamics and systems engineering blends well with the understanding of the problem and the planning of the hull loads. At a fundamental level, the program is a systems engineering problem with a lot of hard science thrown on top. There was a lot of work done at DARPA, ahead of this program, analyzing the feasibility of filling the gaps and the opportunity space that a craft like Liberty Lifter could fill. We stand convinced that it's possible. A large seaplane design is a trade between the same "iron triangle" that everybody else has: cost, performance and schedule. But we're trying to get the whole program to push the boundaries on cost and performance, for a craft of this type.

Sea State 4 means waves up to 2.5 meters — would those have defeated the Soviet Union's Caspian Sea Monster?

One-hundred percent, yes. The Ekranoplan [and its predecessors] were severely limited by sea state. They were operating in what we call the 2D ground effect, or deep ground effect, operating where the ground effect

> "The idea is to transport troops and material at helicopter speeds but with efficiencies that are much closer to that of a ship."



▲ Howard Hughes' massive Spruce Goose made its sole flight off the coast of Long Beach, California, in 1947. The aircraft reached an altitude of 25 feet.

FAA

is driven by the ratio of the chord of the wing to the height off the water.

Kent explains ground effect like this: *"The downwash from the wings and the downward component of the wingtip vortices create a higher than normal pressure area below the wings because the air hits the ground and can't 'escape,' increasing lift. Induced drag is reduced because wingtip vortices (causing drag) can't fully develop close to the ground." Also, the chord is the distance from the leading edge of the wing to the trailing edge. — PM*

With wings low on their structure, they were operating really close to the free water surface, right up on the wave. That offers advantages because it's extremely efficient — you can go much faster than we are planning — and it's naturally stable, which is great when you have flat water. But you're coupled to that, so when you start getting waves, you start [experiencing] high [vertical] accelerations.

Kent elaborated by email: *"In ground effect, you'll experience vertical accelerations that vary proportionally to the height and frequency or wavelength of the swells you encounter. In layman's terms, the ride quality is analogous to racing a pickup truck over a washed-out dirt road; it's bone-jarring and from a human factors perspective not sustainable for more than a very short time. This phenomenon limited Ekranoplan operations to relatively calm water and precluded their use in open ocean conditions."*

DARPA and others have spent quite a bit of time studying that [acceleration phenomenon] and we're pretty sure we understand how it worked. And Howard Hughes' planned Spruce Goose seaplane never exited the 2D ground effect into the regime that we actually want to use: the 3D ground effect, which involves vortices being shed off the wingtips and interacting with the ground. So you have two vortices that shed off the wingtips, they interact with the ground, and they are slowed. That slightly increases your lift and slightly decreases your drag. It's not as strong as the 2D ground effect, but it's also not as coupled with the surface, so you can operate in higher sea states in that kind of flight. The shed vorticity actually gives the same effect of that little lift you feel just before you land in an aircraft. Part of that is flare, but part of that is also that the wake vortices are interacting with the ground and you get a little cushion just before you land. That wake vortex is interacting with the ground, slowly processing downwards. When it hits the ground, that slows it, and that shed vorticity is what gives you drag. So you're putting energy into that vortex so if you slow that vortex — if you think about it just from a conservation of energy perspective — you've reduced your drag, and it actually also slightly increases your lift.

How do you differentiate between 2D and 3D ground effect?

2D ground effect is a height over chord length of about a half, meaning the plane is flying at an altitude only

PHOTO: U.S. Air Force/Staff Sgt. Mitch Fuqua

PHOTO: U.S. National Guard/Staff Sgt. Jon Alderman

Performance goals: DARPA wants Liberty Lifter to have the payload capacity of a C-130, but believes that if one or more of the military services were to contract an operational version, an aircraft with C-17 capacity could be possible.

half the width of the wing. The Ekranoplans were flying at 400 knots [740 kph] at about 4 to 8 feet off the water. So it was really low. What we are using in 3D ground effect is less than a wingspan, so it is a much larger number.

Liberty Lifter's planned wingspan of 200 feet and cruising altitude of 100 feet is advantageous for this 3D ground effect?

I'm not going to give you the final numbers, but we're cruising at around half wingspan-ish or less. The deeper you go into it, the more that effect strengthens, until you get into 2D ground effect, and then you get another lift. That's why the Russians went to that regime with Ekranoplan. But the negative of that is that you can't realistically operate a craft like that in an open ocean; you need something that you can decouple from the waves. That's why they used them on the [calm waters of the] Caspian Sea — because they couldn't realistically use them anywhere else.

What makes the wing-in-ground effect a "DARPA hard" problem?

In some of the earliest photos of the design by Aurora Flight Sciences, you'll see that they have inverted winglets, basically downward ones. So they're not steering [the wingtip vortices] down, they're pushing them down by using a winglet. As to why this is technically DARPA-hard, we're going after both cost and operation regions here at a fundamental level, and technically we have three challenges: the takeoff and landing in high sea states, second driving costs out, and control. Why control? A significant negative of the 3D ground effect is it's not naturally stable; the aircraft doesn't want to stay there, so you have to use active control. What we're really leveraging in the program right now is the world's best state-of-the-art active control that is being used for other aircraft and leveraging that into the program to enable flight in that regime. So unlike a pilot steering a landing, we are going to automate the ability to stay in that 3D ground effect region for long periods. And we are targeting costs of one-half to one-third of that of equivalent military aircraft like C-17s, C-130s. We're getting to that by using maritime-style components and construction techniques, using composites in an aircraft and getting an aircraft flight certification for that from DARPA. A maritime-type composite epoxy will be about $30 per pound, and the aircraft one will be something like $140, although it's a very similar chemical epoxy. Maritime components generally do not have the same tolerances and do not have the same strength-to-weight ratios as those in aircraft, but we're buying those back on by operating in ground effects. We're using the additional lift and drag that we can support to get our transport efficiency still higher, regardless of the fact that our aircraft at a fundamental level could be built more lightly. One of the things

that I am personally interested in, and the program is interested in, is bonded joints. Aircraft have epoxy-bonded joints, but manufacturers then spend all the manpower to still rivet it. So bonded-joints actually cost more, because they still have as much labor as a non-bonded joint held together with just rivets. That's because from a flight safety certification, the certification process has not pushed that boundary and has not gotten around except for some very specific cases, the acceptance of joints of that type. So we're pushing that again, trying to see if we can move there.

Are there success stories from the maritime world that give you confidence?

Some 20 to 30 years ago in the Volvo Ocean Race and the America's Cup, boats were breaking all the time, failing catastrophically on the course, rudders would snap — that was bonded joint failure, and that doesn't really happen anymore. The naval architecture world, and the boat world, has moved on and figured out how to design those joints well. This also has the potential to open up a whole new industrial base for being able to build aircraft components in small boatyards spread all over the world, all over the U.S. And you have the opportunity to build aircraft subcomponents in such places, which we're going to test that out here. Large portions of the structure will be built at a shipyard.

What are the advantages of Aurora's proposed monohull design?

The monohull is a much more conventional aircraft. It has some drag advantages for takeoff, but its cargo configuration is a little more challenging as you naturally carry almost twice as much stuff in the twinhull [the design proposed by the second contractor, General Atomic Aeronautical Systems]. But you're much more stable in a high seaway, as catamarans are very stable in big waves. So you fundamentally had more stability for that and had the ability to unload cargo twice as fast in a twinhull design when it's landed. It also gets you a big, fairly long chord length in between the two hulls, which gives you a lot of structural strength in the beam. On a conventional aircraft, the structural joint arrangement to the main fuselage can be challenging, but it's also something that's well understood. Fundamentally, they're both executable designs; it's just we've had to downselect to one performer.

Kent followed up by email: *"Efficiency is baked into the DARPA model, which maximizes our opportunity to create transformational change. For Liberty Lifter, when we reached the point where we realized only one performer was meeting our aggressive schedule and technical goals we streamlined the program to continue to deliver innovation ASAP."*

Once we get through preliminary design review in the next year or so, we'll decide if we're moving out on doing detailed design and construction on the monohull aircraft.

Regarding propulsion, are electric motors a possibility for Liberty Lifter?

Right now, there's just nothing in the 5,000 horsepower-ish range that we need for our takeoff that can consistently deliver the kind of power we need. We need eight 5,000 horsepower engines, and we are also adding in a very corrosive saltwater environment. So our technical challenges don't focus on marinizing big, high-power, aircraft-grade electric motors at this point. Do we see an opportunity space in the future as those continue on the track at which they are going? I do, absolutely; I would not be surprised to see a commercial version of this. What we would really need is a hydrogen-powered commercial version of this because we'd have a lot of volume to fill with hydrogen. But that's just not executable [for the demonstrator], and it doesn't really drive out our need. It also is not necessarily very focused on the military need, and our name does start with "defense."

Tell me more about the control avionics and automation that will be involved in keeping Liberty Lifter in that all-important 3D ground-effect region.

We're looking at wind gust alleviation regimes and approaches that have been used for commercial aircraft and trying to apply them to this platform. Thus far, the analyses that have been done have showed that there seems to be a lot of promise for smoothing out the ride for Liberty Lifter. There's also some interesting behaviors that you have to address. When you're flying in ground effect, for example, a bank turn is no longer a bank turn — because if you just banked, one wingtip would touch the water. So you have to do an active lift control turn, where you lift yourself up and sort of bank around the wingtip, which involves a lot of use of active lift control.

Lay out the big milestones going forward.

We will decide about moving into detailed design and construction in about a year's time, plus or minus a few months. When we will start construction depends on your definition of "construction." We will start purchasing long-lead item stuff very shortly thereafter, but my current expectation is that construction will begin in 2026 and last about a year. We're targeting floating Liberty Lifter sometime in late calendar 2027 — and potentially first flight in late calendar year 2027. ★

The zest to open space to you and me means that the next generation of spacesuits might not be worn by only the usual clientele of professional astronauts. That possibility is inspiring some innovations. **Cat Hofacker** spoke to the designers.

BY CAT HOFACKER | catherineh@aiaa.org

Tomorrow's spacesuits

One of the changes NASA made when the Apollo era closed and the space shuttle era began had to do with spacesuits. Instead of ordering tailor-made, one-piece soft suits, components were made to NASA's specifications in multiple sizes for astronauts to mix and match, a decision made to manage the cost of outfitting upwards of 100 astronauts of varying heights and weights. Another shift was toward a rigid fiberglass torso that, among other purposes, would shield wearers from possible debris impacts as they conducted extravehicular activities, EVAs, from the International Space Station.

The postponement of one such spacewalk in 2019 illustrated one limitation with these current suits. Plans had called for Christina Koch (pronounced "cook") and U.S. Army Col. Anne McClain to replace the lithium-ion batteries that store power gathered by the station's solar arrays with new ones. But once aboard, McClain conducted a spacewalk with Nick Hague and discovered that a size large torso wouldn't work for her, despite having practiced on the ground with that size. She needed a medium, but there was only one of those aboard, and Koch needed it. Hague ended up working with Koch to replace the batteries. The first all-female spacewalk came seven months later, by Koch and Jessica Meir, when another medium was ferried up.

Then there's the question of mobility. Let's say that during a spacewalk, an astronaut wants to touch the chest-mounted display to check the pressure levels of the suit. Doing so would require stretching out the arm to rotate the shoulder bearing, then swinging the arm back toward the chest. Such drawbacks aren't going to work for the commercial marketplace that NASA aspires to seed in low-Earth orbit, in which suit builders would also rent or sell their suits to private interests. Researchers from various walks of life might want to venture outside privately run stations to tend experiments, or private citizens might pay to spend a week in orbit conducting spacewalks mainly for the coolness of it. These people are likely to have a wider range of body types than professional astronauts, who have often come from the military services or other physically and psychologically demanding backgrounds. McClain is an Army helicopter pilot who flew 800 hours in combat during the post-Sept. 11 Iraq war. Koch, meanwhile, spent a year at the South Pole as a researcher and a member of the firefighting and search and rescue teams.

There is also the age of the spacewalk suits to consider: At 43 years old, they are long past their original estimated operating life. As for surface suits, the Apollo versions are now museum items, so new ones will be needed for the return to the moon in the Artemis III mission, targeted for 2026, which is to include the first woman to walk on the lunar surface.

If the next-generation spacewalk and lunar suits are designed to fit a larger percentage of the population, "you get more people involved who can apply their skills," says Tom Jones, a retired astronaut who conducted three spacewalks from the space shuttle Atlantis in 2001. "So let's make full use of the talent pool."

As for the acquisition strategy, that too has changed dramatically over the decades as NASA shifted from tailor-made suits in the '60s and '70s to the mix-and-match suits in the '80s. Now comes what might be its boldest shift yet: This time, NASA set broader requirements, allowing contractors more leeway in the design so long as the suits are proven safe via tests in some kind of "spacelike environment." NASA also will rent the suits instead of owning them.

The strategy began to unfold in 2022, when Axiom Space of Houston received a $228 million contract to provide the two Artemis III surface suits and Collins Aerospace, the EVA incumbent, $97.2 million to make new spacewalk suits. A twist came last year, when NASA exercised the "crossover" option in each contract, paying Axiom an additional fee to adapt the lunar suit for EVAs, and the same to Collins to create a surface variant. It's a two-provider model reminiscent of the strategy behind the agency's Commercial Crew program, in which NASA funded Boeing to help it design and test its Starliner capsules and SpaceX to do the same with its Crew Dragons. The thinking was that if one provider ran into technical trouble, the other would be ready to ensure NASA has a U.S.-built spacecraft available to ferry astronauts to and from ISS.

Speaking of SpaceX, it has developed its own EVA suit without NASA dollars and could scoop everyone this year by conducting the first commercial spacewalk: a two-person tethered jaunt from a Crew Dragon during the planned Polaris Dawn mission beyond the orbit of ISS. SpaceX has yet to announce the date.

Here are the major design considerations:

Appearance

Line up the prototypes of the Axiom, Collins and SpaceX EVA suits that each company is testing side by side, and your first thought would likely be that the Axiom and Collins suits look very similar.

That's in large part because both companies are aiming for "a single-suit configuration" — as Axiom's Russell Ralston put it when we spoke on the sidelines of the Space Symposium in April — meaning a design that needs just a few modifications to go from LEO to the lunar surface and vice versa.

"Now I can train the crew with a single suit design," whether they're preparing for an EVA from ISS or a lunar landing, says Ralston, the company's vice president of Extravehicular Activity and a former spacesuit engineer at NASA's Johnson Space Center in Texas. "That saves time, and you don't have to worry about

▲ The first commercial spacewalk could come this year during the Polaris Dawn mission by SpaceX and billionaire Jared Isaacman. Two crew members are to exit a Crew Dragon capsule attached to umbilical cords that will provide oxygen and communications and keep the flyers from floating off into space.

Polaris Program

people making mental mistakes cause they think they're in one suit when they're in another suit."

Both suits are to have a white, puffy exterior — the better to keep astronauts cool by reflecting sunlight. Axiom also has a version with a dark blue and black exterior, but the company tells me that is only for display purposes. Both suits are also to include tried-and-true elements that go back to the Apollo design: the bubble-shaped helmets, rubber-tipped gloves and large life support "backpacks" that house the astronauts' breathing equipment. The Apollo and ISS suits recirculate oxygen via vent ducts, removing carbon dioxide as needed with canisters of lithium hydroxide cells. Should something go amiss, small tanks of oxygen in the backpack provide a backup supply long enough for astronauts to return to their lunar module or get back inside the station.

For Collins, this continuity was part of a deliberate strategy to keep as much of the current EVA design as possible, only making upgrades to improve astronaut mobility or where new and better technology is available.

"We have basically been taking all the lessons learned in the entirety of the spacewalking program and rolling those up into what we currently have as a next-generation spacesuit," says Danny Olivas, the

"We have basically been taking all the lessons learned in the entirety of the spacewalking program and rolling those up into what we currently have as a next-generation spacesuit."

— Danny Olivas, Collins Aerospace

Inside the NASA contracts

Axiom Space:

In 2022, awarded $228 million to provide two lunar surface suits.

In 2023, awarded initial $5 million to adapt the surface design for spacewalks from the International Space Station.

Collins Aerospace:

In 2022, awarded $97.2 million to deliver an unspecified number of ISS spacewalk suits.

In 2023, awarded initial $5 million to adapt the ISS design into a lunar surface suit.

chief test astronaut for Collins, who completed five spacewalks in the NASA astronaut corps between 2007 and 2009. We spoke in the Space Symposium exhibition hall near a floor model of the suit, though he cautioned me that it's not a completely accurate representation of the prototype that Collins has been testing for several months.

By contrast, the white and black SpaceX suit appears more fitted — only slightly more voluminous than the Teflon suits that astronauts don for riding inside Crew Dragon capsules to and from ISS. Given the limited room inside Dragon, the choice was made to adapt that intravehicular, or IVA, design into a suit that the four Polaris Dawn crew members would wear during ascent and landing as well as for the spacewalk, SpaceX said last month when it revealed the design. Plans call for billionaire Jared Isaacman, a retired U.S. Air Force pilot, and two SpaceX employees to ride in a Crew Dragon out to the Van Allen Radiation Belt to study the effects of radiation on human health. Isaacman and another crew member would conduct the history-making spacewalk, exiting through Dragon's nose hatch for a two-hour excursion at an altitude of 700 kilometers. Information about the pressure, temperature and humidity levels of the suits will be viewed via new heads-up displays inside the copper-coated visor. Dragon will remain open to the vacuum of space the entire time, so the two Polaris Dawn members remaining inside the capsule must also don their suits.

"Aesthetically, it may look similar to the IVA" design, Isaacman said during a May livestream, referring to the ascent suit, "but what they did under the hood is extraordinary, and they did it in two years."

Among the changes, SpaceX says the outer layer of the EVA suit is comprised of a "new textile-based" material interspersed with joints "to provide greater flexibility to astronauts in pressurized scenarios while retaining comfort for unpressurized scenarios."

In another glaring difference to the Axiom and Collins designs, SpaceX eschewed a bulky life support backpack in favor of an umbilical cord. Like the safety tethers that ensure astronauts do not float away from ISS during today's spacewalks, these umbilicals are to keep Isaacman and his crew member connected to Dragon. But they will also serve a greater role: Based on illustrations that the Polaris Program has released, this tether would plug into some kind of shoe-box-sized component on an astronaut's hip to provide life support, an approach reminiscent of the spacewalks conducted during the NASA Skylab program.

"That's the simplest way" to conduct an EVA, says Jones, the retired astronaut. "You just plug [the tether] into the ship's life support system and give your guy a 25-foot tether, and out he goes with an umbilical that supplies oxygen and communications and power and gives you the safety tether function built in too."

Despite the relative ease, this approach might not be ideal for the lunar suits in particular, as it would limit how far astronauts could travel from their landers.

Suiting up

Perhaps the biggest distinction between the three designs centers on how astronauts will put them on and take them off.

SpaceX and Collins made minimal changes from their previous designs. For its EVA suit, SpaceX kept

▲ Axiom Space in April subjected its suit prototype to conditions similar to those on the lunar surface. After being submerged in the Neutral Buoyancy Lab at NASA's Johnson Space Center in Texas, engineers placed weights around the suit to emulate the moon's gravity, which is one-sixth that of Earth's.

Axiom Space

"It's almost like when you go in to get a bespoke suit. We'll have people come in and take [an astronaut's] measurements, and then we can look at our pantry of spacesuit items and we can assemble a suit for them."

— Russell Ralston, Axiom Space

the zipper entry from its ascent suit, but instead of a single zipper running along the inside of the legs, the EVA suit has spiral zippers at the waist, according to the SpaceX website. There are additional zippers at the forearms in the event the Polaris Dawn flyers want to remove their gloves for brief periods while inside the capsule — shortly after ascent to complete some quick task, for instance.

By contrast, the Collins suit is a waist entry, but with some additional steps: An astronaut steps into the legs like one would a pair of pants, then pulls on the upper torso similar to a shirt. The two pieces are connected by a large metal ring designed as a bearing, so the upper and lower parts turn with the wearer. For the upper body, Collins updated the rigid upper torso of the current ISS suit to an adjustable hybrid torso with "soft goods and joints" down the arms, Olivas says.

For its lunar suit, Axiom chose yet a third method of entry. Instead of the zippers on the Apollo suit, Artemis III astronauts will don their Axiom suits through the rear, via a hatch on the side of the life support systems backpack — similar to the door of a front-loading washing machine. After swinging open the hatch, an astronaut inserts feet, then arms, "and you just kind of fall into it," Ralston says. Axiom chose a design without a rigid frame, believing this would reduce the chance of astronauts injuring

themselves if they contorted their bodies while putting on the suits.

That soft outer pressure garment — made of a material that Axiom is not disclosing — is interspersed with joints at the shoulders, elbows, hips and knees. "We've done a lot of testing to iterate the types of basic joints that we use and how we pattern the different soft goods to enable flexibility, like bending your elbow or bending your arm," Ralston says.

Sizing and mobility

Those two considerations go hand-in-hand. "It's not just about what's your range of motion," Ralston says. "It's about how hard is it" to move. "How much force do you have to exert to use that range of motion?"

An ill-fitting suit requires an astronaut to put more force into a movement, and that in turn means getting tired more quickly.

For Polaris Dawn, the SpaceX suits have been custom-made for each crew member. However, the SpaceX website notes that "building a base on the Moon and a city on Mars" will require manufacturing "millions" of suits, and that the company will be able to "produce and scale" the EVA suit "to different body types."

By contrast, Axiom and Collins are taking their cues from the shuttle program's modular approach of manufacturing arms, legs, gloves and boots in multiple sizes. Collins also plans to produce two sizes of the hybrid upper torso that Olivas says "can be adjusted," though he did not specify how.

"It's almost like when you go in to get a bespoke suit," Ralston says. "We'll have people come in and take [an astronaut's] measurements, and then we can look at our pantry of spacesuit items and we can assemble a suit for them."

As for range of motion, Axiom and Collins say that initial testing gives them confidence that their suits will allow astronauts to move easily in LEO and on the lunar surface.

With the Collins suit, Olivas experienced this firsthand earlier this year, when he donned a prototype of the suit and with a handful of Collins engineers boarded an aircraft for two parabolic flights. During dozens of brief moments of weightlessness, Olivas practiced common spacewalking tasks in front of a mock-up of an ISS airlock, which he found "much less of a struggle" than similar movements in the current suit, he says.

For its lunar suit, Axiom has tested the mobility in multiple ways, including late last year at NASA Johnson, when astronaut Victor Glover and Axiom engineers donned prototypes and squatted and knelt in a sandbox to simulate collecting samples on the lunar surface. And in April, an unoccupied suit was lowered into the Neutral Buoyancy Laboratory pool, also at NASA Johnson, with weights added to mimic the lunar gravity that's one-sixth of Earth's. Plans call for a human to get inside the suit during future trials, and Collins prototypes are to have their turn in the pool as well.

▲ Collins Aerospace employees took turns earlier donning prototypes of the company's spacewalking suits and flying aboard a Zero-G aircraft. They did common astronaut tasks during the 20-second intervals of weightlessness to test its mobility.

Collins Aerospace

LEO versus lunar

For Artemis III, Axiom added a few components designed specifically to guard against the harsh conditions of the south pole region, where the crew is to land. In the permanently shadowed regions where sunlight doesn't reach, temperatures will be as low as minus 230 Celsius (minus 382 degrees Fahrenheit), so the Artemis astronauts will wear boots lined with insulating material. Each astronaut will also have a headlamp on their helmet for visibility, because the angle of the sun throws large shadows across boulders and other large protrusions.

The suit must also hold any tools the astronaut need for any scientific tasks, like scooping up samples of lunar rocks and dirt. Here, Ralston says Axiom and NASA are taking their cues from the Apollo program and "keeping it simple," at least for the initial Artemis landings.

"It's amazing how useful a hammer and a chisel is," he says.

NASA is betting that the lunar landings will also guide planning for its first human mission to Mars, notionally targeted by the agency for the 2040s. Ralston said the company has a good sense of the challenges required for spacesuits for Mars, but he added that the company is "laser focused" on completing the Artemis III suits and adapting that design for LEO spacewalks.

"We're trying to go as fast as humanly possible," Ralston says. "If I can make it ready tomorrow, let's make it ready tomorrow."

Mars, in fact, is on Olivas' mind — and he is ready to begin suit development whenever needed.

"I want to be part of that," he says. ★

◀ Plans call for Artemis astronauts to collect samples of lunar regolith and complete other tasks during moonwalks. Astronaut Victor Glover wore the suit last year to practice handling geology tools.

Axiom Space

Taking Artemis' measure

NASA plans to return humans to the moon in 2026. How real is that date? Jonathan O'Callaghan looks at the long to-do list.

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▲ NASA astronauts Nicole Mann and Doug Wheelock climbed into this subscale version of the Starship elevator late last year to test how Artemis crew members might descend to the lunar surface. The mock-up, at SpaceX's California headquarters, had mechanical controls for the astronauts to practice controlling the descent.

SpaceX

By NASA's latest schedule, we are a little more than two years away from witnessing a historic moment: the return of humans to the moon.

Here's a snapshot of what must happen between now and then: SpaceX must boost a Starship spacecraft to Earth orbit atop a Super Heavy booster to prove that it can do the same with the $2.9 billion lunar lander version of Starship. In the 2026 mission, this Starship Human Landing System will have exhausted its propellant after separating from the Super Heavy, so SpaceX must show that it can be refueled in Earth orbit to continue on to lunar orbit and then down to the surface and back up. Ahead of time, multiple Starships must be launched to accumulate propellant in a depot that does not yet exist but which Elon Musk has described as a massive version of Starship. Turning to the crew members, they will have been boosted to lunar orbit separately, in an Orion capsule atop a NASA Space Launch System rocket. Once out there, they must dock with the refueled Starship for the landing. But before NASA entrusts the Starship with their lives, SpaceX must land an unoccupied one on the moon and lift off again. NASA, it could be argued, has it a little easier. Ahead of 2026, it must send a crew looping around the moon in the Artemis II mission, a human version of the unoccupied Artemis I demonstration of 2022.

Given all that, the feasibility of the September 2026 target for Artemis III remains an open question, just as was the case for the previous target dates of 2024 and 2025. NASA has, at times, indicated flexibility about which Artemis mission will mark the return to the moon. At the moment, even the spacesuits for the landing are still in development by Axiom Space in Houston [see "Tomorrow's spacesuits," page 30].

"I do believe that progress is being made, and we are certainly closer now than we ever have been," says space consultant Laura Forczyk of Georgia-based Astralytical. "But there is a lot of work to do."

This account is based on interviews with current and former NASA officials, former SpaceX employees and a review of public remarks, government documents and press releases. Multiple requests were made to SpaceX by phone and email for comment, but the company did not respond.

The delays thus far have stemmed from the mission's ample and interrelated hardware. In Apollo 11, getting three astronauts to space and two of them to the surface required sending up everyone and everything on one rocket, a Saturn V. In Artemis III, getting four astronauts to space and two to the surface will involve more than twice the amount of hardware. Still

NASA is still assessing the damage to the Orion capsule that completed the Artemis I uncrewed test flight in late 2022. That capsule traveled some 43,000 kilometers from Earth and completed several orbits around the moon before splashing down in the Pacific Ocean. NASA

FACT

GATEWAY TO THE MOON: Plans call for the first two segments of NASA's planned lunar space station to be launched together on a SpaceX Falcon Heavy rocket in 2025 or 2026. One is the PPE, the Power and Propulsion Element, and the other is HALO, the Habitation and Logistics Outpost, the part of the station where the crew will reside. Initially, NASA's plan to return astronauts to the moon had the four crew members docking at the Gateway in their Orion capsule; two of them would ride to the surface in a lander that was yet to be chosen. Plans for Gateway slid to the right on NASA's calendar, however, forcing NASA to adjust by having the crew dock with the lander chosen in 2021: a version of SpaceX's Starship. Now, though, with the landing planned for 2026, NASA is beginning to field questions about whether Gateway should be reincorporated into the plan for the historic return. The answer, so far, has been no. "Gateway is not part of Artemis III," NASA's Jacob Bleacher said at the Lunar and Planetary Science Conference in Texas in March.

more hardware will come later when the elements of NASA's Gateway space station are launched and assembled in lunar orbit. Once Gateway is ready, each Orion will dock there instead of with a Starship or Blue Origin's planned Blue Moon lander.

The plan is "complex," says Abhi Tripathi, an aerospace engineer at the Space Science Laboratory at the University of California, Berkeley and a former mission director at SpaceX. "You have the SLS launch, you have an Orion, you have Starship going up and down. The inevitable question must be asked at some point: Is there a way to simplify the architecture?"

NASA has shown no inclination to do so. The agency has been adamant that this collection of vehicles plus Gateway will establish a sustainable era of lunar exploration and avoid anything like the 54-year gap between the Apollo 17 mission in 1972 and Artemis III.

The program's history, and quotes from managers, suggest that they would rather slip the schedule than overhaul the architecture.

As it pushes "boundaries that have not been pushed

before," NASA is "constantly evaluating" its schedule, and indeed has "a lot to do," Jacob Bleacher, NASA's chief exploration scientist, said at a town hall meeting at the Lunar and Planetary Science Conference in Texas in March, according to a video of the event.

In March, SpaceX proved that it can get a Starship to space, although the vehicle disintegrated on reentry. The next milestone will be getting a Starship to space and back to prove its reusability. That will be followed at some point by a demonstration of propellant transfer between two Starships as a step toward the depot.

"I would like to see a detailed plan of how we're going to get the technology developed and demonstrated at scale for the propellant depot," says Dan Dumbacher, CEO of AIAA (publisher of Aerospace America) and formerly a deputy associate administrator at NASA Headquarters in Washington, D.C.

The propellant would need to be kept cold to avoid or limit boil off over time. "It's going to warm up, and you're going to lose some of the quality," says Dumbacher. "You have to account for that in your refueling cadence."

SpaceX has not elaborated on the logistics of transferring and storing the fuel. "Is their plan to have a propellant depot in orbit for five years or whatever?" says Tripathi. "They need to eventually talk more about that. There's nothing in the public domain that I've seen."

There also have been shifting accounts of how many Starship launches will be required to fill the depot. Musk said in a post on the former Twitter in August 2021 that as few as four launches could suffice. But in November, Lakiesha Hawkins of NASA's Moon to Mars Program Office said the number of required launches could run "in the high teens." Her briefing to members of a NASA Advisory Council committee comported with NASA Associate Administrator Jim Free's April statement during an interview with Aerospace America that 12 to 15 launches would be needed.

Lisa Watson-Morgan, NASA's Human Landing System program manager in Alabama, tells me in an interview that she expects SpaceX to begin orbital testing next year to ascertain how big an issue propellant boil off or other factors will be. "Once we prove that out, I think we'll have a more solid number of flights."

As for how the astronauts will get from Orion

▲ Not long after the photo above of Apollo 17 pilot Harrison Schmitt was taken, he and Gene Cernan climbed back into their lunar lander to start their journey home. For Artemis III, a Human Landing System version of Starship is in development by SpaceX as part of a $2.9 billion contract.

NASA

ILLUSTRATION BY SPACEX

"You have the SLS launch, you have an Orion, you have Starship going up and down. The inevitable question must be asked at some point: Is there a way to simplify the architecture?"

— Abhi Tripathi, University of California, Berkeley

onto Starship, Watson-Morgan says work on a docking apparatus, while "not highly publicized," is already underway.

"We had a docking adapter test earlier this year at [the Johnson Space Center in Texas] with the Starship docking system," she says.

Turning to the all-important landing, the concerns are multiple. Starship will come down base first, with an unspecified number of its six engines slowing it. Musk in the past has said that additional thrusters located higher up the vehicle might be installed for the landing maneuver.

"You can imagine it kicking up a lot of rocks," says Tripathi, "which is debris that can impact your spacecraft." That's one reason NASA's HLS contract with SpaceX requires the uncrewed demo landing.

After touchdown, there will also be the matter of getting the astronauts down to the surface from the crew area, which Tripathi estimates will be located about 30 meters up the 50-meter-tall lander, based on his review of NASA documents and the SpaceX illustrations. Plans call for the two astronauts to ride an exterior elevator to the surface, and testing is already underway. A SpaceX photo shared by NASA in December shows two spacesuited astronauts standing in an open-frame, basketlike elevator

“We don’t want to do something like STS-1 where we put the astronaut lives at risk. We had a lot of open risk items on the shuttle program.”

— Dan Dumbacher, AIAA

outside a building at SpaceX’s headquarters in Hawthorne, California. In response to emailed questions, NASA said that once Starship lands, the astronauts must open the payload door to deploy the elevator outside the lander, then climb in for their ride down to the surface.

If you think this sounds potentially precarious, you are not alone.

Starship’s height is a potential concern “from the standpoint of: The closer I have the astronauts to the surface, the easier the job is,” says Dumbacher. “SpaceX has made the calculation the risk is worth the reward. We’re doing this kind of thing for the first time in a one-sixth gravity environment. We’ll be able to figure it out over time, but the first couple of times, Mother Nature has a wonderful way of keeping us all humble.”

▲ NASA earlier this year tested the docking apparatus that will join the Orion crew capsule to the Starship lander so two astronauts can be carried to the lunar surface in the Artemis III mission. In later missions, Orion will dock with the planned Gateway space station before the astronauts head to the surface abaord a Starship or a Blue Origin Blue Moon lander.

SpaceX

Dumbacher compares the situation to the questions over the thermal protection tiles that shielded the Columbia orbiter during its return to Earth in the shuttle design’s 1981 debut. “When we brought shuttle home, it was the first time we tested those tiles,” he says. “We don’t want to do something like STS-1 where we put the astronaut lives at risk. We had a lot of open risk items on the shuttle program.”

Tripathi adds: “I don’t think there’s anything in theory wrong with the elevator,” which is “a perfectly good idea. But when you plan space missions you tend to want to reduce complexity. With an elevator system, you do have to worry about something breaking.”

Watson-Morgan says that, in order for NASA to certify Starship as safe to transport humans, it might require some sort of backup.

▲ SpaceX in May conducted a static firing of the Starship spacecraft that it plans to launch on the design's fourth test flight. During Flight 3, in March, a different Starship separated from the booster and reached an altitude of 150 kilometers, but it disintegrated as it descended toward the Indian Ocean.

SpaceX

"There is a secondary mechanism that we are working with SpaceX on to make sure that we do have the ability to get the crew back should the elevator fail," she says. NASA did not respond to follow-up questions asking for further detail.

Then there is the stability of Starship at landing to consider. Apollo 11's Eagle lander was short and squat compared to Starship. Specifically, Eagle was about 9 meters across, just like Starship, but Starship will be 50 meters tall compared to Eagle's 7 meters.

"As a blanket statement I believe all lunar landers, and certainly the two human lunar landers under contract" — meaning Starship and Blue Origin's Blue Moon — "have a very high bar to prove to NASA that they can land safely and not tip over," says Tripathi by email. Of special concern are "the leg deisgn and center of mass," he adds.

All told, "there is nothing inherent in the illustrations we see of Starship that would make me more concerned about it, than any other lander design, including ones much smaller or uncrewed," he concludes.

Like so much in the Artemis program, there is a lack of certainty about the landing and the technology that the astronauts will depend on. At the moment, even those who should be the greatest advocates of Artemis are left hungering to know more about the landing, about the propellant depot concept, about the docking technology for a mission that in theory could be just 27 months away.

"I wish there was more communication between SpaceX, NASA and the general public," Forczyk, the analyst, says. ★

AIAA Bulletin

DIRECTORY

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We are frequently asked how to submit articles about section events, member awards, and other special interest items in the AIAA Bulletin. Please contact the staff liaison listed above with Section, Committee, Honors and Awards, Event, or Education information. They will review and forward the information to the AIAA Bulletin Editor.

Calendar

FEATURED EVENT

29 JULY–2 AUGUST
Las Vegas, Nevada

AIAA AVIATION Forum and ASCEND will be co-located in Las Vegas. Attendees will receive one all-access ticket to attend the sessions of their choice from these two signature events. Both events will deliver full technical programs, as well as admission to networking events and receptions that are specially designed for everyone, with more opportunities to connect with leading industry executives, government officials, and academia.

aiaa.org/aviation AND ascend.events

DATE	MEETING	LOCATION	ABSTRACT DEADLINE
2024			
3–26 Jun	Design of Experiments Course	ONLINE (learning.aiaa.org)	
3–19 Jun	The Anatomy of Autonomy Course	ONLINE (learning.aiaa.org)	
4–7 Jun	30th AIAA/CEAS Aeroacoustics Conference	Rome, Italy (aidaa.it/aeroacoustics/)	14 Dec 23
10–13 Jun	Applied Space Systems Engineering Course	ONLINE (learning.aiaa.org)	
11–13 Jun*	CEAS EuroGNC 2024	Bristol, UK (https://eurognc.ceas.org)	
17–22 Jun*	Spaceport America Cup	Las Cruces, NM	
18–27 Jun	Guidlines for the Development of Civil Aircraft & Systems Course	ONLINE (learning.aiaa.org)	
13–21 Jul	COSPAR 2024: 45th Scientific Assembly	Busan, Korea	
28 Jul	Regional Leadership Conference (RLC)	Las Vegas, NV	
29 Jul–2 Aug	AIAA AVIATION Forum	Las Vegas, NV	12 Dec 23
30 Jul–1 Aug	ASCEND Powered by AIAA	Las Vegas, NV	12 Dec 23
2–3 Aug	5th AIAA CFD High Lift Prediction Workshop	Las Vegas, NV	
3–26 Sep	Guidance and Control of Hypersonic Vehicles Course	ONLINE (learning.aiaa.org)	
9–12 Sep	Space Domain Awareness Course	ONLINE (learning.aiaa.org)	
9 Sep–16 Oct	Orbital Mechanics and Mission Simulation Course	ONLINE (learning.aiaa.org)	

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.).

DATE	MEETING	LOCATION	ABSTRACT DEADLINE
2024			
9 Sep–18 Nov	EVA 101: Life Support Systems Course	ONLINE (learning.aiaa.org)	
9–13 Sep*	34th Congress of the International Council of the Aeronautical Sciences	Florence, Italy (icas2024.com)	
10–13 Sep	Safety Management System (SMS) in Aviation Course	ONLINE (learning.aiaa.org)	
12–13 Sep	AIAA Rocky Mountain Section's Annual Technical Symposium	Colorado Springs, CO	
17–26 Sep	Aircraft Reliability & Reliability Centered Maintenance Course	ONLINE (learning.aiaa.org)	
24 Sep–10 Oct	Advanced Solid Rockets Course	ONLINE (learning.aiaa.org)	
30 Sep–23 Oct	Spacecraft Lithium-Ion Battery Power Systems Course	ONLINE (learning.aiaa.org)	
1–2 Oct	Fundamentals of Space Domain Awareness Course	ONLINE (learning.aiaa.org)	
8 Oct–7 Nov	Advanced Hydrogen Aerospace Technologies and Design Course	ONLINE (learning.aiaa.org)	
14 Oct–20 Nov	Spacecraft Design, Development, and Operations Course	ONLINE (learning.aiaa.org)	
14–18 Oct*	75th International Astronautical Congress	Milan, Italy (iac2024.org)	
19–20 Oct	SmallSat Education Conference	Cape Canaveral, FL	
22 Nov	AIAA Young Professionals, Students, and Educators (YPSE) Conference	Laurel, MD	
25–26 Nov	Region VII Student Conference	Melbourne, Australia & Online	4 Aug 24
2025			
6–10 Jan	AIAA SciTech Forum	Orlando, FL	23 May 24
26–27 Feb	ASCENDxTexas	Houston, TX	
1–8 Mar*	IEEE Aerospace Conference	Big Sky, MT (www.ieee.org)	1 Jul 24
15–17 Apr	AIAA DEFENSE Forum	Laurel, MD	15 Aug 24
21–25 Jul	AIAA AVIATION Forum	Las Vegas, NV	
22–24 Jul	ASCEND Powered by AIAA	Las Vegas, NV	
29 Sep–3 Oct	75th International Astronautical Congress	Sydney, Australia (iac2025.org)	

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

● AIAA Continuing Education offerings

2024 AIAA Awards Gala Held in May

AIAA presented its premier awards at the AIAA Awards Gala, 15 May, at The John F. Kennedy Center for the Performing Arts in Washington, DC. The Class of 2024 AIAA Fellows and AIAA Honorary Fellows also were recognized.

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1 Class of 2024 AIAA Honorary Fellows: (left to right) John Langford, Hitoshi Kuninaka, Azad Madni, and Christopher Scolese.

2 Class of 2024 AIAA Fellows.

3 Carlos Cesnik, Chair, Board of Guggenheim Award (left), and President Laura McGill (right) with Michimasa Fujino, recipient of the 2024 Daniel Guggenheim Medal.

4 AIAA CEO Dan Dumbacher (left) and President Laura McGill (right) with Kurt Polzin, recipient of the 2024 AIAA Engineer of the Year Award.

5 AIAA CEO Dan Dumbacher (left) and AIAA President Laura McGill (right) with Michelle N. Banchy, recipient of the 2024 AIAA Lawrence Sperry Award.

6 AIAA CEO Dan Dumbacher (left) and AIAA President Laura McGill (right) with Leland Melvin, recipient of the 2024 AIAA Public Service Award.

7 AIAA CEO Dan Dumbacher (left) and AIAA President Laura McGill (right) with Paul Nielsen, recipient of the 2024 AIAA Distinguished Service Award.

8 AIAA CEO Dan Dumbacher (left) and AIAA President Laura McGill (right) with Jean-Yves Le Gall, recipient of the 2024 AIAA International Cooperation Award,

9 AIAA CEO Dan Dumbacher (left) and AIAA President Laura McGill (right) with Mark Miller, recipient of the 2024 AIAA Reed Aeronautics Award.

10 AIAA CEO Dan Dumbacher (left) and AIAA President Laura McGill (right) with W. Michael Hawes, recipients of the 2024 AIAA Goddard Astronautics Award.

11 AIAA CEO Dan Dumbacher (left) and AIAA President Laura McGill (right) with members of the U.S. Air Force Artificial Intelligence (AI) Technology Demonstration Team, the recipient of the 2024 AIAA Award for Aerospace Excellence.

12 Immediate Past President Laura McGill passing the gavel to new AIAA President Dan Hastings.

13 AIAA Foundation Chair Basil Hassan (left) and AIAA President Laura McGill (right) with 2024 Roger W. Kahn Scholarship recipients: (l to r) Khue Phan, Daisy Li, Leslie Nava, and Alexis Andrulonis.

14 AIAA Foundation Chair Basil Hassan (left) and Valerie Fitton-Kane, Vice President, Development, Partnerships, & Strategy, Challenger Center (right), with the 2024 Trailblazing STEM Educator Award winners (l to r)—Jenn Donais, Darryl Newhouse, and Sarah Leonard.


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AIAA Supports PEGASUS Student Conference in Spain

The 20th PEGASUS Student Conference took place 26-27 April, at the Universidad Politècnica de Catalunya in Terrassa, Spain. This conference gives graduate students the opportunity to present their technical work. The first-, second-, and third-place winners receive cash prizes from AIAA, and the first-place winner will compete at the International Student Conference, 6–10 January 2025, Orlando, FL, with the other first-place Regional Student Conference winners.

- **1st Place –**"Optimization Strategies for System Architecting Problems," **Santiago Valencia Ibanez**, TU Delft
- **2nd Place –** "Experimental study of flame/wall interaction for hydrogen/air mixtures," **Malik Suryadeb,** ENSMA
- **3rd Place (tie) –** "Joint analysis of Europa Clipper and JUICE missions to contain the Galilean moons' ephemerides," **Vittorio Gargiulo**, Sapienza - Università di Roma
- **3rd Place (tie)** – "Impact of non-ideal fluid modeling on droplet vaporization for aerospace fuels," **Edoardo Forti**, Sapienza - Università di Roma


Rob Kinyoun, who flew several aircraft for the museum, explains the shoulder-yoke controls used in early Curtiss aircraft.

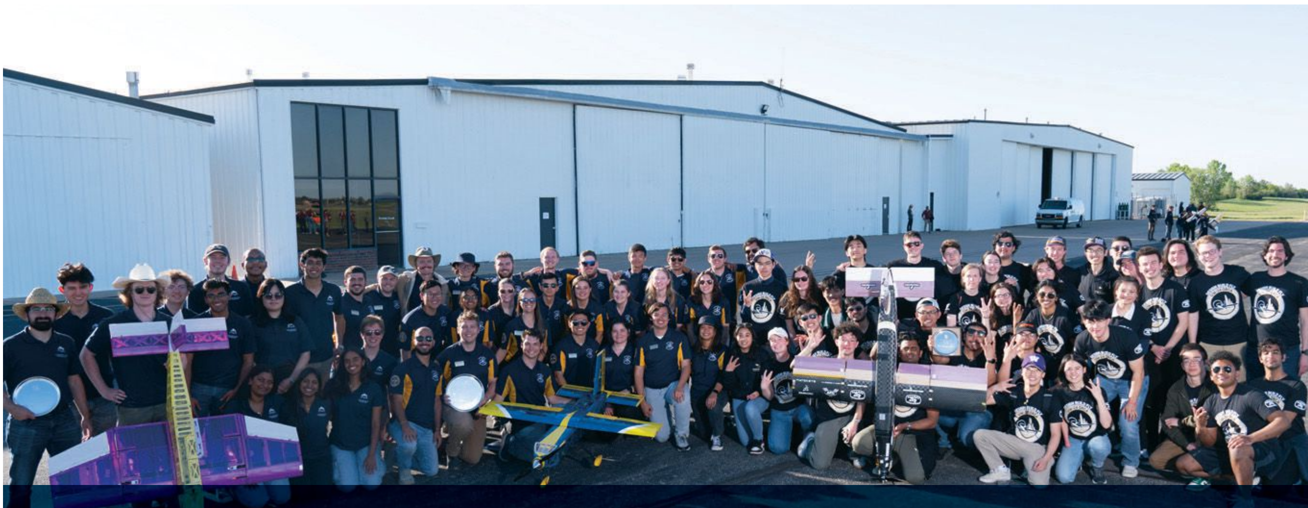

Restoration of a P-40 recovered from a swamp in Florida and restored by museum volunteers.

Niagara Frontier Section Hosts Lecture at Glenn Curtiss Museum

On 28 April, the AIAA Niagara Frontier Section (NFS) held an event at the Glenn Curtiss Museum. **Walter Gordon**, AIAA Distinguished Speaker as well as NFS chair, discussed the "Curtiss Jenny: The Aircraft that Created the Army Air Service." He examined the evolution of Curtiss aircraft from the Model D pusher, with its clear resemblance to the original Wright Flyer, to the Jenny that accompanied the Pershing Expedition to Mexico in just four short years. The talk was attended by about 30 students and faculty from the Rochester Institute of Technology and the University at Buffalo.

MAKING AN IMPACT

2024 DBF Attracted Record Numbers



2024 DBF winners: (l to r) Georgia Institute of Technology; Embry-Riddle Aeronautical University, Daytona Beach; and University of Washington, Seattle

The 2024 Design/Build/Fly (DBF) competition had the largest-ever fly-off participation, with more than 1,000 students on 93 university teams attending onsite. The fly-off, hosted by AIAA Corporate Member Textron Aviation in Wichita, KS, took place 18–21 April. Teams from 12 countries and 32 U.S. states participated in the full DBF Competition, including submitting design reports and attending the fly-off.

This year's flight objective was to design, build, and test a remotely operated radio control airplane for urban air mobility. The airplane needed to be able to conduct a delivery flight, a medical transport flight, and an urban taxi flight. Teams also conducted a ground mission demonstrating how quickly they could change their aircraft configuration from delivery to medical transport to urban air taxi.

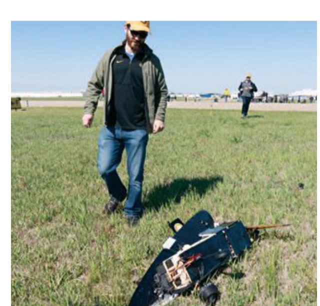
The 2024 DBF winners are:

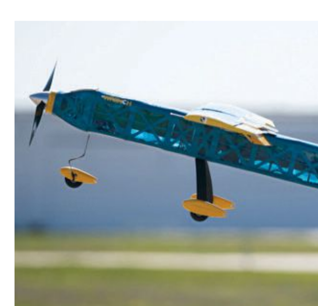
- 1st Place ($3,000): Embry-Riddle Aeronautical University, Daytona Beach
- 2nd Place ($2,000): Georgia Institute of Technology
- 3rd Place ($1,500): University of Washington, Seattle
- Best Design Report ($100): University of Southern California

The success of DBF is due to the efforts of many volunteers from Textron Aviation; Raytheon, an RTX Business; and the AIAA sponsoring Technical Committees: Applied Aerodynamics, Aircraft Design, Flight Test, and Design Engineering. The 2025 DBF competition will be hosted by Raytheon, an RTX Business, in Tucson, AZ, in April 2025. For more information on how your organization can engage with and sponsor this event, please contact Alexandra D'Imperio, alexandrad@aiaa.org.


LEHIGH


ACS





Nominations for AIAA Election Are Being Accepted Through 14 July 2024

The Institute is currently seeking nominations for the following positions.

AIAA President-Elect Nominations

The AIAA Executive Nominating Committee (ENC) will compile a list of potential nominees for the position of AIAA President-Elect. This list will include nominees who will be selected to go to the next step of competency review (see competencies listed below in At-Large Nominations section) and interview held by the nominating committee. The ENC will select specific candidates for the position who will be voted on by the AIAA membership. The final slate of candidates will be publicized by December 2024 for the election that will be held January 2025.

To nominate an AIAA member in good standing for AIAA President-Elect, please submit the nominee's bio and/or CV, history of AIAA activities and/or engagement with other professional societies, and a statement from the nominee of willingness and ability to serve if elected.

AIAA Board of Trustees – Members–At-Large Nominations

The AIAA Executive Nominating Committee (ENC) will compile a list of potential nominees for the Board of Trustees – Members–At-Large. The list will include nominees who will be selected to go to the next step of competency review and interview held by the nominating committee. The ENC will select specific candidates for the Institute's Board of Trustees – Members–At-Large in November 2024. The Board of Trustees – Members–At-Large will be elected by the Council of Directors in January 2025 and announced soon thereafter.

The skills and competencies being sought for the President-Elect and the Board of Trustees are:

- **Vision:** Persons who have the ability to understand present states, clearly define what they should be in the future, and identify steps to achieve those ends.
- **Diverse Business Acumen:** Persons who have the knowledge and understanding of the financial, accounting, marketing, communications, human resources, policy, and operational functions of an organization as well as the ability to make good judgments and quick decisions.
- **Domestic and International Aerospace Knowledge and Experience:** Board membership reflects: a) the breadth of the various major sectors of aerospace both domestic and international; b) all levels of technology and systems development from basic research through all technology readiness levels to product development and deployment; and c) from different disciplines within aerospace.
- **Leadership/Strategy/Execution:** Persons who have the ability to create a shared vision, obtain participation and buy-in, and achieve successful results.
- **AIAA Leadership and Participation:** Board membership reflects experience in successful participation in a wide variety of leadership positions within AIAA, as well as knowledge of the governance model.
- **Experience in Adjacent Aerospace Areas**: As the Institute broadens its reach beyond the traditional "Breguet Equation" disciplines, Board members who have experience and strategic perspectives in these adjacent areas will broaden the Board's view on new and emerging areas.
- **Young Member Knowledge and Experience:** As the Institute evolves, it is important that Board members have knowledge and understanding of issues relevant to young members in the aerospace industry.
- **Experience with Organizational Growth**: Persons with experience in significantly growing organizations will serve as a resource to the Board as the Institute seeks to grow.
- **Experience with Change or Transition Management**: Board members with prior experience in organizational change or transition will serve as a vital resource to the Board as it seeks to execute its role.
- **Demographic Diversity**: In addition to reflecting the membership's diversity in the industry and volunteer involvement, it is important that the new Board membership be seen as reflecting demographic diversity (e.g., gender, ethnicity, age, etc.) as well.

AIAA members may nominate qualified individuals for the AIAA Board of Trustees – Member–At-Large positions by submitting a nomination package of not more than three pages consisting of:

- Nominee's Bio and/or CV and history of AIAA activities and/or engagement with other professional societies
- Statement from the nominee addressing how they meet the sought competencies
- Statement from the nominee of willingness and ability to serve if elected

AIAA Council of Directors Nominations

The AIAA Council of Directors Nominating Committee (CNC) will compile a list of potential nominees for the open Director positions on the AIAA Council of Directors. This list will include nominees who will be selected to go to the next step of competency review held by the nominating committee. The nominating committee will select specific candidates for the open Director positions who will be voted on by the AIAA membership. The final slate of candidates will be publicized by December 2024 for the election that will be held January 2025.

Nominations are being accepted for Regional Directors, Integration and Outreach Group Directors, and Technical Group Directors for the term May 2025–May 2028. AIAA members may self-nominate or nominate members qualified for the open position. **Regions coordinate the activities of geographically-related sections to facilitate cooperative efforts between the various geographical areas.** A Regional Director shall lead each region. Nominations are being accepted for:

- Region IV – South Central, Director
- Region V – Mid-West, Director

For more information on AIAA regions and sections, visit aiaa.org/get-involved/regions-sections.

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Integration and Outreach Groups coordinate the activities of related Integration and Outreach Committees to facilitate cooperative efforts between the various professional areas. Nominations are being accepted for:

- Aerospace Outreach Group, Director
- Integration Group, Director
- Young Professionals Group, Director-Elect

For more information on AIAA integration and outreach, visit aiaa.org/get-involved/committees-groups/Integration-and-Outreach-Division-Committees

Technical Groups coordinate the activities of related technical committees to facilitate cooperative efforts between the various technical disciplines. Nominations are being accepted for:

- Information Systems Group, Director
- Propulsion & Energy Group, Director

For more information on AIAA technical activities, visit aiaa.org/get-involved/committees-groups/technical-committees.

AIAA Integration and Outreach Group Division Chief Nominations

AIAA Integration and Outreach Division (IOD) is the heart and muscle of AIAA's programmatic and societal activities. These groups cover all programmatic and societal interests of the Institute. Work across technical disciplines to forward innovation in our industry by joining an Integration and Outreach Group.

The Chief of the IOD will lead the division and shall be elected by simple majority of the votes cast by the IOD Directors and the Division committees. The Chief will not be a current IOD Director; however, the Chief must have served as an IOD Director in the past. The term of the Chief shall be three years and there shall be a limit of the Chief serving one consecutive term.

A full listing of Division Chief responsibilities, can be found at aiaa.org/about/Governance/nominations-and-elections.

Please go to AIAA Nominations and Elections (aiaa.org/about/Governance/nominations-and-elections) to learn more and submit nominations no later than 14 July 2024, 6 p.m. ET.

Obituaries

AIAA Fellow Fester Died in May 2023

Dale A. Fester died on 7 May 2023. He was 90 years old.

Fester graduated from the University of Denver, receiving a Bachelor of Science degree in 1953 and later a Master of Science degree in 1961, both in Chemical Engineering.

Upon graduation, he worked for Philips Petroleum Company and then served two years in the Army at Fort Ord, Fort Monmouth, and White Sands Proving Ground. He worked for GOG L of Consulting Engineering and University of Wisconsin Solar Energy for six years.

After receiving his Master's degree, Fester worked for Martin Marietta Astronautics in Denver for 32 years, and then formed Denver Space Systems where he consulted for other space companies for three years. During his aerospace career, Fester served as a specialist in propulsion and fluid management, thermal control, post-boost propulsion, design of satellite, telescope, and high-energy laser systems and advanced exploration initiatives. He worked on propulsion solutions for Apollo, the Mars Viking Lander, the Manned Maneuvering Unit, and aspects of the Space Shuttle. He also evaluated numerous space systems technologies for NASA and the Air Force.

He was an internationally recognized expert in low-gravity fluid management and cryogenic systems and authored more than 150 technical papers and reports. He was a Lifetime Fellow of AIAA, where he served on the Board of Directors for ten years, including as Vice President of Membership (1989–1991). He received an AIAA Special Service Citation in 2000 and an AIAA Sustained Service Award in 2001. He also was the U.S. Vice President of the International Astronautical Federation for four years and a member of the International Academy of Astronautics. He was a founding member of the National Aviation Hall of Fame and the National Air and Space Society.

AIAA Fellow Stafford Died in March 2024

Thomas Stafford died on 18 March. He was 93 years old.

Stafford attended the U.S. Naval Academy, earning a Bachelor of Science degree in 1952. He received his pilot wings at Connally Air Force Base in 1953, before completing advanced interceptor training and receiving an assignment to the 54th Flight Interceptor Squadron at Ellsworth Air Force Base. In 1955, he was assigned to the 496th Fighter Interceptor Squadron at Hahn Air Base in Germany.

Stafford attended the U.S. Air Force Experimental Test Pilot School and was an instructor in flight test training and specialized academic subjects — establishing basic textbooks and directing the writing of flight test manuals for use by the staff and students.

In 1962 he applied for astronaut selection. He served on Gemini 6A with Wally Schirra, launching on 15 December 1965, to rendezvous with the Gemini 7 spacecraft. The capsules did not dock but came within a foot of each other. Between his flights on Gemini 9A and Apollo 10, Stafford headed the mission planning analysis and software development responsibilities for the astronaut group for Project Apollo.

On 18 May 1969, Stafford, Eugene Cernan, and John Young launched on Apollo 10. Once in lunar orbit, Stafford and Cernan moved into the lunar module "Snoopy" and Young remained inside the command module "Charlie Brown." Stafford was at Snoopy's controls as he and Cernan came within just 7.8 miles of the moon's surface.

Stafford was assigned as chief of the astronaut office in June 1969, making him responsible for the selection of flight crews for projects Apollo and Skylab. In June 1971, Stafford became deputy director of flight crew operations at the NASA Manned Spacecraft Center (now Johnson Space Center) in Houston. He was responsible for assisting the director in planning and implementation of programs for the astronaut group, the aircraft operations, flight crew integration, flight crew procedures and crew simulation and training divisions.

Stafford's final spaceflight was as the U.S. crew commander of the Apollo-Soyuz Test Project (ASTP), the first joint mission flown by the United States and the then Soviet Union. The mission included the launch of a Russian Soyuz spacecraft with two cosmonauts aboard and an Apollo command module with a specially-built docking adapter and three NASA astronauts. On 17 July 1975, the two vehicles came together in Earth orbit. The ASTP mission laid the early groundwork for the countries to collaborate on the International Space Station.

Stafford retired from NASA on 1 November 1975, and three days later assumed command of the U.S. Air Force Flight Test Center at Edwards Air Force Base. In 1978, he became the deputy chief of staff for research, development, and acquisition at U.S. Air Force headquarters in Washington, DC, where he initiated the F-117A stealth fighter. In 1979, he wrote the initial desired specifications on and started the advanced technology bomber ATB development, now designated as the B-2 "stealth bomber." He also initiated the AGM-129 Stealth Cruise missile. Stafford retired from the Air Force in November 1979 with the rank of lieutenant general. He served on several corporate boards, including OMEGA Watches and Gulfstream Aerospace, as well as founded his own consulting firm.

In 1990, he began serving on panels shaping the future direction of NASA's human spaceflight programs. He chaired the Synthesis Committee, establishing a plan for lunar and Mars missions, and led the group overseeing the first Hubble Space Telescope servicing mission. He worked as an advisor on Space Station Freedom, the precursor to the International Space Station, and consulted on the Shuttle-Mir program and its series of joint missions. Stafford also co-chaired the task group working to return the shuttle to flight. At the time of his death, Stafford was chair of the NASA Advisory Council Task Force for ISS Safety and Operational Readiness.

For his service to the U.S. space program, Stafford was recognized with the NASA Distinguished Service Medal, the NASA Exceptional Service Medal, the Harmon International Aviation Trophy, the Society of Experimental Test Pilots James H. Doolittle Award, the Congressional Space Medal of Honor, and the Russian Medal "For Merit in Space Exploration," among many other honors. He joined AIAA in 1973 and was awarded the 1976 Chanute Flight Test Award and was a co-recipient of the 1978 Haley Space Flight Award.

AIAA Fellow Mullin Died in April 2024

Sherman N. Mullin died 13 April 2024. He was 88 years old.

Mullin had a long successful aerospace engineering and management career without a college degree. Dropping out of Princeton in 1954, he served in the U.S. Army from 1954 to 1957. Graduating from the Army Guided Missile School in 1955, he was appointed to the faculty at age 19. In 1957 he joined Burroughs Corporation as a digital computing instructor, a technology he pursued in depth.

In 1959 he joined Lockheed Electronics Company as an electronics field engineer, later assigned to the Polaris missile program, and two years later he was promoted to senior digital electronics design engineer, becoming a supervisory engineer in 1964 and a department manager in 1967.

In 1968 Mullin was promoted and transferred to Lockheed California Company, managing avionics systems development and integration on the Navy P-3C patrol aircraft and S-3A Viking carrier antisubmarine warfare aircraft. This included pioneering digital avionics systems. He became chief engineer of P-3 aircraft in 1974. From 1976 to 1980 he was P-3 Orion aircraft program manager, including aircraft for the U.S. Navy, as well for Australia, Japan, and the Netherlands.

From 1982 to 1985 he was Lockheed Skunk Works vice president and program manager for the secret Air Force F-117 stealth fighter that achieved operational capability in 1983. He completed the Stanford Executive Program in 1984, and then from 1986 to 1990 he was vice president and general manager of the Lockheed-Boeing-General Dynamics F-22 fighter aircraft team, which produced two prototype aircraft and a prototype advanced technology digital avionics system, winning the Air Force Advanced Tactical Fighter competition.

Mullin concluded his 35-year Lockheed career as president of Lockheed Advanced Development Company (the Skunk Works) from 1990 to 1994, leading its successful transition to successful post-Cold War operations. He led the development of advanced low observable technology, the acquisition of new programs, and profitable company consolidation in Lockheed's modern plant in Palmdale, CA. He mentored a flock of young aerospace engineering managers, most of whom led major future accomplishments at Lockheed and elsewhere.

From 1994 to 2010 he was an independent aerospace consultant, including six years as an advisor to the Air Force Scientific Advisory Board, co-author of six major study reports. He was a director of Mercury Computer Systems (1994-2008).

In 1992 Mullin was the AIAA Wright Brothers Lecturer in Aeronautics, and also co-recipient of the 1992 AIAA Aircraft Design Award for the F-22 fighter. He became an AIAA Fellow in 1996. He was recognized as a Pioneer of Stealth and was a Life Senior Member of the IEEE.

To learn more about Sherman Mullin, read the March 2023 *Aerospace America* interview with him.

JAHNIVERSE

CONTINUED FROM PAGE 64

In the space community, the group Astro Advocates was formed to fight sexual harassment and any form of bullying in the industry and to offer support to victims. If you're a victim, Astro Advocates invites you to find them on their private Facebook group and share your account, anonymously if you prefer.

I also have borne witness to such misconduct firsthand, on several occasions. I've been a wingman for women at conferences and events, and I have literally placed myself between them and drunk, harassing men. These cases are poignant reminders of the urgent need for change.

Solving this problem will, in part, require a stronger recognition of the dangers presented by excessive availability of alcohol. Vriend points to a 2007 study in the Journal of Occupational Health Psychology showing a link between "the number of heavy-drinking male employees" in an organization and "a culture of gender harassment against women in a workplace." Data also shows that the risk posed by easy access to alcohol goes beyond harassment. See for example "The Relationship Between Alcohol Consumption and Sexual Victimization" in the Applied Research Forum, a publication of VAWnet, an online network for information about violence against women.

Too often, especially after hours, space conferences and events become more like bars and parties than off-site work events. Hotel suites co-located with conference venues, oftentimes sponsored by space companies, have open bars serving people way beyond mild intoxication. I've seen this firsthand, and it's common in our community.

Some event organizers have taken steps in the right direction. The AMOS Conference, the annual Advanced Maui Optical and Space Surveillance Technologies event, has established an anti-harassment policy that includes the ability to report an incident anonymously and to contact the event's director directly. The American Institute of Aeronautics and Astronautics (Aerospace America's publisher) requires registrants to agree to the terms of its anti-harassment policy. AIAA also provided me with a statement: "It is the policy of AIAA to maintain a professional environment at its events that is free from all forms of discrimination, harassment and conduct that can be considered unprofessional, disruptive, inappropriate or discourteous."

The studies and data cited in this column suggest that still more must be done. Too often, there is a disconnect between rhetoric and reality. Again, part of that reality is that only one in five women will, on average, report a case of harassment to their organization. Also, not enough is said or done by organizations about the catalyst for much of the harassment: alcohol abuse.

On the behavioral side, Astro Advocates proposes some pragmatic solutions that I am strongly in favor of and suggest organizers consider. The ideas include mandatory background checks for all attendees; blacklisting of known offenders; stricter enforcement measures, such as the removal of harassers without refund; and criminal prosecution where appropriate. Such steps would hold violators accountable and safeguard the integrity of space conferences.

By addressing excessive alcohol consumption, amplifying the voices of women in the space industry and empowering them to speak out against harassment, we can begin to create the "welcoming environment" that Vriend and all of us in the community deserve. As custodians of scientific progress, we must confront these issues head-on, ensuring that every individual, regardless of gender, can pursue their scientific aspirations free from fear and intimidation. ★

LOOKING BACK

COMPILED BY FRANK H. WINTER and ROBERT VAN DER LINDEN

1924

June 4 The U.S. Naval airship USS Shenandoah completes a 24-hour flight from Lakehurst, New Jersey, to Niagara Falls and back. Thunder showers and lightning threatened the ship on the return trip, but the Shenandoah rode them out without difficulty. **Aviation**, June 16, 1924, p. 645.

June 9 Capt. Pelletier d'Oisy and Sgt. Bernard Vesin of France arrive in Tokyo, concluding a long-distance flight from Paris that began April 24. Reaching Tokyo became the goal after their crash last month in Shanghai, China, disqualified them from the race to complete the first around-the-world flight. **Aviation**, June 16, 1924, p. 647; **The Aeroplane**, June 11, 1924, p. 504.

June 15 The 13th Gordon Bennett Balloon Race takes place on the Solbosch plain outside Brussels, sponsored by the Aero Club de Belgique. Seventeen balloons representing seven nations participate. Belgian aeronaut Ernest Demuyter wins the competition for the third consecutive year, landing 714 kilometers from the starting point, near St. Abbs, Berwickshire, England. **The Aeroplane**, June 25, 1924, p. 564; **Aviation**, June 23, 1924, p. 671.

June 20 Portuguese Capt. Brito Paes and Lt. Sarmento Beires leave Hanoi in their de Havilland D.H. 9 biplane to complete the last leg of their Lisbon to Macao flight. As they approach Macao, bad weather prompts them to divert toward Canton, and the plane crashes at Sham-Chun, on the outskirts of Hong Kong. The fliers receive only slight injuries but decide to conclude their flight without reaching Macao. **Flight**, June 26, 1924, p. 413.

June 22-23 U.S. Navy Lts. F. W. Wead and J. D. Price set five world records for class C seaplanes at Anacostia Naval Air Station in Washington, D.C., in a Curtiss CS-2. Among the accomplishments, they set the mark for speed, flying 74.17 mph (119.36 kph) over 1,500 kilometers. **United States Naval Aviation 1910-1970**, p. 55.

June 23 U.S. Army Air Service Lt. Russell L. Maughan makes the first dawn-to-dusk flight across the U.S., traveling from Mitchell Field in New York to Crissy Field in San Francisco, in a Curtiss PW-8 pursuit fighter. Maughan flies the 4,300 km in 21 hours, 48 minutes, 30 seconds, stopping five times to refuel. **Aviation**, June 30, 1924, p. 696.

1949

1 **June 3** Lockheed test pilot Anthony "Tony" Le Vier completes the first flight of the XF-90, an experimental twinjet long-range escort fighter. This first prototype is powered by two Westinghouse J34 turbojets, and afterburners are added to the second prototype to augment the thrust. Despite this change, the design is deemed underpowered by the U.S. Air Force and not ordered into production. **Aviation Week**, June 13, 1949, p. 14; **Aircraft Year Book for 1949**, p. 337.

June 9 The Lockheed PO-1W Constellation makes its first flight. This version of the Lockheed Super Constellation transport equipped with early warning and control radar is a step toward the development of airborne warning and control aircraft, or AWACS. **Aviation Week**, June 27, 1949, p. 14; **Aircraft Year Book for 1949**, p. 338.

2 **June 14** A V-2 rocket is launched from White Sands, New Mexico, carrying a capsule with Albert II, a monkey belonging to the Air Force Aero Medical Laboratory. The capsule reaches an altitude of 133 km, but the parachute malfunctions during landing and it crashes, killing Albert II. NASA, **Aeronautics and Astronautics, 1915-1960**, p. 62.

June 24 During a test flight at Muroc Dry Lake, California, Douglas test pilot Eugene May takes a D-558-2 Skyrocket past the speed of sound for the first time. A J-34 turbojet engine and a Reaction Motors LR-8 6000-lb thrust rocket engine power this supersonic research aircraft, developed by Douglas, the U.S. Navy and NASA's predecessor, the National Advisory Committee for Aeronautics. **Flying**, June 1953, p. 53; Richard P. Hallion, **Supersonic Flight**, p. 153.

3 **Also in June** Douglas test pilot John Martin completes the first flight of a Douglas Super DC-3. This variant of the original DC-3 design has more powerful Pratt and Whitney R2000 engines, rather than the original R1830s; a shorter wing with greater leading-edge sweepback; redesigned and streamlined engine nacelles; and a redesigned larger tail group. The Super DC-3's top speed of 391 kilometers per hour exceeds that of the original DC-3 by 65 kph. **Aviation Week**, July 11, 1949, p. 33.

Also in June The U.S. Air Force scraps the sole Douglas XB-19, the experimental bomber that at one point was the world's largest airplane. Before and during World War II, the XB-19 flew in numerous Army experimental programs aimed at informing the design of other large bombers. The aircraft made its first flight on June 27, 1941. **Aviation Week**, June 20, 1949, p. 161.

1974

June 3 NASA's Hawkeye 1 satellite is launched aboard an all-solid-fuel Scout E launch vehicle with five stages, the first use of that variant. The fifth stage places the satellite into a polar orbit with a 124,477- km apogee. The primary mission of Hawkeye 1 is to investigate the interaction between the solar wind and Earth's magnetic field. NASA, **Astronautics and Aeronautics, 1974**, p. 111.

June 3 NASA announces that Italy will build a ground station to receive data from NASA's Earth Resources Technology Satellites. The station is to be situated in Fucine, in central Italy, and complement existing stations in Fairbanks, Alaska; Goldstone, California; Greenbelt, Maryland; Prince Albert, Canada; and Cuiabá, Brazil. **NASA Release** 74-142.

4 **June 4** NASA Administrator James Fletcher presents Richard Whitcomb (pictured), head of the Transonic Aerodynamic Branch at NASA's Langley Research Center, a $25,000 cash award for Whitcomb's invention of the supercritical wing. With a flat top and rounder underside, Whitcomb's design allowed aircraft to travel at higher supersonic speeds without experiencing drag, thus preventing increased fuel consumption. **NASA Release** 74-148.

June 5 The European Space Research Organization awards a $226 million, six-year contract to the German firm VFW-Fokker/Erno Raumfahrttechnik GmbH to lead design and development of Spacelab, a reusable laboratory that is to be orbited by a NASA space shuttle orbiter in the 1990s. **ESRO release**, June 5, 1974.

5 **June 9** Northrop's YF-17 Cobra prototype makes its first flight. After takeoff from Edwards Air Force Base in California, the twin-engine aircraft that is Northrop's entry into the U.S. Air Force's Lightweight Fighter competition remains aloft for 65 minutes, reaching an altitude of 10,000 feet. **Air Force Systems Command Newsreview**, July 1974, p. 4.

June 11 A giant nylon parachute built by Goodyear Aerospace Corp. is demonstrated at NASA's Kennedy Space Center in Florida as a possible means of recovering the space shuttle's solid-fuel rocket booster casings for reuse. **Spaceport News**, June 27, 1974.

June 13 A Concorde supersonic jet sets a speed record for transatlantic flight, traveling from Paris to Boston in 3 hours, 9 minutes. The trip is made to mark the dedication of a new terminal at Boston's Logan International Airport. **Boston Sun**, June 14, 1974, p. A11.

June 17 NASA announces the selection of a Boeing 747 to transport the space shuttle orbiter and related hardware from the West Coast to Kennedy Space Center in Florida. Plans call for modifying the 747,

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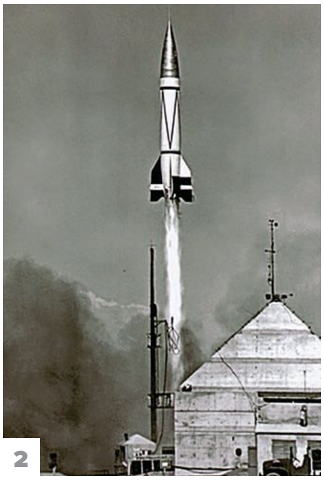

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purchased from American Airlines, to allow the quick installation of the orbiter on top of the aircraft. **NASA Release** 74-160.

6 **June 24-July 12** Eight NASA astronauts take part in training in Star City near Moscow for the coming Apollo-Soyuz Test Project. Over the course of three weeks, they train with Soviet cosmonauts in flight simulators and mock-ups to learn the Soyuz spacecraft systems. **NASA Release** 74-121.

June 25 The Soviet Union's Salyut 3 research station is launched from the Baikonur Cosmodrome in preparation for a July docking with the Soyuz 14 capsule carrying cosmonauts Pavel Popovich and Yuri Artyukhin. The crew is to demonstrate techniques that are to be employed during the U.S.-Soviet Apollo-Soyuz Test Project in July 1975. NASA, **Astronautics and Aeronautics, 1974**, p. 122.

June 27 NASA announces a joint mission with Great Britain to study the remnants of the Puppis A supernova. Plans call for NASA to design and fabricate an X-ray telescope that will be launched by a British Skylark sounding rocket next year. **NASA Release** 74-179.

June 27 Vannevar Bush, the engineer who directed the development of the U.S. atomic bomb during World War II, dies at 84. Bush served as chairman of NASA's predecessor, the National Advisory Committee for Aeronautics, for a year before President Franklin Roosevelt named him director of the Office of Scientific Research and Development in 1941. In that capacity, he oversaw development of the atomic bomb, amphibious vehicles and other technologies. **Washington Post**, June 30, 1974, p. B8.

1999

June 2 The Ilyushin Il-96T freighter becomes the first Russian transport to receive FAA certification. The IL-96T is an improved version of the Soviet-era Il-86, powered by four Pratt and Whitney PW2337 high-bypass turbofans engines. **Flight International**, June 16-22, 1999, pp. 26-27.

7 **June 24** NASA's Far Ultraviolet Spectroscopic Explorer satellite is launched by a Delta II. The first satellite whose development was largely undertaken by a university, FUSE was developed by a governmental and university consortium led by Johns Hopkins University in Maryland to determine the amount of mass in the universe crated by the Big Bang. **Aviation Week**, June 28, 1999, p. 20.

Creating the harassment-free environment women deserve

BY MORIBA JAH | moriba@utexas.edu

Beneath the celestial expanse of space exploration, where humanity's boldest dreams converge with cutting-edge science, lurks a familiar and troubling human failing. I'm referring to incidents of sexual harassment and misogyny within the scientific community, a reality that the space profession is not immune to.

These cases are often, though not always, linked to networking events involving alcohol.

Consider Nathalie Vriend, an associate professor of mechanical engineering at the University of Colorado Boulder, writing last year on the website of the American Physical Society: "I myself have experienced harassment on multiple occasions in professional settings, from colleagues who had too much to drink. As a result, I have become more cautious, sometimes leaving events where I feel unsafe — hardly the welcoming environment we aim to create in our scientific communities."

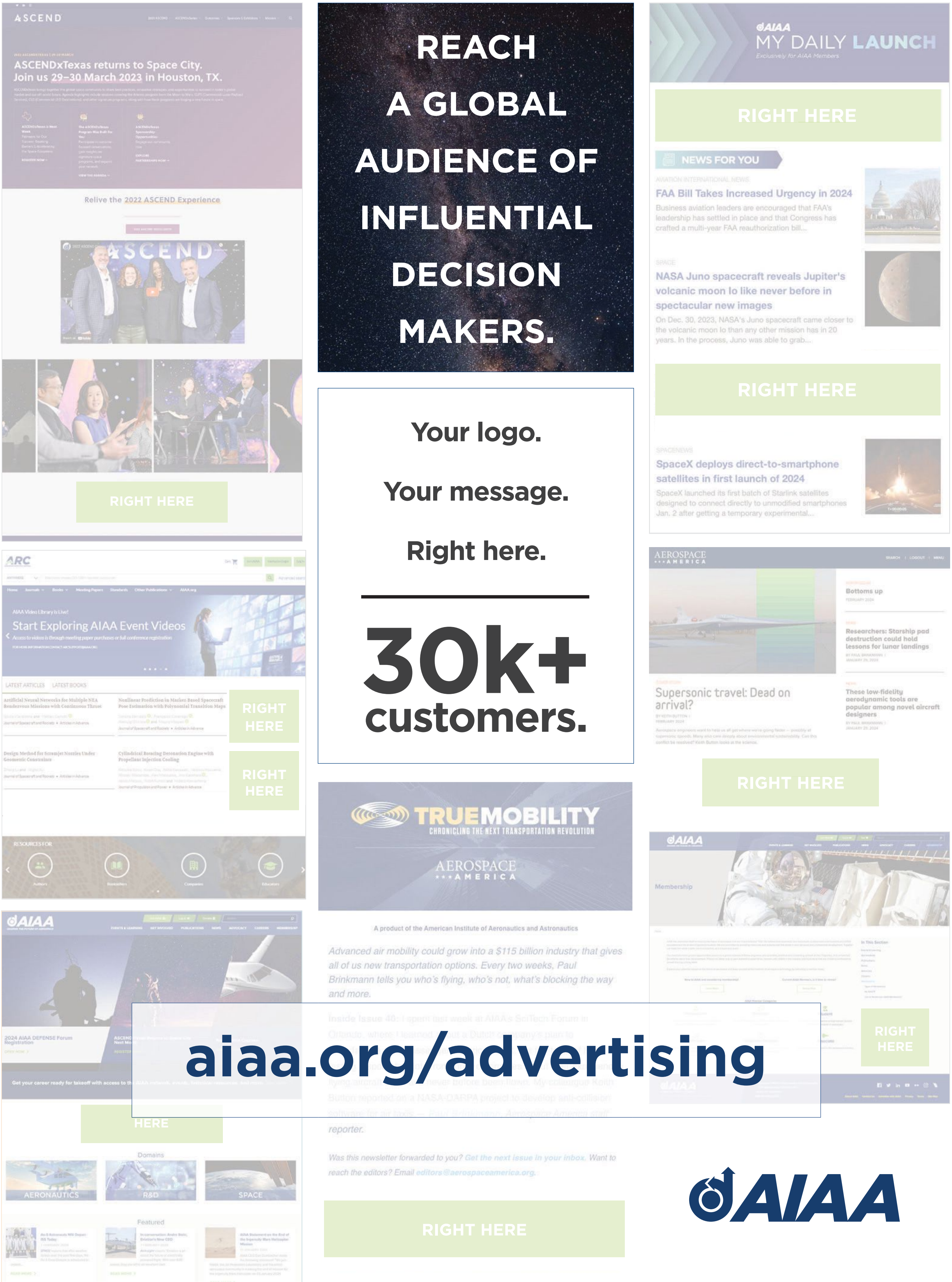
Statistics show that Vriend is not alone. A 2023 study of 5,200 scientists from 117 countries showed that nearly one in two women scientists (47%) reported experiencing an incident of sexual harassment in the last five years. That's an especially appalling result, considering that it comes despite the global reckoning catalyzed by the #MeToo movement and other actions. The study was conducted for the L'Oréal Foundation by Ipsos, the Paris-based opinion research group.

The study also showed that only about one in five women (19%) who experienced harassment spoke out about the incident within their institution. So, the problem could well exist in your organization and at its events, and you just don't know it.

The impact of sexual harassment extends far beyond the immediate trauma inflicted upon victims. For 65% of those affected, the repercussions reverberate throughout their careers, corroding their engagement in science and hindering their professional advancement, the Ipsos study noted.

CONTINUED ON PAGE 61

Moriba Jah is an astrodynamicist, space environmentalist and associate professor of aerospace engineering and engineering mechanics at the University of Texas at Austin. An AIAA fellow and MacArthur fellow, he's also chief scientist of startup Privateer.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